ECONOMIC IMPACT OF AIR POLLUTION CONTROLS ON GRAY IRON FOUNDRY INDUSTRY

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
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National Air Pollution Control Administration
Raleigh, North Carolina
November 1970

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402 - Price 65 cents

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National Air Pollution Control Administration Publication No. AP-74

FOREWORD

The Clean Air Act, as amended, (P.L. 90-148) vests primary responsibility for overseeing Federal government activities in air pollution control with the Department of Health, Education, and Welfare. At the same time, the Act encourages cooperation among Federal agencies (Section 102.b), which extends to the statutory requirement for economic cost studies of the impact of air quality standards on the nation's industries (Section 305.a).

In partial fulfillment of the Act, the National Air Pollution Control Administration of the Department of Health, Education, and Welfare conducted a study of the economic impact of air pollution controls on gray iron foundries. Results of the study are contained in this report.

Significant contributions to the study were made by the Business and Defense Services Administration of the Department of Commerce. These contributions included: development and preparation of survey questionnaires, interviewing, arranging financial data retrieval from the Internal Revenue Service, data tabulation, and data analysis. The Gray and Ductile Iron Founder's Society, the American Foundrymen's Society, and other individual firms also made contributions, without which this study and report would not have been possible. Responsibility for the analyses and conclusions rests, of course, with the National Air Pollution Control Administration.

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CHAPTER 1. INTRODUCTION

PURPOSE

The purpose of this study is to identify the costs and to assess the economic impact of controlling air pollution from gray iron foundries.

Two principal considerations commend the gray iron foundry industry to this type of study. First, the industry is an important source of particulate pollution in most urban metropolitan areas. In 1968 the industry emitted an estimated 170,000 tons of particulates or 2.3 percent of the 7.5 million tons of particulate emissions emitted in the United States by industrial processes. This output ranks it twelfth among industries contributing particulate pollution to the nation's atmosphere.[1] Second, the industry includes a large number of small establishments that may find it difficult to finance the purchase and operation of pollution control equipment. Approximately a third of all companies in this industry employ less than 20 employees.[2] Information on the cost and effectiveness of control equipment is useful in directing and anticipating future developments by control officials in managing air quality programs and by foundrymen in the purchase of control equipment.

SCOPE

In this study, concentration was placed on foundries that are primarily producers of gray iron castings. Foundries producing malleable iron or steel castings are specifically excluded. Many gray iron foundries also produce a closely related product called ductile iron. Because the production processes and the pollution characteristics of these two are similar, ductile iron foundries are included among the foundries surveyed in the study.

Although these foundries are the source of other pollutants, particularly carbon monoxide and odors, the scope of this study was restricted to particulate pollution.

Metal-melting processes are the major uncontrolled source of particulate emissions in foundries. Other nonmelting processes generate particulate pollution, but these either tend to be under control or are not considered serious forms of air pollution in terms of neighborhood effects. This report, therefore, addresses only the problems associated with controlling melting processes.

The greatest source of particulate emissions from melting processes, both in terms of the number of sources and the emission strength of each source, is the cupola. The second ranking source is the electric arc furnace. Electric induction furnaces, which are relatively pollution-free, enter the discussion for comparative purposes.

Pollution control costs are examined for the various types of systems commonly applied to reduce furnace emissions. Factors that may influence control costs are tested between the different types of control systems and within types of systems. The control costs developed herein include various components of both total investment costs and annual costs. Model control costs are developed for typical sizes of installations.

Costs of control are measured against the economic strength of the industry and against the financial condition of firms in the industry; this allows explicit judgments on the impact of the absolute costs of pollution control. In the absence of well-specified supply and demand relationships, however, conclusions on the incidence or burden of air pollution control may only be implied.

STUDY TECHNIQUES

The experience of foundries presently controlling emissions from their melting operations was evaluated to furnish insight about the economic impact of pollution control on uncontrolled foundries. Two types of data were collected, individual company data and aggregated industry data.

The aggregated data include published and unpublished Federal statistics and information gathered during the course of this study. All the known producers of gray iron were surveyed by mail in 1968 to determine which ones had installed pollution control equipment, the types of equipment, and the costs.

A stratified random sample of respondent firms having pollution control equipment was interviewed to learn the production aspects of individual foundries and their attendant pollution control costs. Appendix A presents the materials employed in both these surveys, and Appendix B discusses the sampling process.

CHAPTER 2. GRAY IRON INDUSTRY

PRODUCT DESCRIPTION

The final product of the gray iron industry is a heavy, brittle metal popularly known as cast iron, but named by the trade after its characteristic gray-white color. The industry also produces castings of ductile iron, which are stronger and less brittle than cast iron.

The chemical and physical properties of castings vary according to requirements of malleability, tensile strength, and corrosion resistance. Individual castings range in size and weight from a few ounces for door lock parts and computer gears to many tons for mill rolls and locomotive frames.

The gray iron foundry industry produces components for a wide variety of manufactured products: automobiles, trucks, construction and agriculture machinery, railway equipment, electrical equipment, rolling mills, machine tools, and various defense products. The industry's products are commonly intermediate to some final manufactured product. Gray iron also finds a substantial market in municipal castings and soil pipe.

The industry faces competition from nonferrous castings, forgings, fabricated steel, plastics, and steel castings.

MELTING AND PRODUCTION PROCESS

The melting process is the major uncontrolled source of pollution in the foundries. The metal for gray iron castings is made by melting pig iron, scrap metal, unused casting parts, rejected castings, and small amounts of alloying metal as needed.

The molten metal is poured into sand molds that are prepared to produce the desired casting shape. Mold-making usually requires wood patterns, synthetic cores, and sand. Sand is packed around the wood patterns or synthetic cores to hold the metal in the design of the wood pattern when it is removed or in the design of the synthetic core, which dissolves under the heat of molten metal.

When the metal has solidified, the sand and extraneous metal are removed. The sand is dried and reclaimed for further use. The extraneous metal is returned for resmelting. Castings are, depending on their final use, either cleaned of rough edges and shipped, or transferred for further refinements such as machining. Figure 1 depicts the flow of foundry operations.

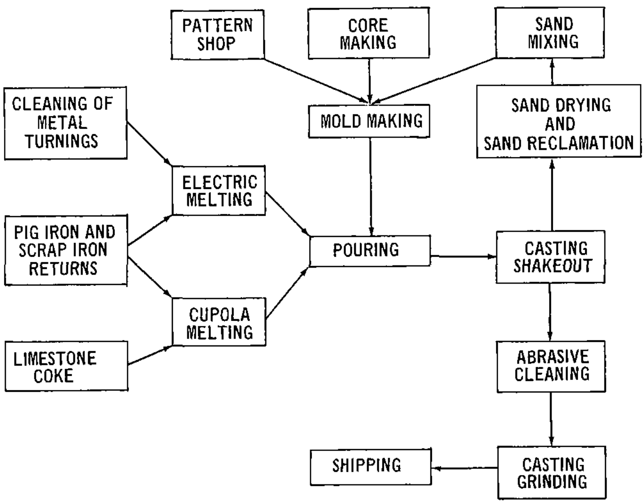

Figure 1. Flow diagram of gray iron foundry.

Two types of furnaces are used to melt the metal, the cupola and the electric furnace. Cupolas are used for the majority of metal poured for gray iron casting purposes. The mail survey of the industry showed that, of the approximately \$3.4 billion worth of castings produced by the respondents during 1967, a little over \$3.0 billion in castings originated in foundries with cupolas. If these values are taken as indexes of production, then cupolas accounted for 88 percent of gray iron casting output.

The cupola is heated by lighting a bed of coke or wood. During melting operations, air is forced into the cupola near the bottom while a mixture of metal, coke, and limestone is charged from an upper level. The contact between the ascending hot gases and the descending charge provides a quick and efficient melting process.

The turbulence created in cupolas by forced air, hot gases, and descending charges, however, generates more emissions than the other types of melting units. The emissions from an uncontrolled cupola have been reported at 17.4 pounds of particulates per ton of metal charged.[3] The results of the survey, however, indicated that an emission rate of 20 to 21 pounds per ton of metal charged is more accurate.

Another aspect of the cupola that distinguishes it from other furnaces is the hot gases laden with particulates that escape to the atmosphere. The gases vary in temperature from 1,500° to 2,000° F. Such high temperatures give the gases a buoyancy that carries them to high levels. Particulates are then dispersed over wide areas.

The melt rates of cupolas range from 1 to 50 tons of metal per hour. Approximately a quarter of the cupolas melt between 1 and 4 tons per hour; more than half melt at 8 or less tons per hour. Table 1 shows the distribution of cupolas by capacity according to melt rate.

Table 1. DISTRIBUTION OF CUPOLA-RATED CAPACITIES[a,5]

Melt rate, tons/hr	Percent of total	Cumulative, %
1 2	7.8	7.8
3 - 4	16.5	24.3
5 - 6	16.4	40.7
7 8	14.8	55.5
9 - 11	13.7	69.2
12 14	7.6	76.8
15 17	6.3	83.1
18 - 21	6.7	89.8
22 - 26	4.6	94.4
27 30	2.2	96.6
31 40	2.6	99.2
>40	0.8	100.0
	100.0	

[a]Based on 1,810 out of 2,530 known installations in 1965-1966.

Electric arc furnaces do not present as great an air pollution problem; they generate emissions between 5 and 10 pounds per ton of metal melted.[4] These furnaces melt metal by passing an electric current between two electrodes that are inserted in a covered chamber containing the metal.

Another type of electric furnace is the induction furnace. It melts by introducing an electromagnetic field through an enclosed charge of metal. Emissions amount to about 2.0 pounds of particulates per ton of metal charged.[3] If pig iron and clean casting returns are charged, no air pollution control equipment is usually necessary. Control is more necessary if the charge consists of either contaminated scrap or magnesium to produce ductile iron.[4]

Electric furnaces are being used more and more throughout the industry. One reason certainly is related to air pollution control – electric furnaces have lower emission characteristics. Another reason is the increased demand for the more refined castings.

Furnaces other than cupola or electric are reverberatory, crucible, and blast furnaces. Since these are used in less than 2 percent of all foundries and generate relatively low emissions, they are not considered in this report.

CHAPTER 3. RECENT ECONOMIC CHANGES IN INDUSTRY

INTRODUCTION

Of 418 manufacturing industries, the gray iron foundry industry ranks 24th in employment and 49th in value of shipments. These ratings are based on data for 1967, the most recent year for which data are available.[6] Data for the period 1958 to 1967 are examined in this chapter to investigate the strength of the gray iron foundry industry relative to all the economic sector it occupies. (Many of the basic data are presented in Appendix C.)

The reason for making this comparison is to permit some judgments on the incidence of air pollution control expenditures. The costs of air pollution control, as with any increase in industrial production costs, could, theoretically, be offset through one or a combination of the following ways: (1) an increase in product prices, (2) a decrease in prices paid for raw materials, (3) a reduction in factor costs of labor and capital, or (4) a decline in profits. This chapter inquires into the past behavior of prices, output, and profits as a means of identifying the future incidence of air pollution control costs.

VALUE OF SHIPMENTS

One index of the economic strength of an industry is the value of its shipments, which was $2.7 billion for gray iron foundries in 1967. During the 9 years from 1958 to 1967, the value of shipments from gray iron foundries grew at a compound annual rate of 7.4 percent. The growth rose from a 1958 level of $1.4 billion; however, real growth in value of shipments is 5.4 percent per year since prices for gray iron castings rose steadily at a rate of 2.0 percent.[7]

By way of comparison, the value of shipments of all manufacturing grew during the same period at a compound annual rate of 6.1 percent. Correcting this for commodity price increases at an annual rate of 0.6 percent[8] yields a real growth rate of 5.5 percent. Thus, the growth of production from gray iron foundries follows closely the behavior of all manufacturing.

VALUE ADDED

An indicative statistic for comparing the relative economic contribution of the gray iron industry is that of "value added," which is simply the value of shipments less the cost of materials and services purchased, such as scrap and electricity. Value added includes, therefore, labor charges (wages and salaries), capital charges (depreciation, interest, rent), and profit. Value added affords a truer picture of economic strength than value of shipments since the latter may be inflated by treating castings shipped by one foundry as materials of another foundry.

The value added for gray iron foundries in 1967 amounted to $1.6 billion. Growth of value added has been at a compound annual rate of 7.9 percent for foundries and 7.0 percent for manufacturing. The higher growth rate of value added for foundries may be explained by two sets of factors. First, the price of castings increased at a rate greater than prices for all commodities—2.0 percent versus 0.6 percent—as mentioned above. Second, the major materials costs for foundries declined.

Pig iron and scrap iron are the two major materials purchased for gray iron production. Pig iron and ferroalloy prices fell at an annual rate of 2.3 percent during the decade through 1967, and the price for cupola cast iron scrap declined at an annual rate of 0.3 percent.[7] Thus the relative increase in the price of castings and the relative decrease in the prices of major material inputs permitted a growth of value added for foundries at a higher rate than for all manufacturing.

To learn what preserved the increase in value added of foundries relative to that of all manufacturing requires an examination of the components of value added. Attention should be directed particularly to the shares of value added going to labor, capital, and profit.

Labor Share

Consider first the labor share, which is measured by the fraction of payroll in value added. Foundries have been more labor-intensive relative to all manufacturing since the ratio of payroll to value added for 1967 is 0.619 among foundries and 0.509 for all manufacturing. This difference shows that nearly one-fifth more of the value added in gray iron production was absorbed by wages and salaries than was the case for all manufacturing.

More significant than the level of foundries' labor share is the fact that it fell and fell relative to a similar decline in the labor share of value added in total manufacturing. From 1958 to 1967, the labor share for foundries declined 5.65 percent from a share of 0.654; that for all manufacturing fell 2.55 percent from a level of 0.521. Thus, the labor share of value added for foundries not only fell, but it fell at twice the rate of all manufacturing.

The results may appear inconsistent when it is noted that gray iron foundries experienced, relative to all manufacturing, a more rapid growth from 1958 to 1967 in total employment, production employment, production worker man-hours, payroll per employee, and wages per production worker. These observations suggest an investigation of the other two components of value added—capital costs and profit.

Capital Share

Neither capital costs nor profits are reported in a fashion that allows direct comparison with the labor share. Indirect comparisons are possible, however. One proxy for estimating the behavior of the capital share is the level and growth of capital expenditures. Where capital share includes the interest and depreciation charges associated with plant and equipment usage, and where usage is directly related to capital expenditures, then capital share may be expected to reflect capital expenditures.

It would appear that the capital share for foundries has grown since the annual level of expenditures increased more than five times from \$32.6 million in 1958 to \$173 million in 1967. During the same period, capital expenditures for all manufacturing little more than doubled. This represents a compound annual growth rate of 20.4 percent for gray iron foundries as opposed to a rate of 8.7 percent for all manufacturing.

Several factors help explain a growth in capital share. First, the technical requirements placed by the consumers of gray iron on the producers for castings of higher quality and greater sophistication force new investments. Capital expenditures have also been encouraged by tight labor markets and rising wages. A final factor that cannot be overlooked has been the growing number of air pollution control installations.

Survey results indicate that nearly $70 million has been spent by foundries for air pollution control purposes. It must be realized, however, that the results cannot be strictly included in the foregoing total capital expenditures. One reason is that the $70 million includes expenditures from before 1958 and into the first quarter of 1968. A second reason is that total capital expenditures are limited only to firms that are primarily gray iron producers. The $70 million figure includes air pollution control expenditures on foundries in other industries such as automotive manufacturing. Nevertheless, air pollution control investments have contributed to the growth of capital expenditures in the gray iron foundry industry.

Profit Share

The remaining share of value added to be examined is profit. Although time-series data are not available on profits in gray iron foundries, the 1967 cross section of financial data provided by the Internal Revenue Service and the changing size distribution of foundries lead to a conclusion that profit share also increased through 1967. Table 2 illustrates that as foundries increase in size, they tend to become more profitable as measured against gross receipts.

The distribution of foundries by size has been changing in favor of larger establishments. From 1959 to 1967, the number of gray foundries in the United States declined from 1,251 to 1,055 (see Appendix C, Table C-7). Virtually all of this decline was accounted for by a decrease in the number of foundries with relatively few employees. The number of foundries employing less than 50 persons dropped a third, from 757 in 1959 to 506 in 1967. The number of large reporting units, however, registered substantial increases. Units with 100 or more

Table 2. NET PROFITS BEFORE TAXES AS PERCENT OF GROSS RECEIPTS, BY SIZE OF FOUNDRY

Size of foundry sales, $\$10^6$	Net profits before taxes as percent of gross receipts
<0.5	4.18
0.5 to <1.0	6.63
1.0 to <2.5	6.71
2.5 to <10.0	7.36
≥10.0	6.95

employees increased 22 percent between 1959 and 1967; and the giants of the industry, those with 500 or more employees, increased 46 percent in number.

CONCLUSIONS

The preceding discussion indicates that the gray iron foundry industry, as an industry, was in an economic position to assume air pollution control expenditures. The prices of its products rose relative to all manufacturing, which suggests that the burden of air pollution control could have been shifted to the consumer at least partially. What was not shifted forward to the consumer may have been absorbed in profits that have probably been increasing relative to value added, but that may have increased faster in the absence of pollution control requirements. Foundries also are improving their ability to manage sophisticated air pollution control technologies as is evident from the rapid growth of capital expenditures. An exception to the foregoing conclusions may be the sector of the industry composed of small foundries.

These conclusions must be considered in view of the major influence that a few large gray iron firms have on the industry. The four largest companies accounted for 27 percent of the industry's value of shipments in 1966, while the eight largest accounted for 37 percent.[9] It is also estimated that the 50 largest firms accounted for fully two-thirds of total industry shipments.

Many of these large firms are "production foundries," which have the capability to produce economically large lots of closely related castings. Much of the output of these "production foundries" is captive, i.e., produced for the parent company's end product. In fact, about 40 percent of all gray iron casting production originates from "captive foundries." The rest is produced for sale.

In contrast to the large "production foundries" are the smaller "jobbing foundries," which produce relatively smaller lots of varied types and sizes of castings on custom order. This group is composed of the largest number of foundries. Furthermore, most gray iron firms maintain only one establishment.

CHAPTER 4. CURRENT ECONOMIC STATUS OF INDUSTRY AND OF INDIVIDUAL FIRMS

INTRODUCTION

This chapter seeks to answer several questions: (1) How profitable is the gray iron foundry industry compared to all manufacturing? (2) How profitable are various sized firms in the industry? and (3) How does air pollution control affect profits?

No attempt was made in either the postcard or the interview survey to collect data bearing on the financial status or general profitability of gray iron foundries because of the privileged nature of such information. Instead, arrangements were made for the Internal Revenue Service to consolidate individual company financial data based on 1966 income tax returns, with selected distributions based on size, type of operation, type of organization, and existence of air pollution control equipment.

Portions of the IRS data are not included in this financial analysis for technical reasons. (See Appendix D for a more complete presentation.) Data from firms having "captive foundries" were excluded because the casting production tends to be integrated financially with other manufacturing operations and, therefore, sheds little light on foundry operations *per se*. Also, foundries that file tax returns as partnerships, proprietorships, and small corporations have been excluded for several reasons: problems of comparability with corporate organizations, inadequate data, and relatively few observations.

Thus the subsample chosen for analysis was that of 240 foundries filing corporate tax returns, which represented 17 percent of all foundries identified in the postcard survey. Their 1966 gross receipts of $756 million amounted to 28 percent of the $2.7 billion of shipments of gray iron castings for that year.[10]

PROFITABILITY OF INDUSTRY

Several measures of profitability are possible. The following presentation dwells on two of these measures — (1) profits before taxes as a percent of gross receipts and (2) profits after taxes as a percent of gross receipts.

The 240 foundries examined showed an average net profit before taxes of 6.9 percent of gross receipts, which was lower than the comparable profit rate of 8.1 percent for all of manufacturing. Profit rates after taxes as a percent of gross receipts for foundries and for all manufacturing confirm the pattern. This may be observed in Table 3, which is based in part on data in Table D-4 of Appendix D.

Table 3. PROFITABILITY OF FOUNDRIES COMPARED TO ALL MANUFACTURING, 1966[11]

Industry	Net profits before taxes as percent of gross receipts	Net profits after taxes as percent of gross receipts
Foundries	6.9	4.0
All manufacturing	8.1	4.6

PROFITABILITY WITHIN INDUSTRY

As pointed out in the previous chapter, the profit rate varies positively with the size of the foundry. Table 4 provides a more detailed confirmation of this behavior. All three categories—cupola and electric arc furnaces with controls, cupola and electric arc furnaces without controls, and electric induction furnaces—show a tendency for *net profits before taxes, as a percent of gross receipts, to rise as* foundry sales rise. The most pronounced variation occurs for electric induction furnaces, which require no controls.

The presence or absence of air pollution controls, however, has no clear, discernible effect on profits. It might be expected that profit rates would be lower for cupola and electric arc furnaces that have outlays for air pollution control purposes. Also, to the extent that induction furnaces are a form of pollution control and entail higher casting-melting costs, one might expect their profit rate to be lower. The fact that profits bear no observable relation to the use of air

Table 4. PROFITABILITY BY TYPE OF FURNACE, EXISTENCE OF CONTROLS, AND SIZE OF FOUNDRY SALES

Furnace type	Size of foundry sales, $\$10^6$	Net profits before taxes as percent of gross receipts
Cupola/arc (controls)	<0.5	3.38
	0.5 to <1.0	5.25
	1.0 to <2.5	7.20
	2.5 to <10.0	6.22
	≥10.0	7.02
	Average	6.86
Cupola/arc (no controls)	<0.5	4.92
	0.5 to <1.0	7.00
	1.0 to <2.5	6.52
	2.5 to <10.0	7.73
	≥10.0	3.29
	Average	6.18
Electric induction	<0.5	-6.84
	0.5 to <1.0	5.97
	1.0 to <2.5	4.07
	2.5 to <10.0	14.61
	≥10.0	15.79
	Average	12.25

pollution abatement processes and equipment may be explained by the absence of data on other factors.

One factor, for example, that may influence profits is the benefit derived from pollution reduction in forms of reduced expenditures for building painting, roof maintenance, and insurance for personal injury and property damage. While attempts were made to quantify these benefits for all foundries, the survey was able to do little more than prove their existence for some foundries.

MAGNITUDE OF PROFITS WITHIN INDUSTRY

The average net profit before taxes of "jobbing" foundries with casting sales under $500,000 amounted to $11,000 in 1966, a profit rate of 4.18 percent. Firms that shipped from $0.5 to $1 million in 1966 had an average profit of $52,000 before taxes and a profit rate of 6.63 percent. These results are presented in Table 5 from data collected in Table D-5 of Appendix D. The table shows that firms that ship more

Table 5. AVERAGES FOR PROFITS, GROSS RECEIPTS, AND PROFIT RATE, BY SIZE OF FOUNDRY SALES AND TYPE OF FURNACE

Size of foundry sales, $\$10^6$	Furnace type	Net profits before taxes, $\$10^3$	Gross receipts, $\$10^3$	Profits before taxes as percent of gross receipts
<0.5	Electric induction (no controls)	-15	219	-6.84
	Cupola/arc (controls)	11	325	3.38
	Cupola/arc (no controls)	13	264	4.92
	Average	11	263	4.18
0.5 to <1.0	Electric induction (no controls)	41	686	5.97
	Cupola/arc (controls)	53	1,009	5.25
	Cupola/arc (no controls)	53	757	7.00
	Average	52	784	6.63
1.0 to <2.5	Electric induction (no controls)	54	1,326	4.07
	Cupola/arc (controls)	135	1,874	7.20
	Cupola/arc (no controls)	113	1,733	6.52
	Average	119	1,771	6.71
2.5 to <10.0	Electric induction (no controls)	750	5,132	14.61
	Cupola/arc (controls)	329	5,287	6.22
	Cupola/arc (no controls)	276	3,569	7.73
	Average	329	4,470	7.36
≥10.0	Electric induction (no controls)	2,309	14,617	15.79
	Cupola/arc (controls)	4,298	61,222	7.02
	Cupola/arc (no controls)	698	21,162	3.29
	Average	3,277	47,141	6.95

than $1 million of castings garner more profits and achieve higher profit rates than their smaller competitors.

Knowing the magnitude of profits within the industry offers some basis for comparing the impact of air pollution control expenditures. This comparison will be given in Chapter 8.

CHAPTER 5. AIR POLLUTION CONTROL REGULATIONS

INTRODUCTION

Industry decisions on whether and how to control air pollution have been considered within the existing pattern of varying state and local standards, regulations, and enforcement practices. Foundries with cupola controls tend to be located in those states or metropolitan regions with air pollution control regulations. Since the number of states and localities with regulations is growing rapidly, most foundries may expect to come under the influence of some air pollution control agency in the next several years. The Federal influence will be indirect because of the provision of the Clean Air Act "that the prevention and control of air pollution at its source is the primary responsibility of States and local governments."

CLEAN AIR ACT

The intent of the Clean Air Act and the policy of the National Air Pollution Control Administration are that air pollution be considered as an individual problem in each region of the country, and that it be attacked by a combination of State and local governments. The intended primary role of the Federal government is to provide information and assistance to the states and local governments to make certain that the machinery of the Act operates at peak efficiency and to ensure that states discharge their responsibilities as outlined in the Act.

Under the Clean Air Act, the Federal government issues criteria on the effects of various air pollutants on health and property, and issues information on the most effective and economical ways to control the sources of those pollutants. Once the states receive this information, they are expected to set air quality standards in regions whose boundaries have been established by the Federal government. Air quality standards are prescribed maximum limits on the levels of air pollution that can be reached, usually during a given period of time. In selecting air quality standards, a region is, in effect, deciding how clean it wants its air to be. An essential part of the standard-setting process is a set of hearings at which the public and industry may express their preferences.

After states select air quality standards for their designated air quality control regions, they must develop an implementation plan that will provide an emission-reduction strategy to attain the air quality standard. The implementation plan sets forth the sources to be controlled, the degree of control to be accomplished, and the time schedule to be met.

The mechanics of the Act are shown in Figure 2, along with the statutory time limits allowed for each step in the process. The process begins for regions once they have been designated and after air quality criteria and control technique information have been published.

The National Air Pollution Control Administration has issued to the states air quality criteria and control technique information on the pollutant of immediate importance to foundries—particulate matter.[12]

Table 6 lists the 39 air quality control regions that have been designated as of July 31, 1970. It is expected that within the next year, regions will be designated for all other major metropolitan areas of the country and for most communities with more than 25,000 population.

TYPES OF REGULATIONS

Five types of emission standards have been predominant: concentration, collection efficiency, process weight rate, potential emission rate, and visible emissions. Each of these regulations will be explained and then evaluated regarding its future use.[13]

Concentration standards restrict pollutant mass per unit gas volume, such as pounds of particulate matter per thousand pounds of gas, grains per standard cubic foot, parts per million, and micrograms per standard cubic meter. These types of regulations are acceptable for pure combustion processes that can be compared by standardizing gas volume. Because foundries utilize processes other than pure combustion, concentration regulations are of limited value.

Another weakness of concentration standards is that pollutant concentration alone does not register total emissions, because the gas

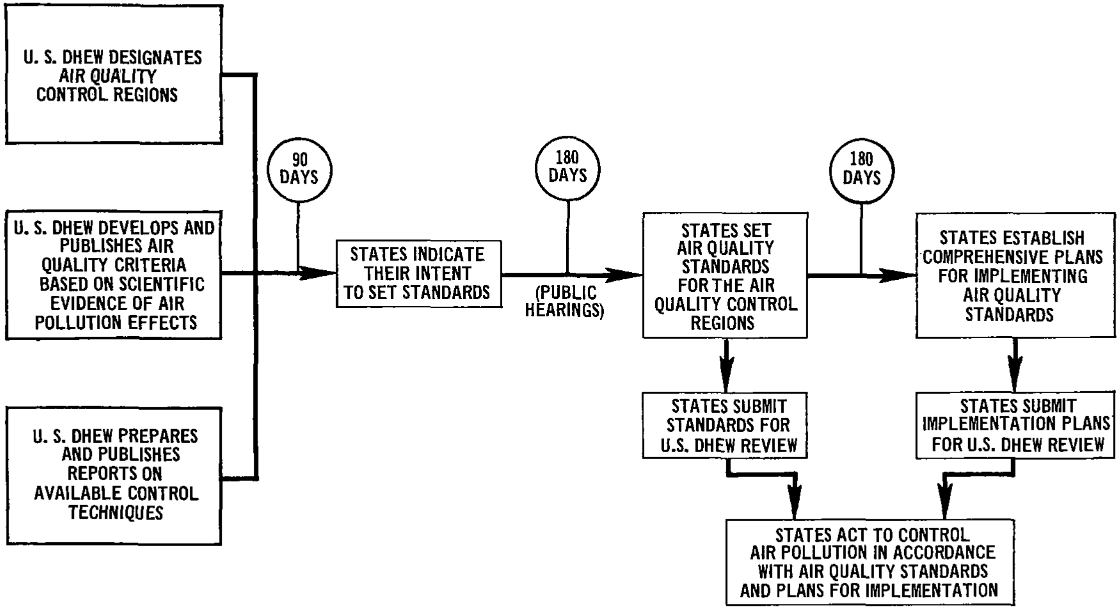

Figure 2. Flow diagram for action to control air pollution on regional basis.

Table 6. AIR QUALITY CONTROL REGIONS DESIGNATED AS OF JULY 31, 1970

1.	Washington, D. C.	21.	Seattle Tacoma, Wash.
2.	New York City, N. Y.	22.	Louisville, Ky.
3.	Chicago, Ill.	23.	Dayton, Ohio
4.	Philadelphia, Pa.	24.	Phoenix, Ariz.
5.	Denver, Colo.	25.	Houston, Texas
6.	Los Angeles, Calif.	26.	Dallas Ft. Worth, Texas
7.	St. Louis, Mo.	27.	San Antonio, Texas
8.	Boston, Mass.	28.	Birmingham, Ala.
9.	Cincinnati, Ohio	29.	Toledo, Ohio
10.	San Francisco, Calif.	30.	Steubenville, Ohio
11.	Cleveland, Ohio	31.	Chattanooga, Tenn.
12.	Pittsburgh, Pa.	32.	Atlanta, Ga.
13.	Buffalo, N. Y.	33.	Memphis, Tenn.
14.	Kansas City, Mo.	34.	Portland, Oregon
15.	Detroit, Mich.	35.	Miami, Fla.
16.	Baltimore, Md.	36.	Oklahoma City, Okla.
17.	Hartford, Conn. Springfield, Mass.	37.	Omaha, Neb.
18.	Indianapolis, Ind.	38.	Burlington, Vt.
19.	Minneapolis St. Paul, Minn.	39.	Virgin Islands
20.	Providence, R. I.		

volume is not taken into account. Thus, a low concentration could be incorrectly associated with low emissions. This is particularly relevant to foundries that infiltrate large quantities of air through the charging door. Robert McIlvaine[14] illustrates how deceptive concentration can be. For a cupola with particulate emissions of 170 pounds per hour, the concentration is 0.96 grain per standard cubic foot with a certain effluent gas volume. A concentration of 0.24 grain per standard cubic foot was measured with a four-fold increase in gas volume but with no change in the mass emission rate of 170 pounds per hour.

A single concentration standard requires about the same degree of control for large as for small sources; this fact is subject to criticism because large sources emit more pollution and are generally able to afford more efficient collectors.

Another type of regulation is one based on percentage removal of particulate matter from the gas stream. This collection efficiency regulation has the same weaknesses as concentration regulations because it does not: (1) limit total emissions generated by the process, (2) usually vary degree of control according to size of source, and (3) prevent circumvention by operators who recirculate collected particles or certain large particles through increased gas flow rates to increase collection efficiency, usually at the expense of increased emission rates.

Process weight rate regulations and potential emission rate regulations do not have the three deficiencies. These regulations: (1) restrict total emissions in pounds per hour, (2) vary in most applications according to source size, and (3) eliminate circumvention by focusing on emissions rather than collections. Allowable emissions vary according to the weight of materials processed per hour, as in the process weight regulation, or according to the uncontrolled emission rate, as in the potential emission rate regulation.

The process weight regulation of the San Francisco Bay Area Air Pollution Control District (Table 7) has been widely adopted by other communities and by states. In this regulation, as the process weight rate increases, the allowable emission rate becomes more stringent in terms of pounds of emissions per ton of material processed.

Process weight rate regulations generally apply to all industries. Some jurisdictions, however, have special provisions for a certain category of small gray iron cupolas. The New York State regulation, for example, specifies a more lenient process weight rate regulation for existing jobbing cupolas, which are defined as those melting less than 50,000 pounds per hour or operating less than 4 hours per day.

The Pennsylvania pollution potential regulation limits allowable emissions in pounds per hour. Potential emission rate is calculated from some suitable parameter and an emission factor associated with that parameter. In the case of foundries, the parameter is melt rate in tons per hour, and the emission factor is pounds of particulate matter produced per ton of metal melted. The regulation contains several emission limits that apply to different areas of the state.

Table 7. ALLOWABLE RATE OF EMISSION BASED ON PROCESS WEIGHT RATE, SAN FRANCISCO BAY AREA AIR POLLUTION CONTROL DISTRICT

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

Visible emission regulations are based on the opacity of the visible plume. Such regulations are widely accepted by State and local jurisdictions, and have been upheld in court.[13] The principal usefulness of visible emission standards is in (1) ease of source surveillance when large numbers of sources are present and (2) direct reduction of the quantity of very small particles that would otherwise contribute significantly to reduction in atmospheric visibility. Enforcement of such standards involves the visual judgment of individual observers whose observations can vary widely under various conditions of lighting and background. Trained observers, however, can reproduce observations to a reasonable degree of accuracy.

It can be expected that, in the future, process weight and potential emissions regulations will be more common in conjunction with an opacity regulation.

EXPECTED TRENDS IN AIR POLLUTION CONTROL

The Federally designated air quality control regions have closely followed the areas defined by respective Standard Metropolitan Statistical Areas (SMSA's). If all of the more than 200 SMSA's become parts of air quality control regions, then the number of foundries facing air pollution control will be determined largely by their location in SMSA's. Survey results show that 58 percent of the gray iron foundries are located in SMSA's, but smaller foundries tend to be outside SMSA's more frequently than do large ones. Approximately half of the foundries with gray iron shipments between $10,000 and under $500,000 are presently located in SMSA's. Nearly two-thirds of those shipping more than $0.5 million in castings are in SMSA's. Thus, larger foundries have a greater likelihood of facing air pollution control regulations.

TAX REFORM ACT OF 1969

The U.S. Tax Reform Act of 1969 provides for a 5-year straight-line depreciation of certified air pollution control facilities. Equipment covered must be placed in operation after December 31, 1968, and before January 1, 1975. Furthermore, the facilities must control pollution from plants in operation before January 1, 1969. Investments that merely diffuse pollutants, e.g., taller stacks, are excluded from the provision.

States must certify to the Department of Health, Education, and Welfare that the equipment conforms with their programs or regulations. Equipment is not eligible if its cost will be recovered over the actual useful life. Where the useful life of control equipment extends beyond 15 years, only part of the capital expenditure qualifies. For example, if the useful life is 20 years, then three-fourths of the capital value may be depreciated over 5 years.

CHAPTER 6. AIR POLLUTION CONTROL EQUIPMENT

INTRODUCTION

This chapter discusses the operating and efficiency characteristics of the several types of equipment commonly available for control of pollutants in foundries. The distribution of control systems is presented according to type of melting operation, size of foundry, and location.

TYPES OF CONTROL EQUIPMENT

The term "emissions control system" refers to all equipment installed at the plant for the purpose of reducing furnace emissions. Such equipment may, for example, include: (1) the cap of the cupola, (2) the ductwork leading from the cupola to the control device, (3) the quenching chambers for reducing gas temperatures, (4) the control device, (5) the demister (if needed) for removing moisture droplets from the gas stream, (6) the fans and pumps, (7) the particulate disposal and water-circulating systems, (8) the afterburner inside the cupola, and (9) automated electrical devices that monitor the system.

For control of particulate emissions, one of the following types of systems of air pollution control equipment is commonly used by gray iron foundries with cupola furnaces.

Wet Caps

The wet cap collection device consists basically of a conical "weatherhood" above the cupola stack. Water pours over the conical section to produce a water curtain through which the hot gases must pass. Overall collection efficiency is not likely to exceed 60 percent of solid particulates, on a total weight basis.[15] Wet caps will not meet a typical process weight regulation such as that presented in Table 7.

Multiple Cyclones

Multiple cyclones include devices in which a vortex is created to separate particles from the main gas stream. These particles then fall by gravity to locations from which they may be removed from the collector. Usual collection efficiency is in the 70 to 85 percent range (total weight basis).[14]

Wet Scrubbers

Wet scrubber systems use a liquid, usually water, to separate or assist in the separation of particulates from the gas stream. Collection efficiency will be a function of energy used to obtain the interaction between dispersed liquid droplets and particulates.

Low-energy wet scrubbers collect with an 85 to 95 percent efficiency.[14] For the purpose of this report, low-energy scrubbers include all those designs with an energy input up to 25 inches water gauge. Scrubber designs with energy requirements greater than 25 inches water gauge are classed as high-energy wet scrubbers. These collect more than 95 percent of uncontrolled emissions.[14]

Fabric Filters

Fabric filters are devices that remove particulate matter from gas streams by retention of the particles in or on a woven or felted fabric through which the gas flows. Collection efficiency can be maintained at more than 99 percent.[16] This equipment is used on electric arc and cupola furnaces.

For each type of air pollution control equipment, a detailed description is presented in Appendix E.

USE OF CONTROL EQUIPMENT

A survey conducted by BDSA identified 1,376 operating gray iron foundries throughout the United States in 1967. Of these, 204 foundries, or 15 percent of the total – accounting for approximately 40 percent of total value of gray iron production – had some type of air pollution control system. (Tables C-8 through C-10 in Appendix C.)

The number of gray iron foundries found to have installed air pollution control equipment was greatest among those with a relatively high value of production (Table 8). Foundries with production worth more than $2.5 million each in 1967 accounted for nearly half of all foundries with air pollution control equipment, although their number

Table 8. FOUNDRIES WITH CONTROL SYSTEMS

By value of production in 1967, $\$10^6$	Controlled foundries, % of total in value group
<0.5	3
0.5 to <1.0	11
1.0 to <2.5	20
2.5 to <10.0	38
≥10.0	65
Not reported	23

represented less than 16 percent of all foundries. Corollary to this, the distribution of "controlled" foundries by production size ran in direct proportion to the production-size class.

The greatest number of controlled foundries (80) was located in the East North-Central Region, as might be expected since over a third of all foundries are located there. The Pacific Region, however, had the highest percentage of foundries reporting some pollution control system. Controlled foundries, numbering 43, accounted for 42 percent of all Pacific Region foundries (Table C-10); all but two of these were located in California. Of the 63 foundries reported operating in California, 54, or 86 percent of the total, either had control equipment or used furnaces (such as electric induction, oil and gas reverberatory) that emit only a very small amount of particulate matter. This high percentage is due to California's stringent air pollution regulations and vigorous enforcement.

About 90 percent (1,232) of all the foundries surveyed operate cupolas; 3 percent, electric arc furnaces; and 7 percent, induction and other types of melting furnaces. Some foundries have more than one type of furnace; but for the purpose of this report, a foundry will be assumed to operate only one type furnace. In all instances, this assumption will be for that furnace that produces the largest output for the foundry.

Of the foundries operating cupolas, 180, or 15 percent, have some air pollution control; 24 of the 42 foundries with electric arc furnaces are controlled. No other type furnace was found to have air pollution controls.

The wet-cap system was used on 95 of the 180 controlled cupola furnaces. Wet caps are not used on non-cupola furnaces. Foundries using wet caps were geographically distributed on a comparable basis with the distribution of all foundries.

The fabric-filter system was used on approximately 30 percent of all controlled foundries. More than half of these (38 foundries) were located in California, where local regulations necessitate high collection efficiencies. One-third of the foundries using fabric filters had electric arc furnaces, and two-thirds had cupolas.

Wet scrubber systems were used at about 15 percent of all controlled foundries. Twenty of these foundries, or three-fifths of the total number using wet scrubbers, were located in the East North-Central Region. Most of the foundries with wet scrubbers operated cupolas; only four foundries applied scrubbers to electric arc furnaces.

Multiple cyclones were used on only 15 foundries, 8 of which were in the East North-Central Region.

An electrostatic precipitator was reported being used by only one foundry in the United States.

Electric induction furnaces without pollution controls were used by 73 foundries, or 5 percent of all reporting foundries. One-third of these are in the East North-Central Region, with the rest scattered throughout the country. About half of the foundries melting with electric induction furnaces are small, with individual foundry production for 1967 under $500, 000; in fact, the distribution of electric induction furnace foundries by production-size class differs only slightly from the distribution of all foundries.

CHAPTER 7. AIR POLLUTION CONTROL COSTS

INTRODUCTION

This chapter analyzes the results of survey interviews of gray iron foundries equipped with air pollution control equipment. A total of 67 interviews was conducted during 1968 among all sizes of foundries. These interviews focused on the costs associated with pollution control, and on the operating and engineering features of foundries that affected costs. The emphasis will be on cupola control systems, although information was collected on foundries operating furnaces other than cupolas and for control systems on nonmelting operations. Accordingly, the principal analysis presented comes from data collected on 51 gray iron foundries with cupolas controlled by wet caps, mechanical collectors, wet scrubbers, and fabric filters. (See Appendix B for a detailed explanation of the survey.)

CONCEPTS ON COST

Data were collected for two basic cost categories: investment costs and annual costs. The investment costs category sums the expenditures for the primary control equipment, any auxiliary equipment, installation, and research and development. For the research and development category, the number of respondents was negligible, and the total amount involved was insignificant. To compensate for differences in installation dates, investment costs were converted to a common base of 1967 dollars. This adjustment was made by using an implicit price deflator series for nonresidential fixed investment consisting of a "structures" and an "equipment" component; basic and auxiliary equipment costs were adjusted by use of the equipment component of this series.[17]

Annual costs, the other basic cost category, include operating and maintenance costs associated with the control system, and capitalized cost associated with the investment. Capitalized cost consists of depreciation and cost of capital. Depreciation was applied on a straight-line basis to the various types of control equipment according to the schedule shown in Table 9.

Table 9. CONTROL EQUIPMENT DEPRECIATION LIFE

Equipment	Life, yr
Wet cap	11
Multiple cyclone	15
Wet scrubber	9
Fabric filter	9

These figures for depreciation life were used to recalculate the depreciation data reported in the survey. An accurate portrayal of the economic life of most of the systems and a comparison with the depreciation life cannot be made because most systems have been in operation less than 9 years.

The long-term cost of capital was calculated at 7 percent of the total investment cost to account for interest incurred or, if a firm used its own capital, to account for the opportunities foregone by committing funds for air pollution control rather than for some revenue-producing investment. Annual costs are underestimated to a certain extent since it was not possible to allocate a portion of plant overhead to the control system.

ANALYSIS OF SURVEY DATA

Investment Costs

Investment costs of the control systems surveyed varied widely according to type, complexity, and size of system. The greatest differentiation in complexity of a given type of system exists between relatively simple low-energy wet scrubbers (up to 25-inch static pressure drop as in spray, impingement, and packed-bed systems) and the higher energy, venturi-type wet scrubbers (25- to 70-inch pressure drop). The investment costs of these two categories are considered separately.

A number of operating variables are indicative of control system size. Among them are melt rate of the cupola, gas volume throughput, and production volume. Analysis of collected data indicated that investment cost varies most directly with melt rate. For those foundries that have several cupolas operating on alternate schedules, yet controlled by the same control system, cost varies with the melt rate of the largest cupola or cupolas operated at any one time.

Table 10 presents total investment cost as a function of cupola melt rate for each type of control system. These costs are derived from functions presented in Appendix F Except for fabric filters, the costs show economies of scale in investments for pollution control systems. In mechanical collectors, for example, the cost of controlling a 16-ton-per-hour cupola is about one and a half times the cost of controlling an 8-ton-per-hour unit, rather than twice the cost as might be expected.

Table 10. INVESTMENT COST BY TYPE OF CONTROL SYSTEM ON CUPOLAS FOR TYPICAL MELT-RATE CAPACITIES ($\$10^3$)

Melt rate, tons/hr	Multiple cyclone	Low-energy wet scrubber	High-energy wet scrubber	Fabric filter
4	a	44	a	45
6	a	51	a	80
8	113	58	a	115
12	144	72	194	185
16	174	87	229	255
20	205	109	265	324

[a]No observations on facilities of this size.

Cost functions have not been derived for wet caps, since they seldom meet control efficiency standards. The average investment cost for wet caps, however, has been calculated as $4,903 per ton of melt rate. Individual control systems vary from as low as $1,031 to as high as $9,825 per ton of melt rate. Major variables affecting the investment costs of wet caps include: number of cupolas serviced; the materials used in construction — hot rolled or stainless steel; and the method of disposing of the dust-laden water — whether by draining to an existing disposal point or by draining to a clarifier tank and returning the "clean" water to the collector.

Multiple-cyclone costs may be expected to vary according to requirements on ducting and cooling. Added to the costs associated with these variations are costs related to the number of cyclones or banks of cyclones in the control system.

Variation in installed costs of wet scrubbers stems from the large number of equipment designs, use of corrosion-resistant metals, and a spread in the operating pressure drops from 4 to 70 inches water gauge.

Fabric-filter installations usually are designed for either batch or continuous foundry operations. Batch-type collectors are cheaper, but normally are suited only to small foundries that melt during a part of a shift.

Costs also may vary for the same type of control systems installed on comparable-size cupolas. Factors contributing to such cost variance are summarized in Table 11.

Investment Components

Basic and auxiliary equipment costs are the principal components of total investment. As shown in Table 12, equipment costs represent from 57 to 74 percent of total control investment.

On an individual foundry basis, the ratio of equipment costs to total investment varies considerably. Variations in installation requirements and labor costs were the main factors affecting this ratio.

Annual Costs

A comparison of the economic impacts of different control systems for foundries cannot be made solely on the basis of investment costs. Variations in life spans among different equipment types, as well as variations in operating and maintenance costs, must be considered in order to gain a true cost-comparison of alternatives. These factors and others that are considered in the derivation of total annual cost are listed on the interview form shown in Appendix B.

Since all relevant cost variables are included in total annual cost, alternate control systems for a given cupola size should be compared on an annual cost basis. Total annual control costs are presented in Table 13. Economies of scale are again evident for wet scrubbers,

Table 11. CONDITIONS AFFECTING INSTALLED COST OF CONTROL DEVICES[12]

Cost category	Low cost	High cost
Equipment transportation	Minimum distance; simple loading and unloading procedures	Long distance; complex procedure for loading and unloading
Plant age	Hardware designed as an integral part of new plant	Hardware installed into confines of old plant requiring structural or process modification or alteration
Available space	Vacant area for location of control system	Little vacant space requires extensive steel support construction and site preparation
Corrosiveness of gas	Noncorrosive gas	Acidic emissions requiring high alloy accessory equipment using special handling and construction techniques
Complexity of start-up	Simple start-up, no extensive adjustment required	Requires extensive adjustments; testing; considerable downtime
Instrumentation	Little required	Complex instrumentation required to assure reliability of control or constant monitoring of gas stream
Guarantee on performance	None needed	Required to assure designed control efficiency
Degree of assembly	Control hardware shipped completely assembled	Control hardware to be assembled and erected in the field
Degree of engineering	Autonomous "package" control system	Control system requiring extensive integration into process; insulation to correct temperature problem; noise abatement
Utilities	Electricity, water, and waste-disposal facilities readily available	Electrical and waste-treatment facilities must be expanded; water supply must be developed or expanded
Collected waste-material handling	No special treatment facilities or handling required	Special treatment facilities and/or handling required
Labor	Low wages in geographical area	Overtime and/or high wages in geographical area

Table 12. EQUIPMENT COSTS AS PERCENTAGE OF TOTAL CONTROL INVESTMENT

System	Equipment costs as percent of total control investment
Wet caps	63
Multiple cyclones	72
Wet scrubbers:	
Low-energy	57
High-energy	74
Fabric filters	72
All types	71

Table 13. ANNUAL COST BY TYPE OF CONTROL SYSTEM ON CUPOLAS FOR TYPICAL MELT-RATE CAPACITIES ($\$10^3$)

Melt rate, tons/hr	Multiple cyclone	Low-energy wet scrubber	High-energy wet scrubber	Fabric filter
4	a	13	a	13
6	a	15	a	24
8	18	16	a	34
12	33	20	60	55
16	50	24	72	77
20	67	28	84	a

[a]No observations on facilities of this size.

but not for multiple cyclones and fabric filters.

On the basis of total annual cost, low-energy wet scrubbers appear to be considerably less costly than multiple cyclones, even though wet scrubbers achieve a higher collection efficiency. This relationship is not unreasonable in view of the fact that wet scrubbers have an average rated gas volume of 2,000 acfm per ton of melt rate, while the conversion ratio for multiple cyclones is 5,200 acfm per ton of melt rate. In effect, the multiple cyclones surveyed were designed for gas volumes 2.6 times as great as the rated gas volumes of wet scrubbers on cupolas of comparable size.

Of the two types of high-efficiency collector systems, fabric filters account for all control systems on cupolas of less than 12 tons per hour. High-energy wet scrubbers, however, predominate in the cupola-size range from 12 to 50 tons per hour. This relationship is supported by the fact that the annual cost of high-energy wet scrubbers falls below the annual cost of fabric filters as cupola size rises above 12 tons per hour. Note the annual cost functions in Appendix F.

The average annual cost for wet caps is $1,497 per ton of melt rate. The range, however, is from $470 to $3,096 per ton of melt rate.

Operating and Maintenance Costs

Operating and maintenance (O and M) costs per hour of operation show a considerable range for each of the different types of control equipment. One reason may be the difficulty some plants had in developing this information; internal bookkeeping and auditing systems often include these expenditures in total plant-operating costs. Also, operating and maintenance costs vary with such factors as the quality and suitability of the control equipment and a foundry's operating and maintenance practices. Operating and maintenance cost factors peculiar to each type of control system are discussed below.

Wet Caps "O and M" costs for wet caps involve primarily the costs of water, electric energy, maintenance associated with pumping water, and disposal of collected wet material and water.

Multiple Cyclones For multiple cyclones, the significant operating costs are for electric power (which varies with the unit size), water for hot-gas cooling, and waste-disposal operations. Maintenance costs include the costs of servicing the fan motor, replacing any parts worn by abrasion, and flushing the clogged small-diameter tubes.

Wet Scrubbers (Low- and High-Energy) In addition to the cost of waste disposal, the major operating costs for wet scrubbers are power and scrubbing-liquid costs. Power requirements vary with equipment size, liquid circulation rate, and pressure drop. Maintenance includes servicing the fan or compressor motor and the pump, replacing worn or corroded parts, cleaning piping, and any necessary chemical treatment of the liquid in the circulation system.

Fabric Filters Operating costs for fabric filters include power costs for operating the fan and the bag-cleaning device, water costs for hot-gas cooling, and disposal of collected dry material. Maintenance costs include costs for servicing the fan and shaking mechanism, and replacing worn bags and parts.

Operating and maintenance costs accounted for from 35 to 49 percent of total annual costs, depending on the type of system; these costs are shown in Table 14.

Table 14. CONTROL SYSTEM OPERATING AND MAINTENANCE COSTS AS PERCENTAGE OF TOTAL ANNUAL COSTS

System	"O and M" costs as percent of total annual costs
Wet caps	41
Multiple cyclones	48
Fabric filters	46
Wet scrubbers:	
Low-energy	35
High-energy	49
All types	45

ELECTRIC INDUCTION FURNACES

Electric induction furnaces are a relatively new type of melting unit used by the gray iron foundry industry. Under existing air pollution control regulations, these furnaces usually do not require emission control equipment. Unlike uncontrolled cupolas, emission levels of electric induction furnaces are normally within acceptable levels set by current control regulations. Thus, for air pollution control purposes, investment in an electric induction furnace might be considered as an alternative to investment in a cupola and requisite control equipment. To gain information for evaluating these alternatives, the survey included information from ten foundries operating a total of 21 electric induction furnaces.

Of the 21 furnaces operated by the surveyed foundries, 14, or two-thirds, of these furnaces were installed since 1965. As seen in Table 15, only one of the furnaces was installed prior to 1963.

Table 15. DATES OF ELECTRIC INDUCTION FURNACE INSTALLATIONS

Number of furnaces	Date of installation
2	1968
4	1967
7	1966
1	1965
4	1964
2	1963
1	1962

In all but one of the surveyed foundries, electric induction furnaces replaced cupolas. The main reasons that foundrymen gave for replacing cupolas with electric induction furnaces were: compliance with air pollution regulations, economy of operation, and better metallurgical quality control.

Even with the additional costs of pollution control equipment, cupolas are, in most cases, less expensive than electric induction furnaces. Nevertheless, some foundries have found it to their advantage to replace cupolas with electric induction furnaces. Unfortunately, the interview survey provides only partial answers for this trend. Data on foundry profits and operating costs of cupolas and electric induction furnaces were not collected; therefore, it cannot be determined from the survey whether the profitability of foundries operating induction furnaces was higher or whether higher investment costs for electric induction furnaces were offset by lower operating costs than those experienced with cupolas.

In the absence of more comprehensive data, it appears that, for some individual foundries, investment in electric induction furnaces is a feasible alternative to investment in air pollution control equipment for existing cupolas. On the other hand, many foundries have replaced or added to their melting capacity with cupolas. In spite of the substantial cost of cupola air pollution control, many foundries, especially those pouring large tonnages, appear to still favor the cupola.

CHAPTER 8. FINANCIAL IMPACT OF AIR POLLUTION CONTROLS ON MODEL GRAY IRON FOUNDRIES

INTRODUCTION

The purpose of this chapter is to draw together data on financial aspects and pollution control costs in the context of typical plants. Comparisons are made for six model plants between annual pollution control and profits, between investment in pollution control systems and total investment in plant and equipment, and between annual pollution control costs and value of shipments. These comparisons of pollution control costs with financial data offer some basis for judgment of the economic impact of air pollution control costs on gray iron foundries.

MODEL PLANTS

Six plants with cupolas ranging in size from melt rates of 4 to 20 tons per hour have been used as models for the impact analysis. One reason for selecting this range of cupola sizes is that approximately three-fourths of all cupolas fall in this range. Another reason is that model plants are allowed that show the full range of profit rates in the industry.

Table 16 shows the size and operating characteristics of the model plants in terms of melt rate in tons per hour, hours of melting per day, days of melting per year, and the number of cupolas available for melting. Also presented are the values of shipments associated with these characteristics. Melting operations in hours per day and days per year are approximations of the observed averages for the respective foundry sizes. The model plants reflect the fact that a majority of the sampled foundries with melt rates under 10 tons per hour operated one cupola, and those over 10 tons per hour operated two cupolas. Note, however, that with few exceptions foundries with two cupolas used each only on alternate days.

Table 16. MODEL PLANT OPERATING CHARACTERISTICS AND VALUE OF SHIPMENTS

Model plants	Melt rate/cupola, tons/hr	Melt time,		Number of cupolas	Value of shipments, $\$10^3$
		hr/day	days/yr		
A	4	3	175	1	447
B	6	5	200	1	741
C	8	7	225	1	1,228
D	12	9	240	2	3,502
E	16	12	250	2	6,390
F	20	16	250	2	11,779

Value of shipments was determined from an equation in the form:

$$\log Y \quad a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4$$

where: $\log Y$ value of shipments, $\$10^3$

X_1 melt rate, ton/hr

X_2 number of cupolas

X_3 = melt time, hr/day

X_4 = annual melt time, days/yr

This form was fit by least squares techniques to 34 observations with complete records on the five variables. The derived equation is:

$$\log Y - 1.6003 + 0.02932X_1 + 0.21180X_2 + 0.03677X_3 + 0.00349X_4$$

Solving the equation for a melt rate of 4 tons per hour and a melt time of 3 hours per day for 175 days a year with one cupola yields the log of \$447,000. This falls in the smallest-size category of surveyed foundries since the model plant's value of shipments is less than \$500,000. It is assumed that this construction is typical of foundries under half a million dollars in value of shipments. Note from Table 16 that each of the five categories of value of shipments is represented by at least one model plant except for the \$2.5 to <10.0 million category, which has two.

Financial aspects of the model plants are presented in Table 17. Profits for each plant are calculated according to the average rate of taxable income to gross receipts for cupolas and electric arc furnaces. These rates were calculated from the data reported by the Internal Revenue Service for corporate tax returns in the five value of shipment

Table 17. MODEL PLANT FINANCIAL CHARACTERISTICS

Model plants	Value of shipments, $\$10^3$	Profit rate, %	Profit, $\$10^3$	Rate of return on investment, %	Investment, $\$10^3$
A	447	4.84	22	9.26	234
B	741	6.68	49	18.39	269
C	1,228	6.78	83	18.96	439
D	3,502	6.82	239	15.91	1,501
E	6,390	6.82	436	15.91	2,739
F	11,779	6.63	781	13.46	5,802

classifications. Investment in each model foundry was determined from knowing the profit and rate of return on investment. The latter was estimated from the same set of data used to calculate profit rates. Part of the Internal Revenue Service data included information on long-term debt and equity. The sum of these two items is defined as investment.

POLLUTION CONTROL COSTS OF MODEL PLANTS

It is now possible to compare the cost of pollution control with economic measures of typical gray iron foundries. Three relationships are investigated: (1) investment costs in pollution control to total investment, (2) annual costs of pollution control to profits, and (3) annual costs of pollution control to value of shipments.

The choices of control systems available to the model plants are determined by the types of regulations they must meet. Because the trend is toward process weight and opacity regulations, it is assumed that the model plants must comply with these. Because opacity is caused by very small particles, alternatives are limited to the most efficient collections systems — high-energy wet scrubbers and fabric filters.

As far as this analysis is concerned, choice is further limited by the absence of observations on high-energy wet scrubbers controlling cupolas with melt rates below 8 tons per hour and on fabric filters controlling cupolas with melt rates as high as 20 tons per hour. To extend cost estimates into these voids and beyond the range of observations would be inadvisably speculative.

Where a choice between the two control systems is possible, the least-cost alternative is selected. Thus a fabric filter is chosen over a high-energy wet scrubber to control the 12-ton-per-hour cupolas of Plant D, and a high-energy wet scrubber is chosen to control the 16-ton-per-hour cupolas of Plant E.

Table 18 compares the investment and annual costs of the control systems to the total foundry investment and profit before taxes for the respective model plants. Note that the impact of pollution control expenditures on the foundries tends to fall as the size of the foundry increases. Two exceptions are the ratios of control equipment investment to total plant investment, and control equipment annual cost to value of shipments for the 4- and 6-ton-per-hour model plant cupolas. One possible explanation is that plant and equipment investment in foundries with a 6-ton-per-hour cupola is little different from that associated with a 4-ton-per-hour cupola, except for those pieces that service the cupola directly, such as pollution control equipment. Thus the pollution control investment increases more rapidly than other plant and equipment investment as cupola size increases for the two smallest model plants.

Table 18. RELATION OF POLLUTION CONTROL COSTS TO TOTAL INVESTMENT, PROFIT, AND VALUE OF SHIPMENTS BY MODEL PLANT
(%)

Model plant	Control equipment	Control equipment investment as percent of total investment	Control equipment annual cost as percent of profit before taxes	Control equipment annual cost as percent of value of shipments
A	Fabric filter	19	59	2,3
B	Fabric filter	30	49	3.2
C	Fabric filter	26	41	2.8
D	Fabric filter	12	23	1.6
E	High-energy wet scrubber	8	17	1.1
F	High-energy wet scrubber	5	11	0.7

An increase in investment carries over in the form of depreciation and interest charges. As a result, the ratio of annual cost to value of shipments is higher for the 6-ton-per-hour cupola plant than for the

4-ton-per-hour cupola plant. The declining impact trend is preserved in the ratio of control equipment annual cost to profit before taxes, because the profit rate increases markedly between the 4- and 6-ton-per-hour cupola model plants.

The impact of pollution control is much greater on the smallest foundry than on the largest, whether measured by pollution control investment as a percent of total plant investment, by annual cost of pollution control as a percent of profits before taxes, or by annual cost as a percent of value of shipments. The annual control cost, which includes depreciation, interest, and operating and maintenance costs, is 59 percent of the profits before taxes for the typical plant under $0.5 million in value of shipments, but only 11 percent of the profit before taxes for the typical plant over $10 million. Annual cost as a percent of value of shipments for the smallest model foundry is more than 3 times as great as that for the largest one. The smallest Plant A would be forced to raise its prices by 2.3 percent in order to cover the annual costs of pollution control, while the larger Plant F would have to raise its prices just 0.7 percent.

It can be seen, therefore, that a small foundry relative to a large foundry must make a greater sacrifice in profits or take more drastic action in pricing if both foundries face equivalent restrictions on air pollution emissions.

CHAPTER 9. SUMMARY AND CONCLUSIONS

1. Nationally, gray iron foundries rank as one of the largest industries in terms of value of shipments, employment, and particulate pollution. Emissions in 1966 amounted to 190,000 tons, which was 2.9 percent of the 5.9 million tons of particulates emitted by industrial processes into the nation's atmosphere.

2. In 1967, particulate emissions were controlled from 204, or about 11 percent, of the 1,376 foundries in the gray iron industry. About half the foundries shipped less than $1.0 million in castings; and of those, only about 5 percent operate air pollution control systems.

3. The four most common pollution control devices, in ascending order of collection efficiency, are wet caps, multiple cyclones, wet scrubbers, and fabric filters. Nearly half the foundries with control systems use low-cost, low-efficiency wet caps, which do not usually satisfy stringent emission regulations.

4. Industry considerations as to whether and how to control air pollution have been influenced by state and local regulations. Federal activity under the Clean Air Act will serve to intensity state and local efforts to combat air pollution.

5. Pollution control costs tend to rise as collection efficiency rises.

6. A comparison of pollution control costs determined from the interview survey with industry financial data provided by the Internal Revenue Service suggests that the impact of stringent pollution control on small firms is greater than on large firms. The annual cost of controlling air pollution, as a percent of profits before taxes, declines, as size increases, from 59 percent for a typical firm with value of casting shipments under $0.5 million to 11 percent for a typical firm with over $10 million in value of shipments.

7. The possibility of foundries shifting air pollution control costs is limited by the price behavior in markets serving and served

by the industry. Up until 1967, there appears to have been some price flexibility as the industry grew relative to all manufacturing in terms of value of shipments, value added in manufacturing, capital expenditures, and profit.

8. While the profit share of value added appears to have risen, the profit rates for all sizes of firms in the industry still remained below those of equivalent-sized firms for all manufacturing. In addition, an analysis of the cross section of foundries shows that profit rate declines as foundry size declines.

9. A time series shows that there has been a steady attrition of small foundries under 50 employees, while those employing over 100 grew in number. The number of foundries with less than 50 employees fell by one-third from 1959 to 1967. About half of the foundries employ less than 50 people. Since about half of the foundries ship less than $1.0 million in castings, these are the most likely victims of attrition.

10. If the reduction in the number of small foundries is an indication of their inability to control or adjust to the market in which they compete, then the burden of air pollution control must be expected to weigh more heavily on them than on larger foundries. It would appear that the growth of larger foundries, the relative increase in casting prices, the relative decrease in raw materials prices, and the increasing profit and capital shares of the industry will allow larger firms to distribute the burden of air pollution control more widely.

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APPENDIX A.

CARD QUESTIONNAIRE AND LETTER OF TRANSMITTAL FOR MAIL SURVEY

U.S. DEPARTMENT OF COMMERCE
BUSINESS AND DEFENSE SERVICES ADMINISTRATION
WASHINGTON, D.C. 20230

April 15, 1968

Gentlemen:

The Business and Defense Services Administration is engaged in a study of the economic effect of air pollution control on the Gray Iron Foundry Industry. A first step involves collection of a minimum of information from all known Gray Iron Foundries. The enclosed BDSAF-807 requests information as to location and size of all Gray Iron Foundries, as well as information as to the kind and cost of air pollution control equipment installed.

This survey has been approved by the Bureau of the Budget and has been discussed with members of the Gray Iron Foundry Industry.

Before completing BDSAF-807, please read the enclosed instructions and definitions.

Your cooperation in completing BDSAF-807 and returning it in the enclosed self-addressed envelope no later than April 25, 1968 will be greatly appreciated.

Sincerely,

Forrest D. Hockersmith

Forrest D. Hockersmith
Acting Administrator

Enclosures

INSTRUCTIONS FOR COMPLETING BDSAF-807

Mailing: Complete and return the enclosed Form BDSAF-807 to the Business and Defense Services Administration, U.S. Department of Commerce, Iron and Steel Division, Washington, D.C. 20230, no later than April 25, 1968. A separate report is to be filed for each Gray Iron Foundry operated by your company. Include those foundries which do not sell any castings, but produce only for internal company consumption. Additional copies of this reporting form can be obtained from the above address.

Plant Location: On the front of the form, please correct name and address if necessary. If the Gray Iron Foundry is located at an address different from the company address, report that location below the company address.

Number of Cupolas: Please report in Item 1 the number of cupolas at this foundry.

Production During 1967: Report in Item 2, the total dollar value of all gray iron castings made at this foundry during 1967. You may report value of shipments if value of production data are not available. If a captive foundry is reporting and no value data are readily available, a value estimate based upon a knowledge of the market price of such castings will be acceptable.

Pollution Control System: Please check one or more boxes in Item 3 to designate the type(s) of pollution control equipment presently in operation at this foundry.. Please report all types of equipment regardless of the date when installed, just so long as the equipment is still in operation.

If you have installed a piece of equipment which is not specifically provided for in Item 3, please check Other and specify the equipment. If no air pollution control system is presently in operation at this foundry, check None. In Item 3B, please report the total initial installed cost of all air pollution control systems checked in Item 2A. This cost should represent not only the initial cost of the equipment but also should include the cost of installing the equipment. Listed below are definitions of the 4 types of air pollution control systems specifically shown in Item 3A.

Electrostatic Precipitator: A device which separates aerosol particulate matter (solid or liquid) from industrial gases by imparting an electric charge to the particles and removing them from the gas stream with the force created by an electric field. It is utilized to clean gases with concentrations of particulate matter of one-tenth of a grain per cubic foot of gas and over.

Fabric Filter: A device in which the dust bearing gas is passed through a fabric in such a manner that the dust particles are retained on the up stream or "dirty" gas side of the fabric, while the cleaned gas passes through the fabric to the down stream or clean gas side, whence it is removed by natural and/or mechanical means. The fabric may be of any fibrous material whether natural or man-made.

Mechanical Collector: A device for the separation in a dry state of entrained particulate material from a gas stream by the application of a combination of the following forces: centrifugal, inertial, gravitational.

Scrubber, Particulate: A device for the removal of particulate contaminants from a gas stream by means of intimate contact with the scrubbing liquid. (If water is added in any form, consider it a scrubber, except wetted wall electronic precipitators and other devices which are primarily mechanical collectors.)

Additional copies of BDSAF-807 or information regarding the form can be obtained from the Iron and Steel Division, 642, U.S. Department of Commerce, Washington, D.C. 20230.

PLEASE READ INSTRUCTIONS BEFORE COMPLETING THIS FORM

1. How many cupolas are there in this foundry? Number ______________________

2. Value of gray iron castings produced during 1967. $ ______________________

3a. What type of air pollution control system has been installed at this foundry? *(Check appropriate boxes)*

- [ ] Electrostatic precipitator
- [ ] Mechanical collector
- [ ] Fabric filter
- [ ] Scrubbers, Particulate
- [ ] Other *(Specify)* ______________________
- [ ] None

b. What was the initial installed cost of the air pollution control system? $ ______________________

(Estimates will be accepted if exact data are not readily available)

Name of person who should be contacted if questions arise regarding this report	Telephone No. and Area Code

Plant location *(If different from company)*	BUDGET BUREAU NO. 41S-68022 APPROVAL EXPIRES SEPT. 1968
	FORM BDSAF-807 (3-27-68) U.S. DEPARTMENT OF COMMERCE BUSINESS AND DEFENSE SERVICES ADMINISTRATION GRAY IRON FOUNDRY AIR POLLUTION CONTROL
Name and address of company *(Include Zip Code) (If name or address has changed please correct below)*	Return to: U.S. Department of Commerce Washington, D. C. 20230 Attention: Business and Defense Services Administration Iron & Steel Division
	Return no later than APRIL 25, 1968

APPENDIX B.

INTERVIEW SURVEY

SAMPLE PROCEDURE

Personal interviews were used to gather comprehensive economic data from plants that were reported to be controlling particulate emissions. Interviewers for the study personally visited the plants and assisted the plant manager in completing the questionnaire (BDSAF-823) used to structure the data.

Information gathered included: general establishment information, data on melting operations, production characteristics, control system characteristics, and costs of emissions control.

Plants visited for the "Interview Survey" represent a sample taken from the returns of the "Postcard Survey" (BDSAF-807). In selecting the sample, all plants with controls were first stratified by control system type and by plant size (Table B-1). Stratification by control system type was made to assure getting cost data for all types of available control equipment. Included in these categories was a group of plants operating electric furnaces—either electric arc furnaces with control systems or electric induction furnaces. The electric induction furnaces were evaluated as a substitute for the cupolas equipped with control devices. Stratification by plant size was considered important so that small as well as large plants would be statistically represented in the survey sample; this minimized bias resulting from differences in plant size.

About one-fourth of the 277 sites available for surveying were selected for visiting. This partial-sample plan was chosen as the most feasible procedure. The expense involved in field visits, combined with time and manpower limitations, prevented visits to all 277 sites.

Emphasis was evenly distributed among the plants of various size, except for the smallest category, where sites were not always available. Wet scrubbers, multiple cyclones, and fabric filters were emphasized because there were only a limited number installed on foundries of all sizes, and they qualify well as candidate systems for meeting future emission control requirements. Wet caps were deemphasized because they are simple devices and capable of meeting only the most lenient of air pollution control regulations.

Table B-1. SELECTION OF PLANTS FOR INTERVIEW SURVEY

System type	Annual value of production, $\$10^6$							Surveyed plants, % of total
	0-0.5	0.5-1.0	1.0-2.5	2.5-10.0	>10.0	Not reported	Total	
Wet caps	1/4[a]	3/11	4/24	2/35	3/7	0/14	13/95	14
Multiple cyclone	0/0	0/1	0/1	6/8	3/5	0/0	9/15	60
Wet scrubber	0/1	2/3	3/3	4/13	4/9	0/1	13/30	43
Electrostatic precipitator	0/0	0/0	0/0	1/1	0/0	0/0	1/1	100
Fabric filter	5/6	2/8	6/15	3/8	1/1	0/1	17/39	44
Electric furnaces[b]	3/43	4/15	4/22	1/8	2/6	0/3	14/97	14
Total	9/54	11/38	17/65	17/73	13/28	0/19	67/277	24

[a]The ratio designates the number of foundries selected for interviews from the total number of sites available.

[b]Includes 73 electric induction furnaces and 24 electric arc furnaces with particulate emission controls.

FORM BDSAF-823
(7-15-68)

U.S. DEPARTMENT OF COMMERCE
U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

BUDGET BUREAU NO. 41-S68067
APPROVAL EXPIRES JUNE 1969

Date

GREY IRON FOUNDRY AIR POLLUTION CONTROL SURVEY

Section I - GENERAL INFORMATION

1. Name and location of company

a. Name ____________________

b. Number and Street ____________________ c. County ____________________

d. City ____________________ e. State ____________________ f. Zip code ____________________

2. Location of Foundry if different from above

a. Number and Street ____________________

b. City ____________________ c. County ____________________

d. State ____________________ e. Zip code ____________________

3. Person to contact regarding this report

a. Name ____________________ b. Area Code/Phone ____________________

4. What is your form of organization? ☐ Corporation ☐ Partnership ☐ Proprietorship

5. What is your Employer Identification Number provided by the U.S. Social Security Administration .... ____________________

6. If your organization is a proprietorship, what is the proprietor's Social Security number? .... ____________________

7. **Employment.** What was the average number of production and production related workers for 1967? ____________

Production and production related workers are those up through the working formen level engaged in fabricating, processing, assembling, inspecting, receiving (not delivering), storage, handling, packing, warehousing, shipping, maintenance, repair, janitorial, watchman service, product development, auxiliary production for plants' own use (e.g., power plant), record keeping and other services closely associated with these production operations.

8. **Production of Castings.** What was the 1967 production of castings (include castings for own use and for sale) ____________________ short tons*

a. Value of total castings produced in 1967 ____________________ dollars

b. Percentage of total 1967 castings for own use ____________ %

Section II - MELTING OPERATIONS

9. **Characteristics of Furnace.** Report below the information for each melting operation within the foundry.
   a. Furnace Number is for reference in succeeding items.
   b. Type of furnace: identify as a cupola, electric arc, electric induction, if other, specify.
   c. Year the furnace was installed.
   d. Total installed cost of the furnace if installed since January 1, 1957. (Omit if earlier than 1/1/57.) Include initial cost of accessories for melting and charging.
   e. Average daily melt rate in tons per hour.
   f. Tons of metal poured in 1967.
   g. Blast volume in standard cubic feet per minute.
   h. Dimensions of the charging door.
   i. Charge door open during melt (yes or no)?

Furnace # (a)	Type (b)	Year Installed (c)	Installed Cost (d)	Melt Rate (e)	Output 1967 (f)	Blast Volume (g)	Charge Door	
							Size (h)	Open (i)
F1								
F2								
F3								
F4								
F5								
F6								

* Report all succeeding tonnage in short tons.

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10. Characteristics of charge for each furnace

Charge	Furnaces					
	F1	F2	F3	F4	F5	F6
Metal to coke ratio						
Scrap as percent of total Metal						
Predominant scrap charged						

11. What is the number of furnaces operated on any typical day?____________

12. How many days do you melt per year? ____________

13. How many hours do you melt per day? ____________

14. How many hours do you "light-up" per day?____________

15. Have you in the last ten years replaced cupolas with different types of furnaces? ☐ Yes ☐ No

a. If yes, with which type of furnace ____________

b. When ____________

c. Reason ____________

Section III - CONTROL SYSTEM

16. **Identification of Control System.** Complete Columns b through h for each control system

a. Control System Identification Number is for reference in succeeding items.

b. Type of control system. Please use the following abbreviations:

Fly ash and spark arrester	SA	Wet scruber	WS
Afterburner	AB	Fabric Filter	FF
Wet cap	WC	Electrostatic precipitator	EP
Mechanical collector	MC		

Where a control system consists of several pieces of connected equipment such as an afterburner, mechanical collector, electrostatic precipitator indicate the sequence by AB/MC/EP.

c. Furnaces serviced by the control system. Use the furnace identification number from Item 9. Furnaces not listed here will be assumed to have no control system.

d. Year the control system was installed.

e. Life over which the control system is depreciated.

f. Rated gas volume in cubic feet per minute at the gas exhauster inlet.

g. Gas temperature at the gas exhauster inlet in degrees fahrenheit.

h. Static pressure at the gas exhauster inlet in inches of water.

Control # (a)	Control System (b)	Furnace(s) Controlled (c)	Year Installed (d)	Depreciation Life (e)	Gas Vol. (f)	Gas Temp. (g)	Static Pressure (h)
C1							
C2							
C3							

17. Characteristics of the control systems. Complete the applicable items below

	Control Systems		
	C1	C2	C3
a. Height of exhaust stack above ground level (Ft.)			
b. Afterburner size in btu's/hours			
c. Water consumption in gallons/minute			
d. Do you have a noise chamber (yes/no)			
e. Duct work material (specify e.g. stainless steel)			
f. Duct work lining material (specify)			
g. Major control system material (specify)			
h. Filter fabric (e.g. glass, cotton)			
i. Air to cloth ratio			
j. Electrostatic precipitator kilowatt rating			

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18. **Operation of control system.**

Report below for each control system. In Columns (a) through (c) record any two of the following: inlet concentration, outlet concentration, and collection efficiency. Specify whether particulate concentrations are measured in terms of grains per standard cubic foot (gr/scf), pounds per thousand pounds of gas (#1000#gas), or pounds per hour (#/hr). In Column (d) indicate the furnace melting rate in tons per hour at which these measurements were taken.

Furnace #	Particulate Concentration		Collection Efficiency (%)	Melt Rate
	Inlet (a)	Outlet (b)	(c)	(d)
C1				
C2				
C3				

19. **Controlled non-melting operations.**
From the following list indicate in Column (a) below, the number of each of the operations in which your foundry engages.

1. Metal pouring and mold cooling
2. Oil removal operation from metal turnings
3. Coremaking operations
4. Sand drying and sand reclamation
5. Sand mixing
6. Molding sand handling
7. Mold and casting shakeout
8. Abrasive cleaning
9. Casting tumbling operations
10. Grinding operations
11. Annealing and heat treating furnaces
12. Pattern shop sawdust and chip systems
13. Casting surface treatment

In the other columns include the following information:
(b) Type of control equipment (specify, e.g. Fabric Filter)
(c) Year control equipment installed
(d) Rated size in cfm
(e) Amount of particulate collected in pound per week

Foundry Operation	Control Equipment			
(a)	Type (b)	Year Installed (c)	Size (cfm) (d)	Collection (#/week) (e)

Section IV - COSTS OF POLLUTION CONTROL

20. **Investment costs.** Report on lines 1 - 4, the designated costs associated with each of the control systems. Described below are examples of the items to be included in each type of investment cost. The column headed "All Other Control Systems" should include investment cost totals for all non-melting control systems as reported in item 19 above.
   1. Basic equipment. Include taxes and shipping charges with F.O.B. price on the "flange to flange" cost of basic equipment. If you manufactured the basic control equipment, estimate the cost of fabrication.
   2. Auxillary equipment. Include the following items essential to the successful operation of a control system but not generally manufactured by gas cleaning equipment suppliers:
      a. Air movement equipment
         (1) Fans and blowers
         (2) Electrical; motors, starters, wire conduit, switches, etc.
         (3) Hoods, duct works, gaskets, dampers, etc.
      b. Liquid movement equipment (in wet collection systems)
         (1) Pumps
         (2) Electrical; motors, starters, wire conduit, switches, etc.
         (3) Piping and valves
         (4) Settling tanks
      c. Storage and disposal equipment
         (1) Dust storage hoppers
         (2) Sludge pits
         (3) Drag lines, track way, road way, etc.
      d. Support construction
         (1) Structural steel work
         (2) Cement foundation, piers, etc.
         (3) Insulation (thermal)
         (4) Vibration and/or anti wear materials
         (5) Protective cover

e. Instrumentation: *measurement and/or control of:*
   (1) Air and/or liquid flow
   (2) Temperature and/or pressure
   (3) Operation and capacity
   (4) Power
   (5) Opacity of flue gas (smoke meters, etc.)

3. Research and development. Allocate the cost of research and engineering expenditures required for the selection of the specific control system, including such items as: material specifications, gas stream measurements, pilot operations, etc.
4. Installation. *Include the following items when applicable:*
   Labor to install
   Cleaning the site
   Yard and underground
   Building modification
   Design contingency
   Inspection
   Field contingency
   Overtime
   Existing facilities protection
   Supervision and engineering
   Field Office charges
   System start-up
   Profit reduction attributable to plant shutdown for installation
5. Total. This should be the sum of all investments made for control.

Investment Cost Categories	Control Systems on Furnaces			All Other Control Systems
	C1 (a)	C2 (b)	C3 (c)	(d)
1. Basic Equipment				
2. Auxillary Equipment				
3. Research and Development				
4. Installation				
5. Total				

21. Annual costs.
Report in lines 1 - 6 the designated annual costs associated with each of the control systems. Described below are examples of the items to be included in each type of annual cost. The column headed "All Other Control Systems" should include annual cost totals for all non-melting control systems in item 19 above.

Annual Cost Categories

1. Operating costs.
   a. Utilities needed to operate such as electricity, water, and gas
   b. Waste disposal operations
   c. Materials consumed in operating the system
2. Maintenance costs include labor and materials for:
   a. Replacement of parts and equipment
   b. Supervision and engineering
   c. Repairs
   d. Lubrication
   e. *Surface protection (cleaning and painting)*
3. Depreciation is the straight line allocation of total investment costs over the accounting life of the equipment
4. Other overhead for the control system includes:
   a. The cost of capital at 7% of the total investment cost
   b. Property taxes
   c. Insurance
   d. Miscellaneous
5. Process and equipment changes: include here changes in melting processes, melting equipment and furnace charge which were made when pollution control equipment was installed. This item will reflect the information reported in questions 11, 12 and 20.

Annual Cost Categories	Control Systems on Furnaces			All Other Control Systems
	C1 (a)	C2 (b)	C3 (c)	(d)
1. Operating				
2. Maintenance				
3. Depreciation				
4. Overhead				
5. Process and equipment changes				
6. Total				

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22. List and evaluate any benefits from controlling your air pollution such as reduced plant maintenance, reduced roof maintenance, increased property value, by-product recovery, reduced insurance premiums and fewer complaints by employees and neighbors.

23. Remarks

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APPENDIX C.

INDUSTRY SURVEY STATISTICAL TABLES

Table C-1. ECONOMIC STATISTICS FOR GRAY IRON FOUNDRY INDUSTRY[a]

(SIC 3321)

Year	Total employment		Production workers			Value added, $10^3	Value of shipments, $10^3	Capital expenditures, $10^3
	Number	Payroll, $10^3	Number	Man-hours, 10^3	Wages, $10^3			
1958	112,670	531,152	96,414	178,006	418,935	810,758	1,434,701	32,559
1959	125,862	644,417	109,132	217,159	525,482	1,002,896	1,803,001	34,072
1960	121,516	627,498	104,330	199,652	503,590	968,427	1,718,773	53,202
1961	113,685	602,316	97,468	183,888	481,672	923,970	1,622,700	52,307
1962	119,234	675,413	102,822	204,064	543,179	1,076,146	1,836,197	60,498
1963	120,528	730,279	104,239	214,285	596,109	1,168,478	1,984,944	64,823
1964	126,329	825,229	109,928	235,612	679,946	1,353,828	2,286,233	75,910
1965	134,894	921,798	117,109	252,953	760,351	1,559,350	2,602,590	171,468
1966	140,709	978,295	122,142	259,742	803,004	1,646,364	2,728,235	221,295
1967	143,000	993,000	123,000	250,000	804,000	1,603,000	2,718,000	173,000

Year	Value added as percent of shipments	Payroll per employee, $	Wages per production worker, $	Value of shipments per production worker, $	Value added per production worker man-hour, $	Value added per dollar of wages, $	Wages per production worker man-hour, $	Annual man-hours per production worker
1958	56.5	4,714	4,345	14,881	4.555	1.935	2.353	1,846
1959	55.6	5,120	4,815	16,521	4.618	1.909	2.420	1,990
1960	56.3	5,164	4,827	16,474	4.851	1.923	2.522	1,914
1961	56.9	5,298	4,942	16,649	5.025	1.918	2.619	1,887
1962	58.6	5,665	5,283	17,858	5.274	1.981	2.662	1,985
1963	58.9	6,059	5,719	19,042	5.453	1.960	2.782	2,056
1964	59.2	6,532	6,191	20,816	5.746	1.991	2.886	2,145
1965	59.9	6,833	6,493	22,224	6.165	2.051	3.006	2,160
1966	60.3	6,953	6,574	22,337	6.338	2.050	3.092	2,127
1967	59.0	6,944	6,537	22,098	6.412	1.994	3.216	2,033

[a]U.S. Department of Commerce, Business, and Defense Services Administration, Industrial Profiles: 1958-1967, Washington, D. C., 1969, p. 87.

Table C-2. ECONOMIC STATISTICS FOR ALL MANUFACTURING OPERATIONS IN UNITED STATES[a]

Year	Total employment		Production workers			Value added, 10^3	Value of shipments, 10^3	Capital expenditures, 10^3
	Number	Payroll, 10^3	Number	Man-hours, 10^3	Wages, 10^3			
1958	15,423,112	73,875,152	11,681,143	22,679,219	49,605,180	141,540,618	326,722,817	9,543,528
1959	16,062,862	81,203,626	12,272,622	24,443,617	54,714,135	161,535,816	N.A.[b]	9,139,992
1960	16,149,888	83,672,541	12,209,514	24,174,380	55,555,452	163,998,531	N.A.	10,097,837
1961	15,729,570	83,677,413	11,778,518	23,289,389	54,764,619	164,281,080	N.A.	9,779,800
1962	16,154,702	89,819,178	12,126,537	24,269,571	59,134,113	179,071,122	N.A.	10,436,210
1963	16,234,506	93,288,785	12,232,041	24,509,450	62,093,601	192,103,102	420,528,098	11,370,935
1964	17,268,508	106,048,071	12,403,299	25,245,482	65,838,852	206,193,600	447,985,142	13,262,323
1965	18,047,608	114,143,178	13,058,819	26,577,538	71,736,328	226,974,525	492,028,808	16,606,592
1966	19,065,997	125,458,784	13,810,393	28,220,286	78,283,386	251,013,903	538,494,230	20,234,304
1967	19,388,000	131,929,000	13,975,000	27,925,000	81,025,000	259,301,000	555,863,000	20,268,000

Year	Value added as percent of shipments	Payroll per employee, $	Wages per production worker, $	Value of shipments per production worker, $	Value added per production worker man-hour, $	Value added per dollar of wages, $	Wages per production worker man-hour, $	Annual man-hours per production worker
1958	43.3	4,790	4,247	27,970	6.241	2.853	2.187	1,942
1959	N.A.	5,055	4,458	N.A.	6.609	2.952	2.238	1,992
1960	N.A.	5,181	4,550	N.A.	6.784	2.952	2.298	1,980
1961	N.A.	5,320	4,650	N.A.	7.054	3.000	2.351	1,977
1962	N.A.	5,560	4,876	N.A.	7.378	3.028	2.437	2,001
1963	45.7	5,746	5,076	34,379	7.838	3.094	2.533	2,004
1964	46.0	6,141	5,308	36,118	8.168	3.132	2.608	2,035
1965	46.1	6,325	5,466	37,678	8.540	3.180	2.686	2,035
1966	46.6	6,580	5,668	38,992	8.895	3.206	2.774	2,043
1967	46.6	6,805	5,798	39,776	9.286	3.200	2.902	1,998

[a]U.S. Department of Commerce, Business, and Defense Services Administration, Industrial Profiles, 1958-1967, Washington, D. C. 1969, p. 142.

[b]N.A. = Not available.

Table C-3. GRAY IRON FOUNDRY VALUE OF SHIPMENTS (PRIMARY PRODUCTS), 1963[a]

	Amount, $\$10^6$	Percentage distribution
Gray iron shipments by all industries		
Gray Iron Foundry Industry	1,794[b]	88
Other industries	252	12
Total	2,046	100
Shipments of primary products by Gray Iron Foundry Industry (SIC 3321)		
Gray iron castings, unspecified by type	1,656	92
Molds for heavy steel ingots	101	6
Malleable iron castings	22	1
Steel castings	15	1
Total	1,794[b]	100

[a]Bureau of the Census 1963 Census of Manufacturers.

[b]Excludes $134 million of minor products and $56 million of miscellaneous receipts.

Note: Value of shipment total differs from that reported in Table C-1, since the latter is defined as SIC 3321.

Table C-4. COST OF MATERIALS FOR GRAY IRON FOUNDRY INDUSTRY (SIC 3321), 1963[a]

Materials consumed	Cost, $\$10^6$
Pig iron (excluding silvery iron)	276
Nonferrous metals, alloys and ferroalloys	
Aluminum, unalloyed	2
Aluminum-base alloys	2
Copper-base alloy raw materials	5
Magnesium and magnesium-base alloys	5
Ferromanganese	3
Other ferroalloys, including silvery iron	36
Scrap (purchased only)	171
Other materials, parts and supplies	167
Total materials consumed	667
Cost of resales	40
Fuels consumed	56
Electric energy purchased	21
Contract work	28
Grand total	814[b]

[a]Bureau of the Census 1963 Census of Manufacturers, Vol. II, Part 2, pp. 33B-9 and 33B-16.

[b]Detail does not add to total due to independent rounding.

Table C-5. WHOLESALE PRICE INDEX[a]
(1957-1959 = 100)

Year	Gray iron castings	Cupola cast iron scrap, Chicago	Pig iron and ferroalloys
1957	98.3	93.8	99.6
1958	99.2	93.2	100.1
1959	102.5	113.0	100.3
1960	104.7	93.6	96.3
1961	104.8	92.1	94.7
1962	106.2	83.0	91.1
1963	107.3	84.9	81.8
1964	108.3	94.5	77.7
1965	110.2	98.8	80.2
1966	113.5	103.8	80.2
1967	122.1	96.6	80.0

[a]U.S. Department of Labor, Bureau of Labor Statistics.

Table C-6. CONSUMPTION OF SCRAP AND PIG IRON IN FOUNDRY CUPOLAS[a,b]

Year	Scrap iron		Pig iron		Total	
	10^3 tons	Percent of total	10^3 tons	Percent of total	10^3 tons	Percent
1957	8,992	68.9	4,057	31.1	13,049	100.0
1958	7,696	70.0	3,237	30.0	10,933	100.0
1959	9,438	70.9	3,939	29.1	13,377	100.0
1960	8,830	72.4	3,420	27.6	12,250	100.0
1961	8,425	73.4	3,098	26.6	11,523	100.0
1962	9,516	75.9	3,137	24.1	12,653	100.0
1963	10,597	76.8	3,295	23.2	13,893	100.0
1964	11,837	78.4	3,356	21.6	15,193	100.0
1965	12,932	79.7	3,453	20.3	16,385	100.0
1966	13,490	80.6	3,360	19.4	16,850	100.0
1967	12,404	81.4	2,928	18.6	15,332	100.0

[a]Includes foundries other than gray iron.

[b]U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, Vol. I., Washington, D. C. 1959-1968.

Table C-7. CLASSIFICATION OF GRAY IRON FOUNDRIES (SIC 3321) BY NUMBER OF EMPLOYEES, 1959-1967[a]

Employees/ foundry	Year											
	1959		1962		1964		1965		1966		1967	
	Foundries	Percent of total	Foundries	Percent of total	Foundries	Percent of total	Foundries	Percent of total	Foundries	Percent of total	Foundries	Percent of total
<20	405	32	410	34	329	30	303	28	270	26	249	24
20 - 49	352	28	308	26	277	25	274	25	255	24	257	24
50 - 99	232	19	230	19	217	20	222	21	223	21	229	22
100 - 249	171	14	168	14	175	16	179	17	188	18	203	19
250 - 499	56	4	48	4	55	5	59	5	64	6	66	6
500 or more	35	3	32	3	39	4	45	4	51	5	51	5
Total reporting[b]	1,251	100	1,196	100	1,092	100	1,082	100	1,051	100	1,055	100

[a]Bureau of the Census, County Business Patterns.

[b]Includes only those foundries classified by Census into SIC 3321, "Gray Iron Foundry Industry. The BDSA-NAPCA Gray Iron Foundry Air Pollution Survey, BDSAF-807, identified 1,376 foundries operating in 1967, including a number belonging to establishments in which gray iron production was a secondary activity.

Table C-8. TOTAL FOUNDRIES AND FOUNDRIES WITH CONTROL SYSTEMS[a]

	Total foundries	Foundries with control systems	
		Number	% of total
By value of production, 1967, $\$10^6$			
<0.5	604	20	3
0.5 to <1.0	240	27	11
1.0 to <2.5	247	49	20
2.5 to <10.0	180	68	38
≥10.0	37	24	65
Not reported	68	16	23
Total	1,376	204	15
By geographic area			
New England	95	9	9
Middle Atlantic	247	26	11
East North-Central	472	80	17
West North-Central	121	13	11
South Atlantic	131	13	10
East South-Central	108	13	12
West South-Central	73	3	4
Mountain	27	4	15
Pacific	102	43	42
Total	1,376	204	15

[a]BDSA-NAPCA Gray Iron Foundry Air Pollution Control Survey, BDSAF-807, 1968 (Postcard).

Table C-9. GRAY IRON FOUNDRIES CLASSIFIED BY OUTPUT-SIZE CLASSES AND TYPES OF AIR POLLUTION CONTROL SYSTEMS[a]

	Value of production in 1967, $\$10^6$						
	< \$0.5 million	\$0.5 to <1 million	\$1 to <2.5 million	\$2.5 to <10 million	≥ \$10 million	Not reported	Total
Cupola foundries							
With control systems							
Wet cap	4	11	24	35	7	14	95
Multiple cyclone	-	1	1	8	5	-	15
Wet scrubber	1	3	3	13	9	1	30
Fabric filter	6	8	15	8	1	1	39
Electrostatic precipitator	-	-	-	-	-	1	1
Subtotal	11	23	43	64	22	17	180
Without control systems	514	200	178	107	7	46	1,052
Total	525	223	221	171	29	63	1,232
Electric arc foundries							
With control systems							
Wet scrubber	2	-	2	-	-	-	4
Fabric filter	7	4	4	3	2	-	20
Subtotal	9	4	6	3	2	-	24
Without control systems	11	-	4	-	1	2	18
Total	20	4	10	3	3	2	42
Induction furnace foundries (no control systems)	34	11	16	5	4	3	73
Other foundries[b] (no control systems)	25	2	-	-	1	1	29
Total foundries	604	240	247	179	37	69	1,376
With control systems	20	27	49	67	24	17	204
Without control systems	584	213	198	112	13	52	1,172

[a] BDSA-NAPCA Gray Iron Foundry Air Pollution Control Survey, BDSAF-807, 1968 (Postcard).

[b] Includes gas and oil reverberatory, crucible, and blast.

Table C-10. GEOGRAPHIC DISTRIBUTION OF GRAY IRON FOUNDRIES BY TYPE OF FURNACE AND TYPE OF AIR POLLUTION CONTROL EQUIPMENT[a]

Region	Type furnace								Totals		Type control				
	Cupola		Electric arc		Electric induction		Other				Wet cap	Fabric filter	Wet scrubber	Multiple cyclone	Electrostatic precipitator
	C[b]	U[c]	C	U	C	U	C	U	C	U					
New England	9	78	0	0	0	4	0	4	9	86	7	0	1	1	0
Middle Atlantic	22	207	4	0	0	11	0	3	26	221	17	3	4	2	0
East North-Central	72	356	8	6	0	23	0	7	80	392	41	11	20	8	0
West North-Central	12	103	1	1	0	2	0	2	13	108	11	1	1	0	0
South Atlantic	11	110	2	2	0	5	0	1	13	118	9	1	3	0	0
East South-Central	12	88	1	1	0	5	0	1	13	95	6	1	3	3	0
West South-Central	3	59	0	0	0	7	0	4	3	70	3	0	0	0	0
Mountain	3	15	1	1	0	6	0	1	4	23	0	2	2	0	0
Pacific	36	36	7	7	0	10	0	6	43	59	1	40	0	1	1
Totals	180	1,052	24	18	0	73	0	29	204	1,172	95	59	34	15	1

[a]BDSA-NAPCA Gray Iron Foundry Air Pollution Control Survey, BDSAF-807, 1968.

[b]C = controlled.

[c]U = uncontrolled.

APPENDIX D.

FINANCIAL DATA SURVEY

INTRODUCTION

In order to estimate the financial impact of installation and operation of air pollution control equipment of gray iron foundries, BDSA requested that the Internal Revenue Service tabulate certain data from income tax returns filed for tax year 1966. To this end, Reimbursable Service Agreement Project Number 69-47 was approved on December 3, 1968, and the tabulation was transmitted to BDSA by IRS on April 29, 1969.

SAMPLE

Of the 686 firm names that BDSA submitted to IRS, the latter tabulated returns on 492, or 72 percent. Individual company data were not provided by BDSA; IRS provided only information consolidated by class sizes. The major categories for which data were provided were corporations, small corporations, partnerships, and proprietorships, as determined by type of tax return filed. In addition, each category was further broken down by size of foundry sales in intervals of:

<$500, 000
$500, 000 to <$1, 000, 000
$1, 000, 000 to <$2, 500, 000
$2, 500, 000 to <$10, 000, 000
≥$10, 000, 000

The number of firms in each category is set forth in Table D-1.

The data supplied by IRS for each category except proprietorships were:

1. Number of returns.
2. Gross receipts.
3. Cost of goods sold.
4. Amortization, depreciation, and depletion.
5. Taxable income.

6a. For corporations: total income tax.
6b. For small corporations: compensation of officers.
6c. For partnerships: payments to partners.

7. Current assets.
8. Current liabilities.

Table D-1. IRS GRAY IRON FOUNDRY TABULATION, 1966

Type of tax return Type of foundry furnace	Total number of foundries	Returns with balance sheet items		Returns without balance sheet items
		Jobbing foundries[a]	Captive foundries[b]	
Corporations				
Electric induction (no controls)	44	18	22	4
Cupola/arc (controls)	102	58	43	1
Cupola/arc (no controls)	285	164	114	7
Total corporations	431	240	179	12
Small corporations				
Electric induction (no controls)	1	1	-	-
Cupola/arc (controls)	2	2	-	-
Cupola/arc (no controls)	19	12	7	-
Total small corporations	22	15	7	0
Partnerships				
Electric induction (no controls)	-	-	-	-
Cupola/arc (controls	2	2	-	-
Cupola/arc (no controls)	25	14	4	7
Proprietorships				
Electric induction (no controls)	2	-	-	2
Cupola/arc (controls)	10	-	-	10
Cupola/arc (no controls)	-	-	-	-
Total partnerships and proprietorships	39	16	4	19
Total	492	271	190	31

[a]Firms in which gross receipts were less than twice foundry sales; this is construed to include most "jobbing foundries."

[b]Firms in which gross receipts were more than twice foundry sales; this is construed to include most "captive foundries."

9. Long-term debt.
10. Gross value of fixed assets.
11. Depreciation reserves.
12. Equity.

Returns without balance sheet items (7 through 12) were tabulated for items 1 through 6 only. Proprietorships were tabulated for items 1 through 5 only.

SUBSAMPLE

The financial analysis has been limited to a subsample of 240 corporation tax returns. This has been necessary for several reasons. First, partnerships and proprietorships were excluded due to comparatively small numbers of firms and the larger proportion without balance sheet items. Second, small corporations were not included because of small numbers again but, also, because of the absence of a measure of profits after taxes. Third, corporations without balance sheet items lacked information that would allow complete inclusion with corporations reporting balance sheet items. Finally, foundries classified as "captive" were excluded. "Captive foundries" were defined to the IRS as those companies with gross receipts more than twice the value of gray iron castings shipped. To include those companies would have been misleading where foundries were the major interest. "Captive foundries," under our definition, clearly had other important interests. For example, the 186 corporate "Captive foundries" are components of firms with 1966 gross receipts of over $60 billion. These clearly do not belong in the gray iron foundry industry classification, which reports shipments valued at $2.7 billion.

The 240 foundries represent 17 percent of all the 1,376 foundries in the industry (Table D-2). Included in the subsample are 28 percent of the firms melting with cupolas or electric arc furnaces that have air pollution control systems. The 240 firms filing corporate tax returns in 1966 reported gross receipts totaling $756 million, or approximately 28 percent of the value of shipments reported in that year (Table D-3).

Table D-2. IRS CORPORATE SUBSAMPLE AS PROPORTION OF ALL GRAY IRON FOUNDRIES, 1966

Furnace type	Size of foundry sales, 10^6	Industry	Subsample	Subsample as percent of industry
Electric induction	<0.5	34	6	18.0
	0.5 to <1.0	11	7	64.0
	1.0 to <2.5	16	2	12.5
	2.5 to <10.0	5	2	40.0
	≥10.0	4	1	25.0
	Unreported	3		
	Subtotal	73	18	25.0
Cupola/arc (controls)	<0.5	20	4	20
	0.5 to <1.0	27	9	33
	1.0 to <2.5	49	23	47
	2.5 to <10.0	68	16	24
	≥10.0	24	6	25
	Unreported	16		
	Subtotal	204	58	28
Cupola/arc (no controls)	<0.5	550	60	11
	0.5 to <1.0	202	48	24
	1.0 to <2.5	182	38	21
	2.5 to <10.0	107	16	15
	≥10.0	9	2	22
	Unreported	49		
	Subtotal	1,099	164	15
	Total	1,376[a]	240[b]	17

[a]Number of foundries in industry; also see Appendix C, Table C-7.
[b]Number of firms in subsample; see also Table B-1.

Table D-3. IRS CORPORATE SUBSAMPLE CLASSIFIED BY AMOUNT OF SALES, 1966

Size of foundry sales, 10^6	Type of furnace			Total[a]	
	Induction furnace	Controls: cupola/arc	No controls: cupola/arc	Number of firms	Firms' receipts, 10^6
<0.5	6	4	60	70	18
0.5 to <1.0	7	9	48	64	50
1.0 to <2.5	2	23	38	63	112
2.5 to <10.0	2	16	16	34	152
≥10.0	1	6	2	9	424
Total	18	58	164	240	756

[a]15 corporations filing small corporation returns were omitted from portions of the analysis because fully comparable data were unavailable.

FINANCIAL AVERAGES

Financial averages were prepared for the 240 observations. The seven averages presented are: (1) net profits before taxes, (2) income tax, (3) net profits after taxes, (4) cash flow, (5) gross receipts, (6) net worth, and (7) amortization, depreciation, and depletion. These are summarized by size of foundry sales from averages by type of furnace (Table D-4), and by type of furnaces from averages according to size (Table D-5).

COMPARABILITY PROBLEMS

Comparisons between the interview survey data (Chapter 4) and the IRS data (Chapter 5) are subject to the following technical difficulties:

1. The former are from establishments; the latter are from firms.
2. The former take into account the important differences in cost and effectiveness between different types of control equipment; the latter do not.
3. Despite some inevitable overlapping, the two sets of data are not from the same group of foundries.
4. The former have been adjusted to 1967 prices; the latter are on a 1966 basis. It was felt that the advantages of using the latest available figures in each instance outweighed the advantages of having both sets of data as of the same year.

Table D-4. SELECTED FINANCIAL AVERAGES OF SAMPLE OF GRAY IRON FOUNDRIES CORPORATIONS ONLY, CLASSIFIED BY SIZE OF FOUNDRY SALES, 1966[a]

Size of foundry sales, $\$10^6$	Type of furnace	Number of firms	Averages per firm, $\$10^3$						
			Net profits before taxes	Income tax	Net profits after taxes	Amortization, depreciation, depletion	Cash flow	Gross receipts	Net worth
<0.5	Electric induction (no controls)	6	-15	1	-16	5	-11	219	68
	Cupola/arc (controls)	4	11	3	8	10	18	325	149
	Cupola/arc (no controls)	60	13	4	9	4	13	264	126
	Subtotals	70	11	4	7	5	12	263	122
0.5 to <1.0	Electric induction (no controls)	7	41	12	29	19	48	686	168
	Cupola/arc (controls)	9	53	15	38	18	56	1,009	256
	Cupola/arc (no controls)	48	53	21	32	12	44	757	255
	Subtotals	64	52	19	33	13	46	784	245
1.0 to <2.5	Electric induction (no controls)	2	54	16	38	18	56	1,326	322
	Cupola/arc (controls)	23	135	57	78	33	111	1,874	551
	Cupola/arc (no controls)	38	113	38	75	52	127	1,733	631
	Subtotals	63	119	44	75	44	119	1,771	592
2.5 to <10.0	Electric induction (no controls)	2	750	317	433	229	662	5,132	2,717
	Cupola/arc (controls)	16	329	186	143	257	400	5,287	2,395
	Cupola/arc (no controls)	16	276	116	160	44	204	3,569	1,099
	Subtotals	34	329	161	168	155	323	4,470	1,804
≥10.0	Electric induction (no controls)	1	2,309	1,079	1,230	231	1,461	14,617	5,390
	Cupola/arc (controls)	6	4,298	1,826	2,472	2,201	4,673	61,222	30,903
	Cupola/arc (no controls)	2	698	179	519	549	1,068	21,162	4,164
	Subtotals	9	3,277	1,377	1,900	1,615	3,515	47,141	22,126
	Electric induction (no controls)	18	229	102	127	49	176	1,869	725
	Cupola/arc (controls)	58	598	265	333	315	648	8,714	4,126
	Cupola/arc (no controls)	164	82	30	52	28	80	1,326	425
	Totals	240	217	92	125	99	224	3,152	1,342

[a]Based on Internal Revenue Service tabulations for 1966 from income tax returns filed by firms in the Gray Iron Foundry Industry.

Table D-5. SELECTED FINANCIAL AVERAGES OF SAMPLE OF GRAY IRON FOUNDRIES, CORPORATIONS ONLY, CLASSIFIED BY TYPE OF FURNACE, 1966[a]

Furnace type	Size of foundry sales, $\$10^6$	Number of firms	Averages per firm, $\$10^3$: Net profits before taxes	Income taxes	Net profits after taxes	Amortization, depreciation, depletion	Cash flow	Gross receipts	Net worth
Electric induction (no controls)	<0.5	6	-15	1	-16	5	-11	219	68
	0.5 to <1.0	7	41	12	29	19	48	686	168
	1.0 to <2.5	2	54	16	38	18	56	1,326	322
	2.5 to <10.0	2	750	317	433	229	662	5,132	2,717
	≥10.0	1	2,309	1,079	1,230	231	1,461	14,617	5,390
	Subtotals	18	229	102	127	49	176	1,869	725
Cupola/arc (controls)	<0.5	4	11	3	8	10	18	325	149
	0.5 to <1.0	9	53	15	38	18	56	1,009	256
	1.0 to <2.5	23	135	57	78	33	111	1,874	551
	2.5 to <10.0	16	329	186	143	257	400	5,287	2,395
	≥10.0	6	4,298	1,826	2,472	2,201	4,673	61,222	30,903
	Subtotals	58	598	265	333	315	648	8,714	4,126
Cupola/arc (no controls)	<0.5	60	13	4	9	4	13	264	126
	0.5 to <1.0	48	53	21	32	12	44	757	255
	1.0 to <2.5	38	113	38	75	52	127	1,733	631
	2.5 to <10.0	16	276	116	160	44	204	3,569	1,099
	≥10.0	2	698	179	519	549	1,068	21,162	4,164
	Subtotals	164	82	30	52	28	80	1,326	425
	<0.5	70	11	4	7	5	12	263	122
	0.5 to <1.0	64	52	19	33	13	46	784	245
	1.0 to <2.5	63	119	44	75	44	119	1,771	592
	2.5 to <10.0	34	329	161	168	155	323	4,470	1,804
	≥10.0	9	3,277	1,377	1,900	1,615	3,515	47,141	22,126
	Totals	240	217	92	125	99	224	3,152	1,342

[a]Based on Internal Revenue Service tabulations for 1966 from income tax returns filed by firms in the Gray Iron Foundry Industry.

APPENDIX E.

PARTICULATE EMISSIONS AND AIR POLLUTION CONTROL EQUIPMENT

INTRODUCTION

This appendix first lists the different types of foundry particulate emissions; second, it describes in some detail the performance of foundry furnace gas-cleaning equipment.

FOUNDRY PARTICULATE EMISSIONS

1. Unburned combustible - Volatilized oil, fine particles of coke breeze. This fraction produces the black smoke appearance when uncontrolled.
2. Coarse solids, plus 44 microns* Burned sand particles adhering to foundry remelts, weathered limestone fines, dirt adhering to purchase scrap. This fraction falls quickly in the plant and neighborhood areas close to the cupola stack.
3. Fine particles, 2 to 44 microns - Finely divided material from the same source as the coarse fraction. This material stays in suspension longer, and gradually settles over large areas of the community.
4. Metallic oxides Submicroscopic particles formed from oxidation of the charge. Iron oxide particles produce the red plume typical of ferrous metallurgical processes. Particles stay in suspension for long periods before reaching ground level, except where local downwash or temperature inversions force the fume to ground level.

Typical particle-size distributions have been reported[1] and are given in Table E-1. Quantitatively, each fraction will vary widely with

Table E-1. PARTICLE-SIZE DISTRIBUTION OF PARTICULATES

Particle-size range, μ	Percent by weight of total particulate
0 - 5	4 10
5 10	2 - 15
10 - 25	4 15
25 - 50	5 15
50 and over	45 85

*One micron = 1/25, 000 inch.

material charged and the melting technique. The larger the pieces of scrap or remelt, the smaller the surface area per pound of metal and the less area for accumulation of burned sand, dirt, and oil. Extremes would be remelts that had been abrasive-cleaned and steel scrap like railroad rails for the clean charge, contrasted to remelts from small castings with much burned sand and oily punchings or borings.

CONTROL EQUIPMENT DISCUSSED IN THIS REPORT:

1. Wet Caps. This collection device is basically a conical "weatherhood" above the cupola stack. A shower of water is issued from the top of the conical section to produce a falling curtain of water through which the hot gases must pass.

   Contact between gas and water cannot be intimate because the unit relies on natural stack draft to induce the gas through the water curtain. Better contact from higher velocity passages would cause enough back pressure to force blowout of hot contaminated gas at charging door openings.

   Collector is low in first cost, requires no induced-draft fan and removes a high percentage of the coarse material. Maintenance and nuisance from fallout on plant roofs and immediate ground-level areas are greatly reduced. Water volumes range from 200 to 350 gallons per minute. Corrosion should be anticipated from sulfur and fluoride emissions. Water clarification and the neutralization of recycled water are both common practices.

   Often water is used for slag-quenching after leaving the wet cap.

   Overall collection efficiency is likely to be 40 to 60 percent[2] of solid particulates, on a total weight basis.

2. Multiple Cyclones. The basic multiple cyclone unit is composed of a bank of cones in parallel. The dust-laden gas enters the cones tangentially, and then centrifugal forces separate the particles from the gas stream. A duct connects the collector device to the cupola, normally at a point above the charge door. The duct serves as a quenching cooler in directing the gas from

the cupola to the collector. The temperatures in the duct are reduced from 1,500° to 500°F by water jets. The particulates are normally captured in a bin at the base of the collection unit. Periodically, this material is removed manually by cart or automatically by a conveying system. The dry material is normally disposed of on the plant site or trucked away.

The temperatures of the gas stream normally handled by the collection unit are in the 450° to 550°F range. These temperatures are maintained to prevent condensation that could cause plugging or corrosion of the collector or the exhaust fan. Because of these temperatures, even with the evaporative cooling, the material is collected dry. The pressure loss in these systems is 3 to 4 inches water gauge at the operating temperature.

The usual collection efficiency is approximately 82 percent, with an expected range from 70 to 85 percent on a total weight basis. Multiple cyclones will effectively remove particles greater than 10 microns.[2]

Multiple cyclones on foundries provide the lowest cost collection system using induced-draft fans (wet caps function on natural draft). For the efficiency achieved, relative to wet scrubbers and fabric filters, the initial investment is high, but this is offset by low operating and maintenance costs.

3. Wet Scrubbers. Wet collectors operating on a number of different principles have been used on cupolas for particulate collection. The degree of removal by wet scrubbing increases in proportion to the amount of energy exerted to obtain contact between dust particles and liquid.

Conventionally designed dust collectors (low-energy wet scrubbers) operating in the pressure-loss range of 6 to 25 inches water gauge have good efficiency for removal of particles as small as 3 microns,[3] yet produce little reduction in the metallurgical fume component. Collection efficiency can vary from 85 to 95 percent on a total weight basis. Elimination of visible metallic fumes by wet scrubbing requires high-energy input (high-energy wet scrubbers) equivalent to 45 to 70 inches water gauge. This high-energy input is sufficient to reduce effluent to less than 0.05 grain per standard cubic foot at a collection efficiency from 95 to greater than 99 percent.

Corrosion protection is generally needed. Stainless steel is a frequently used construction material, and recirculated water is neutralized with caustic soda or other chemical treatments to counteract corrosion.

With wet collector designs, exit gases will be in the range of 120° to 160° F and will approach saturated conditions, producing a pronounced visible plume containing water droplets. Cooling the gas stream sufficiently to condense out the water vapor before gases leave the stack requires added heat exchangers. With high-energy scrubber designs, the cost of heat exchangers can be offset by improved economics in handling reduced gas volumes and reducing horsepower on the draft fan.

4. Fabric Collectors. These are devices that remove particulate matter from gas streams by retention of the particles in or on a woven or felted fabric through which the gas flows. Collection efficiency higher than 99 percent (total weight basis) can be maintained.

Most of the fabric collectors for cupola gas cleaning are of the continuous operating designs with four to six compartments. Compartments are dampered off from the hot gas stream one at a time for cleaning, and the cycle is repeated two to four times each hour.

Controlled water sprays in cooling towers hold exit gas temperatures in the higher operative temperature ranges of the fabric employed. Where glass cloth can be used, inlet temperatures in the range of 450° to 500° F are usual. Water vapor produced from flash cooling in this temperature range is insufficient to cause condensation on fabric or collector housings. The basic limitation of glass cloth is its sensitivity to chemical attack in processes where flouride compounds are used.

Use of low-temperature (250° to 275° F) fabrics, such as Orlon and Dacron, has been limited. Designers express much concern over potential condensation damage that may result from cooling in cold climates. Use of indirect heat exchangers has also caused problems for low-temperature fabrics.

Collectors operate at 4 to 6 inches water gauge pressure loss with air to cloth ratios of 1.5 to 2.0. Collection efficiency is excellent. No visible discharge is apparent as long as the collector is properly maintained.

Blinding of fabric due to condensed oil vapors has been reported where incineration time or temperature has not been sufficient. There is also a certain fire hazard with combustible particulates that may carry over into the fabric filter.

Because dust and fumes are collected dry and include substantial fine-particle fractions, attention must be given to dust-free handling of the collected dust from hopper to disposal area.

CONTROL EQUIPMENT NOT DISCUSSED IN THIS REPORT:

1. Afterburners. This inexpensive control technique reduces the black smoke of unburned volatiles by maintaining ignition temperatures in the cupola stack above the charging door. A stack height above the door of 25 to 30 feet may be needed to get sufficient contact time. Gas flow has the turbulence needed for good combustion, caused by the convergence of the blast air from the melt zone with the induced cold outside air at the charging door. Temperatures should be maintained at 1,200° to 1,500° F and the heat input required will vary with the carbon monoxide produced and the dilution caused by the cold outside air pulled through the door opening. With gases rich in carbon monoxide and with modest amounts of cold air entering the charging door, afterburning requires only an ignition or "torching" burner to keep carbon monoxide ignited between periods of snuffing as a bucket drops its charge. With lean gas and large charging door indraft volumes, substantial added heat is required to maintain incineration temperatures. Heat

input of 100,000 Btu per hour per ton of metal melted can be required under these adverse conditions.

Basically, afterburning eliminates the black smoke of poor combustion. Some combustible solids may be reduced to finer ash, but the impact on solids fallout is minimal. For this reason, this type equipment was not discussed separately in the body of the report; it was treated, though, as a component of the control device or system in establishing control costs.

2. Electric Precipitators. Experience with electric precipitators in the United States has been limited to a very few installations. Fluctuating gas volumes and the changing chemical composition of the gases and solids could explain the reports of variable collection efficiency and chemical attack.

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APPENDIX F.
ANALYSIS OF COST DATA

INTRODUCTION

Initial plots of cost data against melt rate indicated that any line that would approximate the data would have a non-zero intercept. The use of an average cost per ton of melt rate would result in a line having a zero intercept. Such a line would diverge from the actual cost data at both the high and low ends of the melt-rate range.

The method of least squares was therefore employed to determine the line that best fit the data points. Linear equations were obtained for both annual cost and investment cost of each type of control system. Although the number of observations for each equipment type was insufficient to achieve a statistically valid regression analysis, the lines obtained were considered the best approximation of cost obtainable from the available data.

INVESTMENT COST EQUATION

Investment cost equations were obtained by regressing melt rate as the independent variable against investment cost as the dependent variable. Excellent correlations were obtained for wet scrubbers and fabric filters. Less reliable, yet satisfactory, results were obtained for mechanical collectors. The investment cost equations are presented in Table F-1. Graphs of each equation and the corresponding data are presented in Figures F-1 through F-4.

ANNUAL COST EQUATION

Separate regressions were run for annual cost in order to cross check the results obtained by calculating annual cost as the sum of depreciation, capital cost, and operating and maintenance costs. The annual cost equations yielded very good correlations and plotted better against actual data than did indirect calculations of annual cost. Again, fabric filter and wet scrubber equations yielded excellent correlations. The cost equation for mechanical collectors yielded only slightly poorer results. The annual cost equations are presented in Table F-2. Graphs of all equations and data are presented in Figure F-5 through F-8.

Table F-1. INVESTMENT COST EQUATIONS FOR POLLUTION CONTROL EQUIPMENT

Equipment type	Investment cost equation	Limits of observations	r	Regression parameters: F test	Regression parameters: Standard error	T	N
Multiple cyclone	I = 51,428 + 7,675R	23 ≥ R ≥ 8	0.55	2.2	70,520	1.5	7
Low-energy wet scrubber	I = 29,316 + 3,578R	26 ≥ R ≥ 4	0.81	7.9	26,058	2.8	6
High-energy wet scrubber	I = 86,959 + 8,908R	50 ≥ R ≥ 12	0.93	20.3	63,474	4.5	5
Fabric filter	I = -24,837 + 17,464R	40 ≥ R ≥ 3	0.98	373.1	33,536	19.3	16

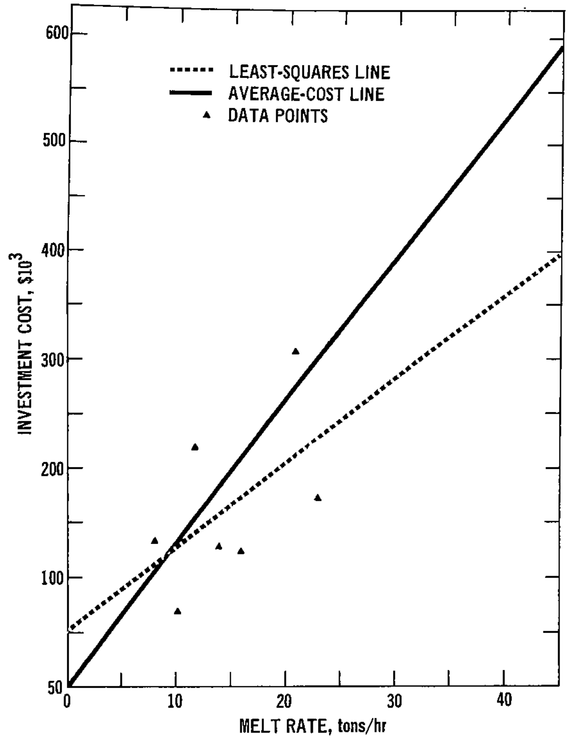

Figure F-1. Investment cost versus melt rate for multiple cyclones.

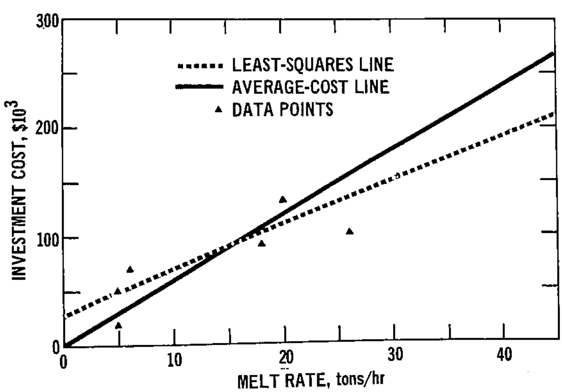

Figure F-2. Investment cost versus melt rate for low-energy wet scrubbers.

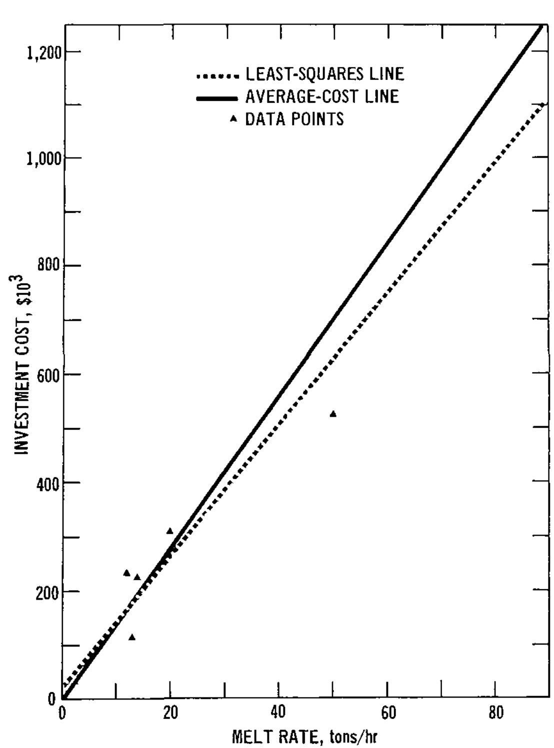

Figure F-3. Investment cost versus melt rate for high-energy wet scrubbers.

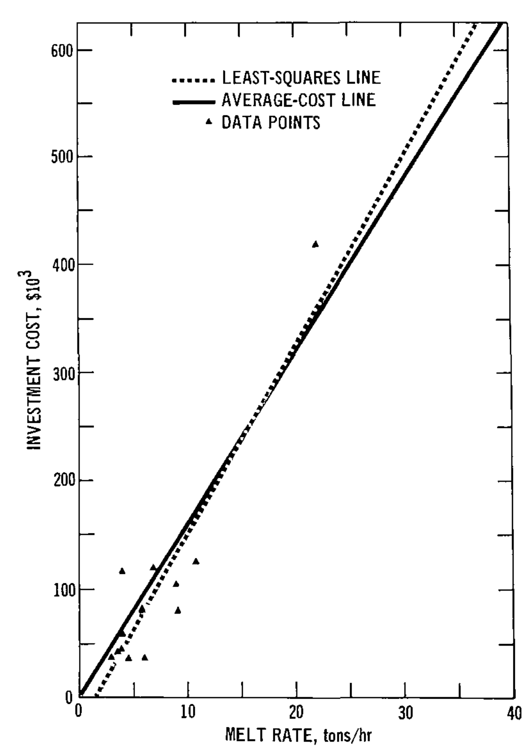

Figure F-4. Investment cost versus melt rate for fabric filters.

Table F-2. ANNUAL COST EQUATIONS FOR POLLUTION CONTROL EQUIPMENT

Equipment type	Annual cost equation	Limits of observations	r	Regression parameters: F test	Regression parameters: Standard error	F	N
Multiple cyclone	A = -17,787 + 4,217R	23 > R > 8	0.78	7.6	20,789	2.7	7
Low-energy wet scrubber	A = 8,911 + 938R	20 > R > 5	0.83	9.1	6,363	3.0	6
High-energy wet scrubber	A = 23,037 + 3,058R	50 > R >12	0.94	22.7	20,625	4.8	5
Fabric filter	A = -8,054 + 5,289R	12 > R > 3	0.99	486.0	8,898	22.0	16

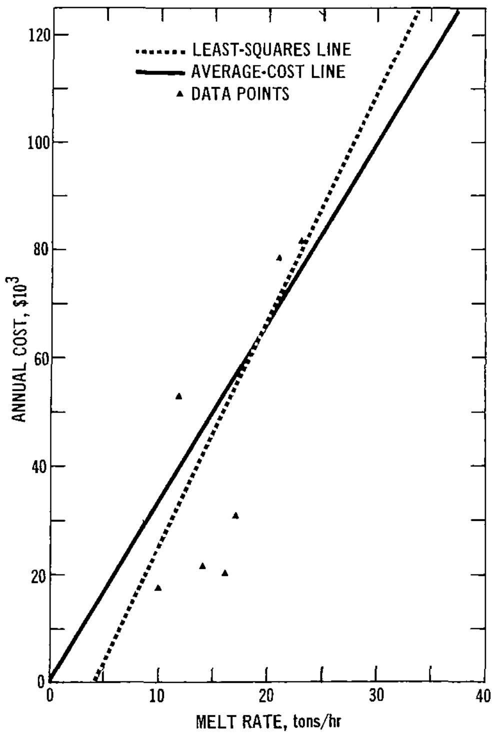

Figure F-5. Annual cost versus melt rate for multiple cyclones.

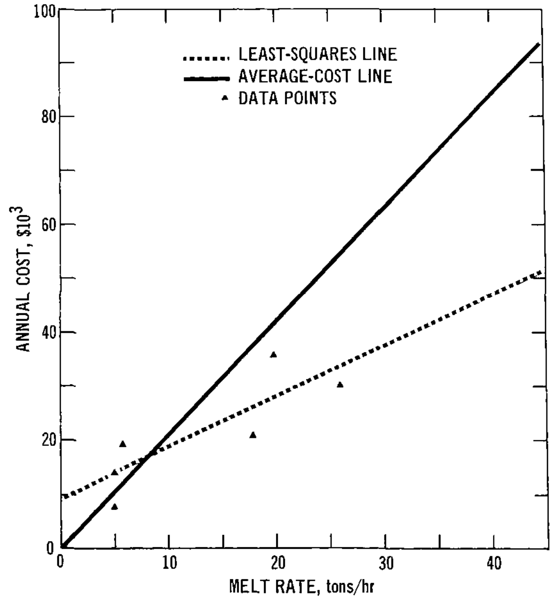

Figure F-6. Relation of annual costs to melt rate for low-energy wet scrubbers.

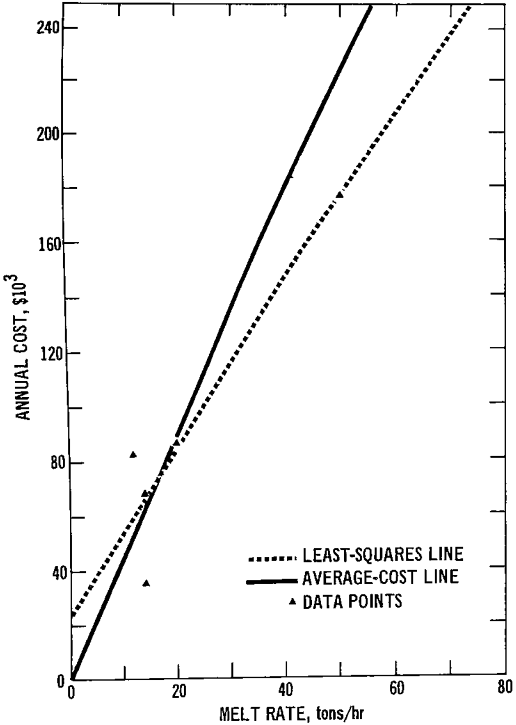

Figure F-7. Annual cost versus melt rate for high-energy wet scrubbers.

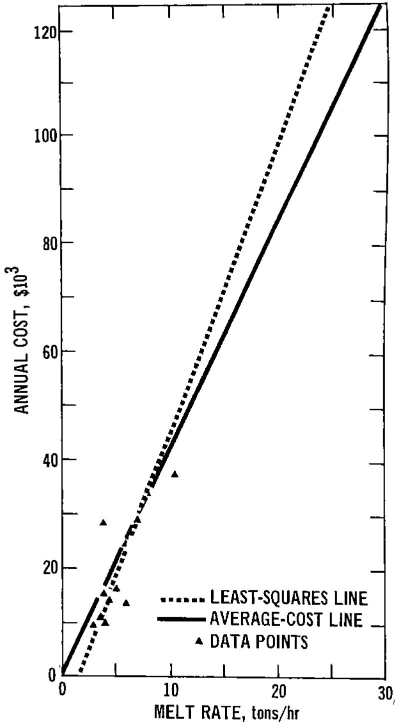

Figure F-8. Annual cost versus melt rate for fabric filters.

APPENDIX G.

TECHNICAL DATA ON EMISSION CONTROL

INTRODUCTION

The interview survey conducted as part of this study produced significant information on cupola operation in the following areas:

1. Variations in emission rates.
2. Exit concentrations.
3. Indraft through charging door.
4. Charging door closures.
5. Influence of afterburning on collector size.

VARIATIONS IN EMISSION RATES

Fourteen of the foundries surveyed provided data on their cupola emission rates. These data are shown in Table G-1, including melt rate, emissions per ton of melt, charge composition where available, and an indication of the method of emission measurement. While emissions as low as 6 pounds per ton and as high as 36 pounds per ton were reported, an average of 20 to 21 pounds per ton was reached from each of the following analyses:

1. Average of the 14 reports.
2. Average of the middle 10 reports with their narrowed range of 13 to 26 pounds per ton.
3. By developing a weighted average using:

$$\frac{\text{lb/ton x melt rate}}{\text{total lb}}$$

Confidence should be placed in these results with due respect for possible sources of variation. First, the method of measurement can be the cause for some variation. Second, more accurate data would result it the catch were actually weighed for an operating day and if the collection efficiency were known. Third, calculations in Table G-1 are based on complete collection by fabric filters, and 85 percent collection by multiple centrifugals where the catch was reported. Finally, inlet samples, when run for short sampling periods, could be subjected to the greatest variation due to uneven particulate loadings in the gas stream or fluctuations in cupola operation.

EXIT CONCENTRATIONS

Table G-2 reports the loss to atmosphere from 12 foundries for which such data have been obtained from stack gas sampling of the

Table G-1. PARTICULATE EMISSIONS IN CUPOLA STACK GASES

Observation number	Emission, lb/ton melt	Melt rate, tons/hr	Composition of charge, %					Measurement method
			Returns	Pig	Cast iron scrap	Steel scrap	Briquettes	
1	26	20.0	21	-	79	-	-	Below charge door takeoff. 2,580 lb in 8 hr in fabric filter—1,600 lb in afterburner and quencher.
2	21	10.8	22	-	78	-	-	Fabric filter—1,800 lb in 8 hr
3	36	8.75						Inlet samples at multiple cyclone
4	22	17.0	35	45	10	10	-	Inlet samples at multiple cyclone
5	14	40.0	40	-	-	40	20	Fabric filter catch
6	6	8.0	35	5	30	30	-	Fabric filter catch—49.4 lb/hr
7	13	17.0	20	25	-	55	-	Inlet samples at multiple cyclone
8	24	7.0	30	43	17	-	10	Fabric filter—22,560 lb in 136 hr
9	20	3.5	-	-	-	-	-	Fabric filter—69 lb/hr
10	26	17.0	50	20	-	30	-	2,850 lb sludge, 21% H_2O from 120 tons melt, plus wet cap exit samples
11	35	10.0	40	25	-	15	20	Multiple cyclone catch 3,000 lb in 10 hr; assumed 85% efficient.
12	7	8.0	-	70	30	-	-	Fabric filter—550 lb in 10 hr
13	17	12.0	30	-	70	-	-	Fabric filter—200 lb/hr
14	21	12.0	51	20	-	29	-	Multiple cyclone collector 18 lb/ton melt catch; assumed 85% efficient.

Table G-2. EMISSIONS ESCAPING FROM CONTROLLED CUPOLAS

Observation number	Emissions, lb/ton	Melting rate, tons/hr	Collector type and comments
1	6.8	17	Wet cap
2	5.4	17	Dry multiple centrifugal 600° F hot blast - charge: 33% remelt. 47% pig, 10% steel scrap, 10% cast iron scrap
3	4.5	16	Dry multiple centrifugal
4	5.4	21	Dry multiple centrifugal, hot blast, dry centrifugal precleaner
5	4.6	13	10 inches water gauge wet collection efficiency - 86% oily scrap
6	1.6	6	12 inches water gauge wet clean scrap, high percentage remelt, no coke breeze, no afterburner
7	4.7	20	14 inches water gauge wet 600° F hot blast - charge: 40% remelt, 20% pig, 27% steel scrap, 13% cast iron scrap
8	2.5	20	26 inches water gauge wet
9	2.0	13	35 inches water gauge wet collection efficiency 95%
10	1.0	10	45 inches water gauge wet collection efficiency - 99%
11	0.68	12	Electrostatic precipitator
12	0.21	50	58 inches water gauge wet charge 40% remelt, 50% steel flashings, 10% cast scrap

cleaned gas outlet. The data have been recalculated to pounds of emission per ton of metal melted where performance was reported in pounds per 1,000 pounds of gas or grains per standard cubic foot. The former is the more significant because gas volumes for comparable melting rates fluctuate widely as will be discussed later. The data give an indication of the order of performance for multiple dry centrifugal and wet collectors. Data from only one wet cap were available. Because of the high collection efficiency of fabric collectors and the absence of visible escapement, stack gas sampling has not been frequent for this collector type. Table G-3 summarizes the data with the exclusion of Observation 6.

The data confirm that increased energy input in wet collector

Table G-3. PENETRATION OF PARTICULATES BY TYPE OF CONTROL EQUIPMENT

Control equipment	Penetration, lb/ton melt	
Wet cap	6	8
Multiple cyclone	4	6
Wet collector (water gauge in inches)		
10-14	4	5
26-35	2	2.5
40-60	0.2	1.0

devices improves performance, although the order of improvement can be only generalized. The single wet cap performance may or may not be typical of emission rates from this collector group.

INDRAFT THROUGH CHARGING DOOR

A substantial portion of exhaust volume handled by collection equipment consists of: (1) the quantities of outside air pulled inward through the charging door to confine the stack gases, and (2) the significant volume of water vapor generated to cool the hot gases before reaching the collector and exhauster. In Table G-4, data are shown for nine foundries, selected because the inlet temperatures were in the 500° F range and regulated by controlled spray-cooling in the gas stream. If the stack gas temperatures were in the 1,500° F range, approximately 25 percent of the gas volume would be water vapor. Deducting this volume and the known blast volume from the total gives the volume induced through the charging door. This volume was easily translated into indraft velocities because information on sizes of openings was available. The data show a considerable spread. On the medium and larger size cupolas, where mechanical charging requires large door openings, an indraft of 450 feet per minute, as opposed to 300 feet per minute, would represent a 50 percent increase in outside air handled by the system. The impact on collector size and cost can be visualized from a comparison of Observations 6 and 7 (Table G-2). Both have the same 8,000 scfm blast volume, yet 30,000 scfm was involved in Observation 6, while 40,000 scfm—a 33.5 percent increase—was installed at Observation 7. Observations 8 and 9 have practically

Table G-4. RANGE OF INLET VELOCITIES THROUGH CHARGING DOOR[a]

Blast volume, scfm	Water vapor,[b] scfm	Indraft through door, scfm	Total exhaust, scfm	Ratio of indraft volume to blast volume	Charging door indraft, ft/min
2,000	1,900	3,500	7,400	1:5	900
2,700	2,100	3,700	8,500	1:4	185[c]
3,800	3,200	6,000	13,000	1:6	600
4,000	3,900	7,600	15,500	1:9	250
5,000	5,000	11,000	21,000	2:2	480
8,000	7,500	14,500	30,000	1:8[d]	290
8,000	10,000	22,000	40,000	2:7	430
10,800	12,000	26,200	49,000	2:4	435[c]
20,000	13,000	19,000	52,000	1:0	2.5

[a]Temperatures at exhauster inlet approximately 500° F.

[b]Water vapor assumed to be 25 percent of exhaust volume.

[c]Closures on charging door opening.

[d]Downdraft takeoff below charging door.

the same size control system, yet the melting rate of No. 9 is almost double that of No. 8.

By way of qualifications, indraft volumes could be intentionally higher than needed for a particular operation where:

1. Collector capacity was designed for higher melting rates.
2. Design anticipated high melt-down temperatures where added volumes of water vapor would be generated.

To the extent that control system costs are influenced by gas volumes, however, the data suggest economies may be achieved in choice of charging door opening size, indraft velocity, and the water vapor volume with evaporative cooling of the cupola gases.

CHARGING DOOR CLOSURES

Although control equipment size and, thus, its installation and operating costs, affect foundry profitability, there has still been little apparent effort to keep the charging opening closed. Stated objections include:

1. Unreliability of charging door control mechanisms, offering potential for collision between charging bucket and closure device.

2. Gas escapement during the interval when the charging bucket unloads and closure device cannot be in place.
3. Sufficient capacity of installed systems to permit operation without such restrictions.

Nevertheless, the data suggest that greater design attention to closures and their use could reduce costs. This feasibility has been demonstrated at several foundries where control of closures has:

1. Reduced the quantities of cold air that must be heated to the 1,200° to 1,500° F range, thereby reducing or eliminating the fuel cost of afterburning.
2. Reduced aspiration of stack gases where charging openings are exposed to outdoor wind conditions.
3. When applied during meltdown, eliminated the need for excess collector capacity to handle added water vapor produced by the then higher stack gas temperatures.

INFLUENCE OF AFTERBURNING ON COLLECTOR SIZE

Afterburning in the cupola stack was a popular method of reducing visible emissions from unburned combustibles long before the use of sophisticated gas-cleaning equipment was in general use for cupola applications. Little attention was paid to the fuel consumption as long as incineration temperatures were maintained in the turbulent air stream in the cupola stack above the charging door. In fact, the higher the temperature, the greater the stack draft, causing indraft at the charging opening, and the greater the ability to overcome some pressure losses from the influence of spark arrestors or wet cap low-resistance collectors.

The fact that higher temperatures increase gas volume at the collector inlet and require additional cooling expense in some systems, however, suggests that better control of fuel supply in afterburner installations could reduce overall costs. Possible methods of control include:

1. Cutoff of afterburner fuel during meltdown when temperatures are in or above incineration range.
2. Development of charging opening closures so that minimum cold outside air is heated to incineration temperatures.

3. Analysis of stack gas temperatures. Often there is ample carbon monoxide available to maintain incineration temperatures with a need only for a torch to re-ignite in case the flame is snuffed out during the charge.

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