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Summary of Factors Affecting Compliance by Ferrous Foundries, Volume I-Text

Final Report

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PREFACE

Midwest Research Institute has carried out a study for the Division of Stationary Source Enforcement, Environmental Protection Agency, to review the various technical and regulatory factors that affect the compliance of ferrous foundries.

This report presents the results of the study including characteristics of the ferrous foundry industry, emissions from ferrous foundries, the design, operation and maintenance of emissions controls, and state and local air pollution control regulations and policies as related to ferrous foundries.

Mr. D. Wallace, Associate Environmental Scientist, Environmental Control Systems Section, served as project leader, and Mr. J. Hennon, Senior Chemist, Mr. B. Boomer, Assistant Environmental Engineer of MRI and Mr. P. Quarles and Mr. P. Kielty of TRG contributed significantly to the task. The assistance provided by Mr. A. Trenholm Head Environmental Control Systems Section and the guidance provided by Task Manager, Mr. Robert L. King, throughout the project are gratefully acknowledged.

Approved for:

MIDWEST RESEARCH INSTITUTE

for M. P. Schrag, Director
Environmental Systems Department

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1.0 INTRODUCTION

A ferrous foundry is a facility which uses iron and steel scrap (and sometimes raw pig iron) to produce iron and steel castings. In all foundries the four basic operations which are necessary to produce casting are: (a) raw materials handling and storage; (b) melting; (c) pouring of metal into molds; and (d) removal of castings from the molds. Other operations present in most but not necessarily all foundries include preparation and assembly of molds and cores; mold cooling; shakeout; casting cleaning and finishing; sand handling and preparation; and hot metal inoculation.

Each foundry operation has the potential to emit significant amounts of one or more pollutants including particulates, trace metals, carbon monoxide, and a variety of organic compounds, some of which may be hazardous to human health. Often the emissions from these sources are difficult to quantify, and technically and economically feasible controls are difficult to find.

Realizing that the foundry industry is essential to the U.S. economy and as such it must be maintained, but that it is also necessary to attain acceptable levels of ambient air quality, compliance strategies that are compatible with both these objectives must be developed. Several characteristics of the foundry industry make development of compliance strategies difficult. The foundry industry is diverse and changing. Foundries range from highly mechanized captive operations that produce large numbers of the same casting to independent "jobber" foundries that may produce only a few copies of many different castings. Annual production can range from hundreds of tons to several hundred thousand tons. The range of production directly affects emissions control problems. In addition, the foundry population profile is changing. The number of foundries has decreased since 1967, because small foundries (often in areas of low population) have closed; but total production has increased because the larger foundries have increased their levels of production. This changing profile has shifted the impact of emissions on ambient air quality to nonattainment areas, i.e. areas which are not in attainment with particulate national ambient air quality standards (NAAQS).

In addition to the difficulties created by the historical trends in the foundry industry, information on ferrous foundry emissions and emissions control technology has not been compiled in a single volume since 1970. For these reasons, the Division of Stationary Source Enforcement of the U.S. Environmental Protection Agency (EPA) has contracted with Midwest Research Institute (MRI) to prepare an overview of the factors affecting compliance in ferrous foundries. The specific objectives are to: (a) characterize the industry; (b) identify and quantify foundry emissions; (c) identify emissions control difficulties; (d) identify exemplary control systems; and (e) analyze current state implementation plans (SIPs) with respect to ferrous foundries.

1.1 SCOPE OF THE STUDY

To accomplish the above objectives, the program was initiated with the following tasks:

Task 1: Characterization of the industry - The present foundry industry was characterized with respect to foundry size, location, and type of market; and trends in production and air pollution control equipment were identified.

Task 2: Analysis of foundry emissions - This task was directed toward the identification of pollutants emitted from the various foundry processes, and when possible toward quantification of these emissions using available data.

Task 3: Analysis of air pollution control technology - The major technical problems associated with design and/or operation of control equipment were identified, and possible exemplary solutions to these problems were examined.

Task 4: Analysis of state implementation plans (SIPs) - The 50 state agencies and a sampling of local agencies were contacted to identify the statutory and functional aspects of iron foundry regulation.

In order that each of the above tasks could be addressed in some detail, two limitations were established early in the program. First, while ferrous foundries have both particulate and gaseous emission problems, the level of effort in this task allowed only particulate emissions to be covered in detail with respect to emissions quantification, control technology and regulatory analysis. Second, although a major objective of the program was the identification of solution elements which might aid state and local agencies develop their compliance strategies, it was recognized early in the program that the diversity of the industry and control strategies made this on impossible task for all foundry emissions sources. Based on responses from initial contacts with state agencies, it was decided that this portion of the study should focus on operation and maintenance procedures for control equipment. However, information on available control systems for most major particulate sources is included in the report.

1.2 PURPOSE AND ORGANIZATION OF THE REPORT

This report presents the results of the four tasks described above. In line with the original limitations placed upon this study, the report is intended to compile available information on a number of factors which affect (both positively and negatively) foundry compliance. It is not intended as a conclusive document on foundry compliance strategies. Rather, the purpose is to provide background information that can aid the U.S. EPA and state and local agencies in the development of ferrous foundry compliance strategies. Data on emissions and emissions control are also presented for use by foundry personnel to improve voluntary compliance.

The report is divided into two volumes, the text and the appendices. The text summarizes the findings of the study. It includes: (a) an executive summary; (b) a characterization of the ferrous foundry; (c) a brief description of ferrous foundry processes and particulate emissions from these processes; (d) a survey of available control technology with particular emphasis on operation and maintenance of control equipment; and (e) an analysis of state and local regulations and implementation policies.

The appendices contain the detailed information that was the basis of the results presented in the text. Appendix A is a detailed description of ferrous foundry processes and types of emissions associated with these processes; Appendix B is a survey of particulate emissions data for the major ferrous foundry emissions sources; Appendix C includes descriptions of control systems for major emissions sources; Appendix D presents detailed information on operation and maintenance practices applicable to ferrous foundry control systems; Appendix E presents procedures for troubleshooting and correcting fabric filter malfunctions; and Appendix F is a thorough description of regulations and enforcement practices used by state and local agencies.

2.0 EXECUTIVE SUMMARY

2.1 CHARACTERIZATION OF THE FERROUS FOUNDRY INDUSTRY

The ferrous foundry industry comprises those facilities which use iron and steel scrap to produce gray, ductile, or malleable iron or steel castings. The industry is essential to the economy of the United States since almost all heavy industry depends on foundry products. But ferrous foundries can be a significant source of air pollution. Thus, while state and local agencies are generally concerned with bringing foundries into compliance with regulations, it is imperative that the economic viability of the industry be sustained. Several characteristics of the ferrous industry impact this compliance effort as described below.

Estimates compiled during the study on the number ferrous foundries located in the 50 states and District of Columbia range from 1,400 to 1,600 facilities. These foundries produce about 18 million tons of castings annually. The exact number of foundries could not be determined because of differences between listings of the U.S. EPA and industry. The foundry listing identified about twice as many foundries as were on both EPA computerized lists. The probable reason that many foundries do not appear on the EPA listings is that they manufacture intermediary products that are classified under a difference SIC code. However, some foundries appeared on both the Compliance Data System (CDS) and the National Emissions Data System (NEDS) that did not appear on the industry listing. Hence, compilation of a complete inventory of ferrous foundries is not possible.

Two equipment trends projected for foundries potentially affect compliance. First, an industry survey indicates that a significant portion of foundry investment will be directed toward the mechanization of smaller foundries. This will have a positive impact on compliance, as fugitive emissions are more easily controlled in mechanized foundries. A second, and even more important trend, is that foundries have apparently renewed their interest in cupola furnaces. The projected investment in cupolas contrasts with earlier agency views that cupolas would be generally replaced by electric arc and induction furnaces. It now appears that the cupola furnaces will continue to be a major factor in the development of compliance strategies for ferrous foundries.

A final factor which affects ferrous foundry compliance decisions is the location of the facilities. Both geographical distribution and location with respect to nonattainment areas are significant. The study indicated that foundries are widely dispersed geographically; every state but Wyoming and New Mexico has at least one known foundry, and over half of the states have at least 10 facilities. Thus, the issue of foundry compliance is of widespread applicability. A brief analysis of foundry location with respect to attainment status indicates that in the limited number of states examined the majority of foundries are located in either primary or secondary particulate nonattainment areas. Hence, the impact of foundry emissions on attainment of the ambient air quality standards deserves further consideration.

2.2 FERROUS FOUNDRY PROCESSES AND EMISSIONS

A ferrous foundry comprises a number of unit operations that transform scrap iron and steel into usable cast iron and steel products. Basic unit operations that are used in ferrous foundries include: raw materials storage and handling, coremaking, mold preparation, furnace charge preparation, melting, hot metal inoculation, pouring, shakeout or some other method to remove castings from the mold, sand handling and conditioning, patternmaking, and cleaning and finishing operations such as torch cutoff, blast cleaning, grinding, abrasive cutting and cleaning, carbon-air arc cleaning, and heat treating.

The operations described above are accomplished in a variety of ways. For example, melting can take place in a cupola, an electric arc furnace, an electric induction furnace, or a gas or oil-fired reverberatory furnace. Molds and cores can be prepared in a number of different ways with different materials such as permanent metal or graphite molds, green sand molds, oil bake cores, shell sand molds and cores, no-bake cores and molds, and cold box cores. Given the number of different operations that may be used in a particular foundry and the variety of processes used to perform the different operations, it is apparent that any two foundries may be quite different. In fact, foundries vary so widely in design and operating practice that a "typical" ferrous foundry cannot be defined. These differences in foundries also impact on compliance strategy development in that it is difficult if not impossible to develop uniform strategies that apply to all foundries.

Each of the operations described in the above paragraphs can be a source of particulate and/or gaseous emissions. Specific pollutants emitted from foundries include silica dust, metal fume (primarily iron and iron oxide but may include contaminants such as zinc or lead), organic dusts, organic gases (including phenolic compounds, formaldehyde, and amines), carbon monoxide, and sulfur dioxide.

The scope of this study did not allow detailed analysis of all pollutants for all the sources listed above. Based on initial contacts with state agencies, the scope of the study was limited to the major sources of particulate emissions. The results of a review of the emissions data for these major sources are presented below:

Source	Range of emissions estimates (lb/ton)	Best estimate of average emissions (lb/ton)
Cupola	3.8 - 75	20
Electric arc furnace	4 - 40	14
Pouring/cooling	0.6 - 24	5 to 10
Shakeout	0.17 - 18	9
Sand handling	0.6 - 50	Data insufficient to determine average.
Cleaning Room	No test data available.	

Two points about the above data are worthy of note. First, for each of the above processes the range in emissions data is quite wide, varying from one to two orders of magnitude. Given this wide range in emissions between foundries (or between particular operations in a single foundry), the use of average emission factors for compliance calculations is a questionable practice. Second, data for cupolas and electric arc furnaces have been obtained from a variety of sources and can be considered reliable. On the other hand, data from the remaining processes are quite limited, and care should be taken in using these emission estimates. The magnitudes of emissions from these fugitive sources, however, are sufficient to indicate that they deserve further consideration.

2.3 FERROUS FOUNDRY EMISSIONS CONTROL

This study was motivated in part by reports that significant technical problems have been experienced with air pollution control equipment installed at foundries. As a result of these reports, this study was directed toward identification of design and/or operational difficulties associated with ferrous foundry control equipment and the investigation of exemplary systems that had overcome these difficulties.

The investigation of ferrous foundry control technology led to the following findings:

1. Adequate control technology is available for most foundry emissions sources and has been demonstrated to work efficiently. The major exceptions are pouring and cooling emissions, emissions from air-carbon arcing in steel foundry cleaning rooms, and emissions from some types of chipping cutting and grinding operations in the cleaning room.

2. The Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH) concerns about the internal foundry sources that contribute to worker exposure to contaminants as well as fugitive emissions from the foundry have led to the development and implementation of improved capture systems for these sources.

3. Malfunction of control equipment was cited as a major problem by both control agency and foundry personnel. In some cases these malfunctions appear to be the result of poor equipment design (e.g., the use of mild carbon steel for the venturi throat of a cupola scrubber or the installation of a cupola baghouse without using an afterburner). In other cases the malfunctions are a result of improper operating practices (e.g., failure to maintain sufficient pressure to the prequencher spray nozzles or failure to take the baghouse through a full cleaning cycle at shutdown).

4. It is possible to minimize the incidence of control equipment malfunctions by the proper design, operation and maintenance of the control equipment. Section 5 of this report describes design and operating practices that have resulted in downtime due to malfunctions being as low as 1 to 2% in some foundries.

2.4 ANALYSIS OF REGULATIONS FOR FERROUS FOUNDRIES

One of the primary objectives of the study was to develop a detailed analysis of state implementation plans (SIPs) as applied to ferrous foundries for the purpose of highlighting the adequacy of the regulations and ambiguities in the regulations which might hinder enforcement. To accomplish this objective, the regulations of each state were reviewed, and all state and selected local agencies were contacted.

It was anticipated that the survey would identify regulations that limit ferrous foundry emissions and provide information on state and local implementation policies, in particular enforcement problems and agency experience with solutions. As a result of the broad nature of the study and the varied responses of the states, a well-defined picture of foundry regulatory structure could not be developed. However, some of the highlights of the study are presented below.

1. Most state contacts reported that there are few if any significant problems encountered in the regulation of ferrous foundries, that they are generally in compliance with applicable emission limitations, and that they are rarely found in violation. Hence, the development of specific investigation or enforcement strategies to deal with ferrous foundries has been unnecessary. Enforcement problems with ferrous foundries are largely considered to be a problem of the past. These findings appear to be in conflict with opinions voiced by federal regulators that ferrous foundries are a problem source category. Although the survey does not provide a conclusive rationale for this disagreement, several possible explanations were suggested:

a. Ferrous foundries are numerous and diverse. They provide a product essential to industrial growth throughout the nation. Historically, they have been fundamentally important to industrial growth and the economic welfare of small communities. At the same time, in recent years many foundries have become economically marginal. At this stage air pollution control became a significant issue. The conflict between control of air pollution at foundries and the economic welfare of small businesses and maintaining jobs in labor sensitive areas was highly charged. Ultimately the states, backed by new federal clean air legislation, required the installation of control equipment at ferrous foundries. While this control equipment may not adequately address the full pollution potential of foundries, and while the mere installation clearly does not resolve important considerations of control equipment operation and maintenance, what was perceived by the states as the most difficult task--getting control equipment installed at the outset--has generally been accomplished. This success may have subdued interest in any further regulation of foundries.

b. For the most part, ferrous foundries are subject to process weight rate regulations. Usually, these emissions limitation requirements are easily met by control equipment that has been installed. Several contacts pointed out that compliance with the regulation could be maintained even if the control equipment were operating inefficiently.

c. Most states are primarily concerned with control of cupolas, although questions may be raised about the adequacy of control. Most federal regulators have indicated concern over a host of other emission points besides cupolas and have shown special interest in fugitive emissions. On the other hand, the states have shown very little interest in fugitive emissions. Thus, it is possible that the conflict between state and federal officials that was noted in our survey relates primarily to the relative importance attached to particular emission points or particular types of emissions. It is also possible that one reason for the lack of state interest in fugitive emissions relates to the difficulty in many of the states of applying fugitive emission regulations.

2. Process weight rates are generally ineffective when applied to shakeout and sand handling because the large quantities of sand handled result in large process input weights. Hence, the calculated allowable emissions are much greater than can be attained with technically and economically feasible control equipment. States may choose to rely on visible emission regulations as an alternative in order to force appropriate control equipment maintenance and operation. However, depending on the state, these regulations may also allow for operating and maintenance techniques that result in lower efficiencies than can be attained by the control equipment.

3. Regulatory authority for addressing fugitive emission problems is usually problematical and sometimes totally inadequate. Fugitive emission regulations are often unpopular among the state agencies because they require subjective judgment on such issues as whether fugitive emissions are excessive and whether the control measures used are reasonable. Although some fugitive emission regulations have numerical limitations, they usually apply at the property line and require difficult or time-consuming ambient monitoring. Visible emission regulations sometimes provide an alternative route. However, certified observers often feel uncomfortable reading nonstack emissions; any doubt in readings is usually weighed in favor of the source; and the regulations often allow for very substantial emissions. Some states are able to use either their visible emission or fugitive emission regulations. Others are able to use general operation and maintenance requirements and permit regulations to require effective control of fugitive emissions. However, the majority either have problems in applying their regulations to control fugitives or are not concerned about such emissions.

4. Problems in applying vague, subjective, or otherwise difficult-to-enforce regulations may be effectively resolved through the use of an operating permit. In such a case the state may require that the appropriate measures be included within the permit to guard against a violation of the underlying emission control regulation. Any violation of a permit condition would be independently enforceable regardless of whether the underlying emission control regulation would have been difficult or impossible to enforce in the same circumstance.

5. When resources are scarce, investigation strategies rely primarily on random or prioritized inspections and rarely on assistance from other investigative agencies. In a few cases, states expand their surveillance capacity dramatically by coordinating with the state OSHA equivalent, local

health officers, and other similar agencies conducting inspections pursuant to different laws. Some states also expand their capacity by actively encouraging citizen surveillance.

6. Drive-by inspections are probably not an effective preliminary surveillance technique for fugitive emissions. While it is possible to observe gross fugitive emissions during a drive-by inspection, serious problems (such as inefficient capture) may occur that are not easily detected without an in-plant inspection. In-plant inspections also allow for effective identification of numerous potential or developing problems that may result in increased fugitive emissions.

7. Malfunction recording and reporting requirements are a potentially valuable aid to ferrous foundry investigation and enforcement strategies. These regulations usually apply to capture equipment and control equipment. They shift the surveillance burden to those most aware of control problems as they occur. In addition, they allow for targeted follow-up. Most states, however, treat malfunction regulations as variance regulations.

8. Many states have adopted a response oriented surveillance strategy for ferrous foundries which have installed control equipment, and these states have no active, independent effort to discover continuous compliance violations. Investigations in these states are conducted when complaints are received, and the annual in-plant inspections are not conducted with potential enforcement in mind. (See item 1 above.)

9. Several states freely admit that certain foundries are not adequately controlled or are periodically in violation but that enforcement actions are either not warranted or not contemplated. Although the survey does not provide a definite explanation for this response, several possibilities exist, including:

a. The foundries involved are small, jobbing foundries which are economically marginal and whose contribution to overall air pollution in the area is minor.

b. Periods of violation are short term and usually excusable; if due to malfunctioning control equipment, such periods are considered to be inevitable.

c. The state's enforcement strategy may be primarily informal (with formal enforcement reserved only for major problem sources); in such a case, informal efforts to obtain compliance may be pursued.

10. Most of the survey respondents indicated that adversarial enforcement strategies are the most effective. The four strategies cited most often, in order, are:

a. Imposing or threatening to impose fines or penalties.

b. Litigating or threatening to litigate.

c. Use of operating permits and threatening revocation.

d. Referring or threatening to refer the case to EPA.

11. Very few survey respondents felt that a major enforcement effort has been necessary with foundries. Most respondents indicated that foundries have generally complied or are willing to comply with applicable emission limitations or other control measures voluntarily. Although much information obtained suggest that the regulations are often achievable through the purchase of less expensive control equipment, it was also learned that many foundries closed down (again, voluntarily) because of the expense involved. It is not known whether voluntary compliance would continue to be a major factor in state enforcement strategies if any of the following events were to occur:

a. Nonattainment area or prevention of significant deterioration (PSD) considerations could result in the reassessment of emission reduction capability at particular foundry emission points, e.g., cupolas controlled by wetcaps, shakeout and sandhandling currently uncontrolled or controlled by mechanical collectors or other control equipment currently operating inefficiently within acceptable legal limits.

b. A reevaluation of fugitive emission problems resulting in a decision to take more aggressive steps to control fugitive emissions.

12. The use of permit conditions to accomplish compliance objectives is a widely promoted strategy. Permit conditions enable the state to address problems of a source specific nature. Typically, a source with a compliance problem may have its permit revised with specific conditions to be followed. These conditions provide a checklist for the inspector making periodic inspections. They are usually independently enforceable such that violation of the permit condition justifies an enforcement action without regard to whether there is a violation of the underlying emission limitation. Permit conditions are fairly easily imposed since they rarely require finding a violation as a prerequisite.

13. States do not generally list problems with regulations as a primary constraining factor in enforcement; rather, they cite difficulties with legal and administrative redtape, as well as manpower and budget concerns. Among the enforcement constraints cited by survey respondents, in only one case out of 25 was an ineffective regulation mentioned--in this case, a fugitive emission regulation.

3.0 CHARACTERIZATION OF THE FERROUS FOUNDRY INDUSTRY

The first step in a systematic approach to enforcement of air pollution regulations is the development of a baseline characterization of the industry with respect to the factors which affect enforcement strategies. These factors are discussed in the following subsections, beginning with a general definition of the industry, including such items as production rates and trends, number of facilities, and the role of the industry in the overall economy. Other factors relating to individual foundries which are discussed in this section are: market structure of the industry, trends in foundry equipment investments, identification of individual iron foundries, location of foundries, and foundry size.

3.1 INDUSTRY DESCRIPTION

Ferrous foundries are those facilities which use scrap iron and steel (as well as a limited amount of pig iron) to produce gray, ductile, or malleable (called white iron before heat treatment) iron or steel castings. Based on the primary type of metal cast, ferrous foundries are generally classified as:

SIC code	Description
3321	Gray iron (included ductile)
3323	Malleable iron
3324	Investment steel casting
3325	Steel foundries not elsewhere classified

However, a particular foundry in any one of these classes may produce castings from other ferrous or, in some cases, nonferrous metals.

Cast iron and steel are both solid solutions of iron, carbon, and various alloying materials. Although there are many types of each, the iron and steel families can be distinguished by their respective carbon content. Cast irons typically contain 2% carbon or greater; cast steels usually contain less than 2% carbon. Chemical specification of the four types of cast irons are presented in Table 3-1. The processes necessary for production of these castings are very similar. These processes are described in Section 4.1.

TABLE 3-1. RANGE OF COMPOSITIONS FOR TYPICAL CAST IRONS

Element	Gray iron (%)[a]	White iron (%)[a]	Malleable iron (cast white) (%)[a]	Ductile iron (%)[a]
Carbon	2.5 -4.0	1.8 -3.6	2.00-2.60	3.0 -4.0
Silicon	1.0 -3.0	0.5 -1.9	1.10-1.60	1.8 -2.8
Manganese	0.25-1.0	0.25-0.80	0.20-1.00	0.00-1.00
Sulfur	0.02-0.25	0.06-0.20	0.04-0.18	0.03 maximum
Phosphorus	0.05-1.0	0.06-0.18	0.18 maximum	0.10 maximum

Source: Georgieff, N. T. and

Source: Georgieff, N. T. and F. L. Bunyard. An Investigation of the Best System of Emission Reduction for Electric Arc Furnaces in the Gray Iron Foundry Industry. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, October 1976.

[a] Percent by weight.

3.1.1 Industry Size and Production

The ferrous foundry industry is one of the most diverse heavy manufacturing industries in the United States, with estimates of 1,400 to 1,600 facilities across the 50 states and District of Columbia. Because of this diversity, an exact listing of ferrous foundries is difficult to obtain, and there are discrepancies among the various data sources.

The most comprehensive lists of gray and ductile iron foundries are compiled by Penton Publications. Data from a 1974 listing, which was used for an Environmental Protection Agency (EPA) study of cupolas and electric arc furnaces (EAF) in foundries, indicate that there were 1,473 gray and ductile iron foundries located in 48 of the 50 states.[1,2] A summary by state of the total number of foundries and the number producing each of the four ferrous metals is presented in Table 3-2.

Other industry data compiled in a Foundry Management and Technology publication indicates that in 1978 there were 4,438 foundries (including nonferrous) in the United States.[3] This number includes the following total foundries producing ferrous castings.

Number of foundries	Metal cast
1,400	Gray iron
590	Ductile iron
707	Malleable iron
631	Steel

These numbers should not be added to find the total number of U.S. ferrous foundries, since some foundries produce more than one metal.

In addition to the industry data, EPA has two listing of foundries, the Compliance Data System (CDS) which is maintained by the Division of Stationary Source Enforcement (DSSE), and the National Emissions Data Systems (NEDS) which is maintained by the Office of Air Quality Planning and Standards (OAQPS). CDS lists 687 iron foundries, and NEDS lists 884 foundries with a total of 738 gray and ductile iron, 35 malleable iron, and 111 steel foundries. The data from these systems are also presented in Table 3-2. Some of the discrepancies in these data are discussed in Section 3.4.

In 1978, the ferrous castings industry shipped 18.55 million tons. This represented about a 5% increase in the 1977 level which equaled 17.58 million tons. Ferrous casting shipments in 1979 were projected to reach 19.5 million tons, a 5% rise over the 1978 level and representing the fourth consecutive annual increase.[4] Rising capital goods purchases by industry, especially railroad equipment and industrial machinery of all kinds, together with high-level automobile and truck output, support increased casting production. Table 3-3 depicts the trends and projections for various components of the ferrous casting industry.

TABLE 3-2. NUMBER OF FERROUS FOUNDRIES

State	1974 Penton publication list					Industry listing					1979 NEDS printout[d]				1979 CDS[e]
	Total[a/]	Gray	Ductile	Malleable	Steel	Total[b] (including nonferrous)	Gray[b] (1979)	Ductile[b] (1979)	Malleable[b] (1979)	Steel[c] (1977-78)	Total	Gray and ductile	Malleable	Steel	Total
Region I	91	87	25	2	9	331	82	28	9	6	42	33	2	7	40
Connecticut	22	21	6	-	4	97	19	8	5	3	-	-	-	-	5
Maine	8	8	1	-	-	13	6	1	-	-	5	5	-	-	6
Massachusetts	41	40	13	2	2	137	41	16	2	2	20	19	-	1	20
New Hampshire	8	7	2	-	3	31	7	1	1	1	1	-	1	-	2
Rhode Island	8	7	2	-	-	49	5	1	1	-	7	6	1	-	6
Vermont	4	4	1	-	-	4	4	1	-	-	9	3	-	6	1
Region II	105	103	31	2	13	395	81	37	8	12	23	30	-	3	46
New Jersey	37	36	13	-	6	130	22	14	1	3	23	20	-	3	22
New York	68	67	18	2	7	265	59	23	7	9	-	-	-	-	24
Region III	202	198	71	9	25	482	192	83	22	31	94	74	3	17	131
Delaware	1	1	-	-	-	6	1	-	-	2	2	1	-	1	-
District of Columbia	1	-	1	-	-	3	1	-	1	-	-	-	-	-	-
Maryland	11	11	6	1	3	24	8	5	-	-	3	3	-	-	4
Pennsylvania	150	147	52	8	19	375	144	66	20	27	63	49	2	12	106
Virginia	28	28	7	-	3	48	28	7	-	1	12	9	-	3	18
West Virginia	11	11	5	-	-	26	10	5	1	1	14	12	1	1	3
Region IV	204	192	52	3	14	399	170	62	12	17	140	123	3	14	136
Alabama	64	56	22	2	6	94	53	25	1	8	48	45	1	2	49
Florida	11	10	4	-	3	56	8	4	-	3	5	4	-	1	3
Georgia	29	28	7	1	2	47	18	9	8	3	3	3	-	-	9
Kentucky	12	12	-	-	-	28	13	1	1	-	13	10	1	2	7
Mississippi	8	8	1	-	-	14	7	-	1	1	5	5	-	-	6
North Carolina	28	28	6	-	-	52	23	7	-	-	16	15	-	1	19
South Carolina	14	14	5	-	2	28	13	5	-	-	6	5	-	1	8
Tennessee	38	36	7	-	1	80	35	11	1	2	44	36	1	7	35
Region V	529	513	197	23	54	1,608	527	225	46	75	379	324	23	32	184
Illinois	81	79	29	4	6	319	75	34	6	15	49	42	5	2	34
Indiana	70	68	20	1	4	194	72	23	3	10	67	58	3	6	30
Michigan	113	110	48	2	15	351	111	52	15	11	92	78	7	7	21
Minnesota	35	34	9	1	2	91	34	8	1	2	27	26	1	-	14
Ohio	146	143	59	9	18	456	154	70	14	22	103	84	4	15	49
Wisconsin	84	79	32	6	9	197	81	38	7	15	41	36	3	2	36

TABLE 3-2. (continued)

State	1974 Penton publication list					Industry listing					1979 NEDS printout[d]				1979 CDS[e]
	Total[a]	Gray	Ductile	Malleable	Steel	Total[b] (including nonferrous)	Gray[b] (1979)	Ductile[b] (1979)	Malleable[b] (1979)	Steel[c] (1977-78)	Total	Gray and ductile	Malleable	Steel	Total
Region VI	97	93	41	1	18	311	105	57	5	20	37	26	1	10	17
Arkansas	9	9	1	-	-	44	11	4	-	1	5	4	-	-	4
Louisiana	9	9	1	-	2	24	9	1	-	4	4	1	-	3	2
New Mexico	-	-	-	-	-	14	1	-	-	-	-	-	-	-	-
Oklahoma	19	18	14	-	3	46	22	18	-	2	6	5	-	1	6
Texas	60	57	25	1	13	183	62	34	5	13	22	16	1	5	5
Region VII	92	89	27	-	5	265	90	30	3	16	81	73	1	7	61
Iowa	36	35	9	-	1	74	31	11	1	2	34	33	1	-	24
Kansas	24	22	11	-	-	55	34	11	-	2	27	26	-	1	23
Missouri	25	25	6	-	4	116	29	8	2	11	11	7	-	4	9
Nebraska	7	7	1	-	-	20	6	-	-	1	9	7	-	2	5
Region VIII	27	24	9	-	6	73	31	14	2	3	9	8	-	1	11
Colorado	13	12	5	-	3	48	15	6	-	2	4	4	-	-	4
Montana	2	2	-	-	-	3	2	1	1	-	-	-	-	-	-
North Dakota	2	2	-	-	-	1	-	-	-	-	1	1	-	-	-
South Dakota	1	1	-	-	-	3	2	1	-	-	-	-	-	-	-
Utah	9	9	4	-	3	16	11	5	1	1	4	3	-	1	7
Wyoming	-					2	1	1	-	-	-	-	-	-	-
Region IX	88	84	29	2	20	458	87	37	5	19	58	47	2	9	46
Arizona	3	3	1	1	2	21	4	2	2	3	1	1	-	-	-
California	82	78	28	1	16	431	80	35	3	15	56	45	2	9	46
Hawaii	2	2	-	-	11	2	1	-	-	-	1	1	-	-	-
Nevada	1	1	-	-	1	4	2	-	-	1	-	-	-	-	-
Region X	38	37	17	1	9	117	34	18	3	16	21	10	-	11	13
Alaska	1	1	-	-	-	1	-	1	-	-	-	-	-	-	-
Idaho	4	4	1	-	-	6	4	1	-	-	-	-	-	-	-
Oregon	12	12	6	-	1	54	12	7	-	5	5	4	-	1	3
Washington	21	20	10	1	8	56	18	9	3	11	16	6	-	10	10

a Totals are generally less than sum of four metal types, as many foundries were shown to produce more than one type of casting.

b Source: Metal Casting Industry Census Guide: November 1978. Foundry Management and Technology, April 1979.

c Source: Steel Founders Society of America, Directory of Steel Foundries in the United States, Canada, and Mexico, 1977 to 1978. Rocky River, Ohio, 1977.

d NEDS = National Emissions Data System.

e CDS = Compliance Data System.

TABLE 3-3. FERROUS CASTINGS: TRENDS AND PROJECTIONS 1972-1983

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Product												
Quantity shipped, total (000 tons)	17,885	19,972	18,666	15,115	16,827	17,582	18,550	19,491	20,173	20,879	21,610	22,366
Gray iron (000 tons)	13,493	14,801	13,459	10,622	11,935	12,326	-	-	-	-	-	-
Ductile iron (000 tons)	1,835	2,246	2,203	1,824	2,243	2,707	-	-	-	-	-	-
Malleable iron (000 tons)	961	1,031	914	731	846	830	-	-	-	-	-	-
Steel (000 tons)	1,596	1,894	2,090	1,938	1,803	1,719	-	-	-	-	-	-
Value of shipments ($ million)	5,807	7,129	8,779	9,127	10,072	11,751	14,578	16,946	18,302	19,766	21,347	23,055
Average value ($/ton)	324.7	356.9	470.3	603.8	598.6	668.4	785.9	869.4	907.3	946.7	987.8	1,030.8
Industry												
Total employment (000)	216	236	239	221	216	220	231	242	250	259	268	278
Production workers (000)	181	200	203	184	179	180	189	198	205	212	220	227
Value of shipments ($ million)	5,647	6,858	8,535	8,871	9,787	11,418	14,165	16,438	-	-	-	-
Trade												
Value of exports ($ million)	114	157	223	281	283	291	302	315	-	-	-	-
Value of imports ($ million)	37	48	73	76	79	110	132	162	-	-	-	-

Source: U.S. Department of Commerce Industry and Trade Administration, 1979. U.S. Industrial Outlooks, January 1979. pp. 178, 179; and Miske, J. C. Ed. The Foundry Industry--A Look Ahead. Foundry Management and Technology, January 1978, Figure 3, p. 40.

Gray iron castings (including ductile iron) are the major product of ferrous foundries, comprising 85% of the 1977 output and about 81% of 1978 shipments. Gray iron shipments in 1978 were about 12.9 million tons, and ductile iron, approximately 3 million tons. Gray iron shipments in 1977 totaled 15.0 million tons, of which 2.7 million tons were ductile iron. In 1979, gray iron shipments were forecast to reach 13.4 million tons; ductile iron castings were also projected to continue to gain, reaching an estimated 3.3 million tons. Malleable iron castings shipments have been more stable as ductile iron has preempted some markets. Malleable iron shipments were expected to total 850,000 tons in 1978 and 880,000 tons in 1979. In 1977, production of malleable iron castings totaled 829,662 tons.

Buoyed by booming railroad car construction, steel castings shipments were especially active in 1979. Orders for railroad car component castings are largely on extended delivery terms, with contracts that cover the entire annual requirements of car builders occurring quite frequently.[4]

Almost 50% of steel castings production now goes to railcar uses, compared to 35 to 40% in the past. Projections indicated that railcar output would remain strong in 1979, and the improved demands for machinery components indicated continuing growth for steel castings beyond the 1978 shipment level of 1.8 million tons. Shipments of steel castings during 1979 were anticipated to reach 1.9 million tons.[4] In 1977, these shipments were reported at 1.72 million tons.

One particularly interesting phenomenon was identified during the review of the industry size and production trends. Even though foundry production evidenced a slow but relatively steady growth pattern, the A. T. Kearney Co. indicated in their 1970 study that from 1947 to 1969, the number of gray, ductile, and malleable iron foundries had decreased, from 3,200 to 1,670. Based on data presented in Table 3-2, this trend appears to have continued. These trends indicate that average production per foundry is increasing. This probably is an indication that small foundries, quite likely in rural areas, are closing while large foundries, in more populated areas are expanding in size. If this pattern does hold true, foundries will quite likely become an increasingly significant air pollution problem in nonattainment areas.

3.1.2 Economic Value of Ferrous Foundries

As mentioned at the outset, foundry products are essential for the continued operation of almost all heavy industry in the United States. Some major industrial users of castings are summarized in Table 3-4. Iron castings are used in almost all types of equipment, including motor vehicles, farm machinery, construction machinery, petroleum industry equipment, and iron and steel industry equipment. Steel castings are classified on the basis of their steel quality, which determines their end use. Steel casting classifications include general purpose structural, heat resistant, acid resistant, alkali resistant, and wear resistant. These castings are used, for example, in motor vehicles, aircraft, agricultural equipment, ore refining machinery, and chemical manufacturing equipment. Both iron and steel castings are vital for national defense requirements and energy production facilities.

TABLE 3-4. END-USE DISTRIBUTION OF CASTINGS

	SIC code[a]	Industry
A. Iron castings	3714	Motor vehicle parts and accessories
	3523	Farm machinery and equipment
	3519	Internal combustion engines, nec.
	3494	Valves and pipe fittings
	3561,3	Pumps and compressors
	3585	Refrigeration and heating equipment
	3531	Construction machinery
	3566	Power transmission equipment
	3621	Motors and generators
	3541	Machine tools, metal cutting types
B. Steel castings	3743	Railroad equipment
	3531	Construction machinery
	3714	Motor vehicle parts and accessories
	3494	Valves and pipe fittings
	3495	Wire springs
	3559	Special industry machinery, nec.
	3561,3	Pumps and compressors
	3728	Aircraft equipment, nec.
	3711	Motor vehicles and car bodies
	3533	Oil field machinery

Source: Metal Casting Industry Census Guide: November 1978. Foundry Management and Technology, April 1979.

a Ranked by production (highest 10 listed).

In general, the foundry industry is expected to remain a healthy and important section of the economy with a projected increase in volume and value of shipments for several years.

Value of industry shipments for ferrous castings in 1978 was estimated at $14.16 billion, compared to $11.42 billion in 1977. The value of industry shipments includes the value of all products and services sold by the ferrous castings industry (SIC 332). The value of product shipments (i.e., value of shipments of ferrous castings produced by all industries) reached $11.75 billion in 1977 and was expected to reach $14.58 billion in 1978 and then to rise to $16.95 billion by the end of 1979 (a 16% increase over 1978). Table 3-3 expressed these values for recent years and also includes financial projections for future shipments.

Based on the above discussion it is apparent that the ferrous foundry industry has been and will continue to be an important segment of the U.S. industrial structure.

3.2 MARKET STRUCTURE

Ferrous foundries are divided into one of two market classes, captives or jobbers. A captive foundry is a division or a subsidiary of a larger manufacturing concern. The castings producted in a captive foundry are generally used in another segment of the parent company. Jobbers are independent companies which must compete on the market for casting sales. Often jobber foundries are further classified as small, medium, or large.

An understanding of the castings market structure is important for two reasons. First, it provides some understanding of the importance of each of the three classes. Second, the degree of mechanization is related to the market class. As described in Section 5.2, the degree of mechanization impacts greatly upon reasonably attainable control levels.

The captive foundry often produces large number of the same casting on a continual basis for the parent company. As a result it is much easier for captives to be mechanized.

Large foundries compete with other large foundries for about the same market. Some large foundries producing parts will compete with other large foundries producing similar castings even though a segment of the large foundries is really captive. Very large foundries are generally fully automated and produce large numbers of similar castings. This repetitive production of large numbers of castings with automated equipment permits the large foundries to produce castings at a minimum unit cost.

Medium-size foundries, those foundries that have melting rates of 10 to 50 tons/h, generally produce a wider range of casting designs and make fewer of each design than do large foundries. Most medium-size foundries have some automated equipment, however, and make large numbers of some castings but seldom will make a different casting design each day. Medium-size foundries have a higher unit cost than do large foundries; therefore, they must charge more per part.

Very small foundries (those foundries that melt about 4 tons/h for less than 8 h/day) must find markets that are unattractive to the larger foundries. These markets for very small jobbing foundries include replacement parts where only a few castings are needed, castings for customers that only need a few parts per month, and some very low quality castings (for example, counterweights or manhole covers) where very little control is required. The very small foundry has little automated equipment. But these small foundries are important because they provide essential services not available elsewhere in the industry.

3.3 FOUNDRY EQUIPMENT INVESTMENT TRENDS

Another factor which was considered in describing the foundry industry was the equipment investment plans projected by foundry management. Several trends were identified which impact on the development of compliance strategies as described below.

A survey conducted by Foundry Management and Technology indicates that foundries are increasing their investments, even when inflation is discounted. In light of the decrease in the total number of foundries, investment per plant is increasing at an even faster rate than total investment.[6] The study goes on to say that much of the investment is directed toward increasing foundry mechanization, especially in smaller foundries. This is supported by survey results which indicate 15% of all foundries are planning investments in mechanized sand handling equipment, and 14% are planning to invest in mechanized mold-handling equipment. Investment in mechanized equipment will have a positive effect on the level of air pollution control that can be attained in these foundries.

A second factor that is particularly important is the type of melting equipment that foundries plan to install. An earlier foundry study indicated that the total number of cupolas in use was rapidly declining while the number of electric furnaces was increasing. On this basis regulatory agencies have recently given greater attention to the control of electric furnaces, especially electric arc furnaces. However, the Foundry Management and Technology study indicates that "cupola installations seem to be getting a new lease on life as the cost and availability of electricity become bigger problems."[6] In spite of a decline in the number of cupolas from 2,657 used in 1,877 plants in 1967 to 1,493 in 1,093 plants in 1977, more than 70% of the total iron melted still comes from cupolas. This is an indication that cupola emissions will continue to be a major concern of agencies in developing compliance strategy development.

Another interesting aspect of management plans for melting is the number of foundries which plan to invest in induction furnaces. A total of 543 foundries (11% of the industry) planned to invest in coreless induction furnaces in 1977-1978. These furnaces that inherently have lower emissions must certainly be given consideration when developing compliance strategies. It sould be noted that some of these furnaces will be used as duplexing or holding furnaces, not as the primary melting unit. This level of purchases of induction furnaces probably does not indicate a major change in the distribution of primary melting units.

Other data of interest are the plans of the foundry industry for purchasing air pollution control equipment. The type of collectors in which foundries plan to invest and the associated percentage of foundries with such plans are: dry bag filters (13%), mechanical collectors (1%), wet scrubbers (3%), and electrostatic precipitators (1%).[6] A total of 6% of the foundries had plans for additional in-plant dust capture systems.[6] Since less than 1% of the industry plans to installing venturi scrubbers, it is speculated that most new cupola controls will consist of fabric filters.

3.4 IDENTIFICATION OF INDIVIDUAL FOUNDRIES

It seems obvious that if an effective compliance strategy is to be developed for iron foundries, a comprehensive listing of iron foundries is essential. When this study was initiated, it was assumed that such a listing could come from one of two data bases available to EPA: NEDS and CDS. However, an initial accounting of foundries (Table 3-2) showed considerable discrepancy between those listings and the industry listing from Penton.[1]

As a result of these discrepancies, the data from Alabama were examined thoroughly to try to identify patterns in the differences. The data from Alabama were chosen because it has an average number of foundries and the overall number of foundries on the three listings was at least as consistent for Alabama as for most other states. The results of this review are presented in Table 3-5. The data indicate that 24 foundries were identified in the 1974 industry list that are not on the CDS or the NEDS listing. Since these foundries are small to medium sized, it is quite possible that some have closed since 1974. However, it is not likely that all have.

On the other hand, a total of 22 foundries which are not on the industry list appear on either the NEDS or the CDS listing. Thus, the industry list probably contains some inaccuracies.

Since the total number of foundries from the various listings are more closely comparable in Alabama than in most states (see Table 3-1) it is quite possible that the discrepancies between the listings in the other states will be even greater. The scope of this task did not permit development of an accurate inventory of the foundry industry. However, it is strongly recommended that an accurate inventory of foundries be set up if further development of compliance strategies is attempted.

3.5 FOUNDRY LOCATION

Data presented in Section 3.1.1 and Table 3-4 show that the iron foundry population is well dispersed throughout the United States, indicating that some consideration of the industry can be expected by most state agencies. Two aspects of foundry location which are important to states developing enforcement strategies are: (a) the population densities in the vicinity of foundries and (b) the status of areas where foundries are located with respect to attainment of National Ambient Air Quality Standards (NAAQS). Both of these factors impact on the level of effort which enforcement agencies are willing to spend in assuring compliance by ferrous foundries.

TABLE 3-5. COMPARISON OF FOUNDRY IDENTIFICATION IN THE STATE OF ALABAMA

Foundry name and address	City	CDS[a]	NEDS[b]	Penton[c]	Capacity of those foundries not in NEDS or CDS (Mg/hr)
Alex Corporation 14th and Woodbine	Calera	X	X		
Aliceville Castings	Aliceville	X	X		
Alabama Industries, Inc. 5th Street and Main	Sylacauga		X		
American Cast Iron Pipe 2930 16th Street North	Birmingham	X	X	X	
Anderson Electric Corporation Highway 31 South	Clanton		X	X	
Anniston Foundry Company Ware Street	Anniston	X		X	
Atlantic Stove Works, Birmingham Stove and Range Division Huntsville Road and 27th Avenue, North	Birmingham			X	16.3
Atlas Pattern Works 6700 Madrid Avenue	Birmingham			X	0.32
Attalla Div., Dayton M 100 7th Avenue	Attalla	X			
Auburn Foundry Company 2503 Highway, 14 West	Auburn			X	7.3
Avondale Stove and Foundry Company 2820 6th Avenue South	Birmingham			X	9.1
Bama Foundries, Inc. 1427 N. Court Street	Mobile			X	4.5
Barry Pattern and Foundry 801 N. 43rd Street	Birmingham		X	X	
Bethea Casting Corporation Highway 31	Pelham	X	X	X	
Birmingham Stove and Range 2631 Huntville Road	Birmingham	X	X	X	
Biggs, John Company, Inc. Star Route A	Atmore			X	<10 employees
Blue, John Company 2900 Bob Wallace Avenue	Huntsville			X	10.9
Brewton Iron Works[a] P.O. Box 409	Brewton			X	9.1
Brooks Foundry and Machine Brecon Industrial Area	Talladega	X	X	X	
Caldwell Foundry and Machine 518 14th Street North	Birmingham	X	X		
Caldwell Foundry and Machine Dunnavant Road	Leeds	X			

TABLE 3-5. (continued)

Foundry name and address	City	CDS[a]	NEDS[b]	Penton[c]	Capacity of those foundries not in NEDS or CDS (Mg/hr)
Cast South, Inc. County Road 45	Marion	X			
Central Foundry Div. (Gable, Inc.) P.O. Box 2449	Holt (Tuscaloosa)	X	X	X	
Clow Corporation Cast Iron Pipe Div. 1600 National Street	Birmingham	X	X	X	
Continental Moss-Gordin, Inc.	Prattville			X	7.3
Casper Foundry 3521 28th Place	Birmingham	X	X	X	
Crane Foundry Company 3001 North 28th Place	Birmingham	X	X	X	
Dresser, Inc., Dresser Manufacturing Div. West 23rd & R R Avenue	Anniston		X	X	
Diamond C. Foundry, Inc. One Central Park Road	Clanton			X	2.7
Dimick Casting Company 1006 37th Place, North	Birmingham			X	2.7
Fairmont Foundry Company 3125 35th Avenue, North	Birmingham	X	X	X	
Glidewell Specialties 2 West 15th Street	Birmingham	X	X	X	
Goslin-Birmingham, Inc. 3500 8th Avenue, North	Birmingham		X	X	
Griffin Wheel Griffin Wheel Drive	Bessemer	X	X		
Gulf Foundry and Machine Company 1751 Conception Street	Mobile	X	X	X	
Imperial Casting Company 1001-1/2 Florence Boulevard	Florence			X	22.6
Irondale Foundry 2200 1st Avenue South	Irondale		X		
Jacobs Manufacturing Company P.O. Box D	Bridgeport	X		X	

TABLE 3-5. (continued)

Foundry name and address	City	CDS[a]	NEDS[b]	Penton[c]	Capacity of those foundries not in NEDS or CDS (Mg/hr)
Jefferson Foundry 20th and McCoy A	Anniston	X	X		
Jefferson Foundry No. 1 800 41st Street North	Birmingham	X	X	X	
Jefferson Foundry No. 2 730 North 44th Place	Birmingham	X	X		
Jefferson Iron and Metals 5151 Street Avenue North	Birmingham	X			
Jones Foundry Company 2217 Carolina Avenue South	Bessemer	X	X	X	
King Stove and Range 16th Street	Sheffield		X	X	
Kirkland Weather Foundry 13 Avenue	Alexander City	X		X	
Koppers, Inc. General Delivery	Woodward	X			
Lawler Machine 760 44th Street North	Birmingham	X	X	X	
LeHigh Valley Industries, Inc., Mobile Pulley and Machine Div. 908 South Ann Street	Mobile	X		X	
Martin Stove and Range Commerce Street	Florence	X	X	X	
McWane Cast Iron Pipe Company 1201 Vanderbilt Road	Birmingham	X	X	X	
Mead Corporation, Alabama Pipe Div 1501 West 17th	Anniston			X	13.6
Mead Pipe Union Foundry 1900 Parkwin Avenue	Anniston	X	X	X	
Mead Pipe-Water Plant 2700 Dooley Avenue	Anniston	X	X	X	
Miller Foundry Company 78 East Lovick & Alton	Lovick	X	X		
Mueller Company Weaver Avenue, RR 3	Albertville	X	X		
Mudge Foundry, Inc. Box 96	Bessemer			X	4.6
Munford Manufacturing, Inc.	Munford			X	1.6

TABLE 3-5. (continued)

Foundry name and address	City	CDS[a]	NEDS[b]	Penton[c]	Capacity of those foundries not in NEDS or CDS (Mg/hr)
Newberry Manufacturing Company 209 17th	Talladega	X	X	X	
Noble Corporation Front and Elm Streets	Anniston	X			
Opelika Foundry Company, Inc. 1 Williamson Avenue	Opelika	X	X	X	
Phoenix Foundry General Delivery	Phoenix City	X		X	
Precision Manufacturing Company	Brewton	X	X		
Robinson Foundry Company Box 427	Alexander City	X	X	X	
Russell Pipe and Foundry Company Washington Street	Alexander City	X	X	X	
Simsco-Boaz, Inc. 101 Airport Street	Centreville			X	0.45
Simsco, Inc. P.O. Box 785	Columbiana			X	1.8
Simsco-Todd Route 3	Selma			X	10-49 employees
Smith Foundry Company 220 Front Street	Anniston			X	1.8
Southeastern Specialty and Manufacturing Company, Inc. 1906 West 13th Street	Anniston			X	11.8
K. B. Southern 700 North 39th Street	Birmingham	X	X		
Southern Alloy Corporation Highway 280	Sylacauga			X	1.8
Southern Foundry P.O. Box 115	Calera	X			
Southland Mower Company, Inc. Old Montgomery Highway	Selma			X	2.7
Stockham Valves and Fittings 4000 10th Avenue North	Birmingham		X	X	
Strickland Bros. Machine Company 2804 12th Street	Tuscaloosa			X	2.7
Stubbs Foundry Route 1	Helena			X	2.7

TABLE 3-5. (concluded)

Foundry name and address	City	CDS[a]	NEDS[b]	Penton[c]	Capacity of those foundries not in NEDS or CDS (Mg/hr)
Talladega Foundry and Machine Company 301 North Johnson Avenue	Talledega	X	X	X	
Thomas Foundry, Inc. 3800 10th Avenue North	Birmingham		X	X	
Tommie Corporation Industrial Park	Clanton	X	X		
Unexcelled Manufacturing Corporation West 6th Avenue	Attalla		X	X	
U.S. Pipe and Foundry Soil Pipe Division 1831 Front Street	Anniston	X	X	X	
U.S. Pipe and Foundry 3300 1st Avenue North	Bessemer	X	X	X	
U.S. Pipe-MMC 3500 35th Avenue North	Birmingham	X	X		
U.S. Pipe-N Birmingham 3000 30th Avenue North	Birmingham	X	X	X	
Vulcan Foundry 1006 37th Place North	Birmingham	X	X		

[a] CDS = Compliance Data System.

[b] NEDS = National Emissions Data System.

[c] Source: Penton Computer Printout of Gray Iron Foundries in the United States. The Penton Publishing Company, Cleveland, Ohio. March 1974.

Obviously, agency decisions regarding level of enforcement can best be made if specific data are available on the population impacted by foundry emissions within their jurisdiction. The scope of this project does not allow an analysis of this detail. However, unpublished data developed during an earlier MRI study of fugitive emissions from foundries are useful in obtaining a general perspective of foundry location with respect to population.

U.S. Census Bureau data were used to assign a county population density to each foundry listed in the 1976 NEDS printout.[7] These data were then used to examine the relationships between population density and number of foundries (Table 3-6) and population density and annual foundry production (see Figure 3-1). Based on these data, it appears that foundries (both number and production) are as dispersed with respect to population as they are with respect to geographical location. While this is not particularly helpful for agencies developing compliance monitoring strategies, it does point up some of the difficulty in developing a general strategy for the foundry industry.

The major emphasis of local agencies is placed on those sources located in areas not attaining NAAQS. The scope of this program did not permit the determination of NAAQS attainment status for each foundry in the United States. However, for six states representing a cross-section of the foundry population (with respect to number of foundries per state), the total suspended particulate (TSP) attainment status was determined for areas surrounding each foundry. The results are presented in Table 3-7. The foundries were identified using a 1979 NEDS listing. The attainment status of the area surrounding the foundry was taken from EPAs October 1978, definition of particulate attainment.[8,9]

The data in Table 3-7 certainly indicated that compliance of foundries should be a concern in those states examined. The number of foundries in certified attainment areas ranges from 10.7 to 44.1% with an average of 23.4%. An average of almost 70% of the foundries surveyed were in either primary or secondary nonattainment areas. This provides strong justification for a continued effort to develop compliance strategies for ferrous foundries.

3.6 FOUNDRY SIZE

The size of an individual foundry impacts on compliance status in two ways. First, since foundry emissions are directly related to size, a large foundry is more likely to be considered a major emissions source and as such subject to more rigorous regulations and enforcement. This is balanced by the fact that larger foundries are more mechanized and have more highly trained personnel. Both of these factors should improve control levels in the larger foundries.

TABLE 3-6. RELATIONSHIP BETWEEN COUNTY POPULATION DENSITY AND NUMBER OF FOUNDRIES IN COUNTIES OF THAT SIZE

Population density (persons/sq mile)	Percent of foundries
0-49	13
50-99	13
100-199	15
200-499	26
500-999	12
>1,000	21

Source: Unpublished data from a previous MRI study on fugitive emissions from iron foundries.

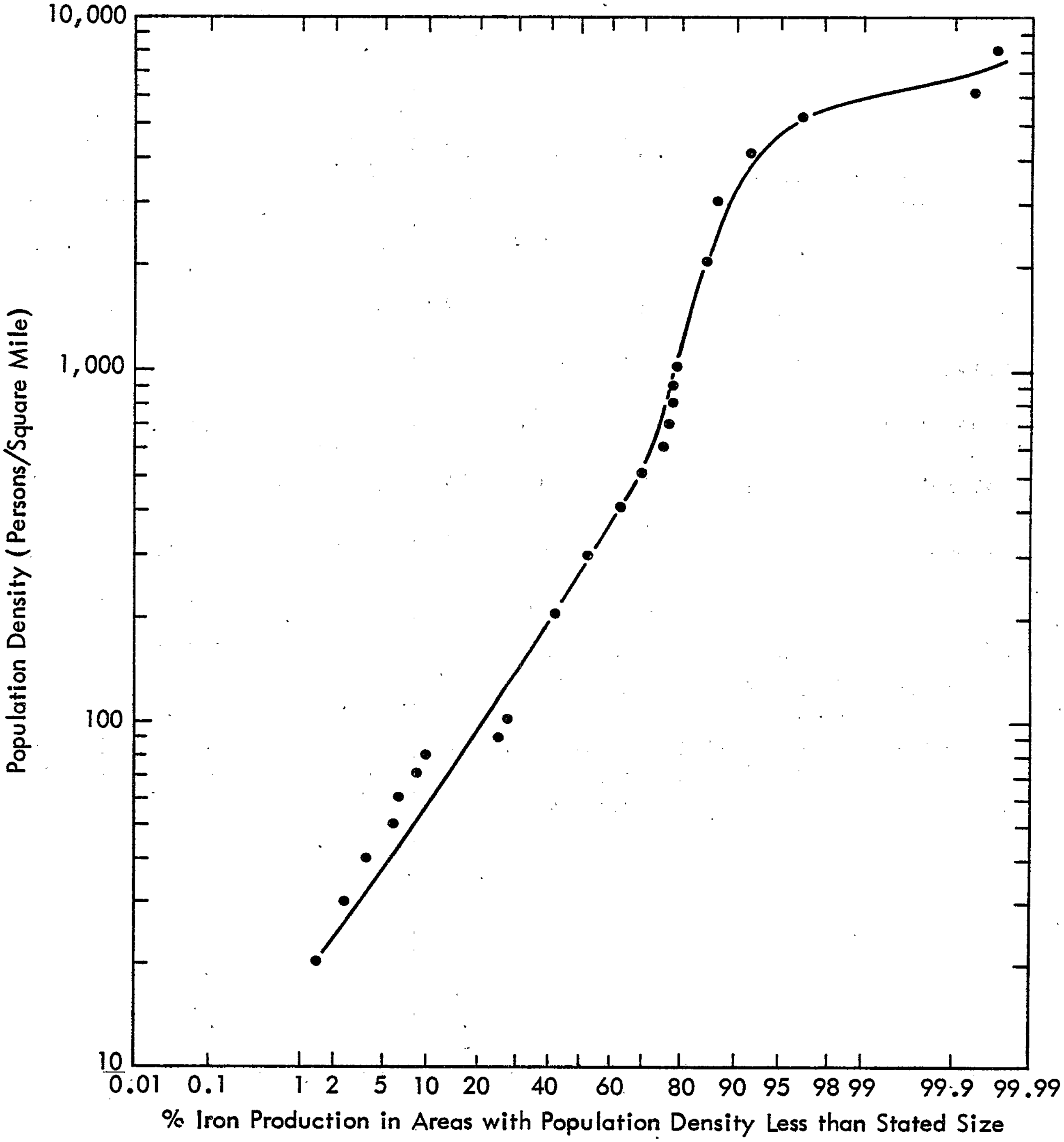

Figure 3-1. Foundry production vs. population density.

TABLE 3-7. FOUNDRY LOCATION WITH RESPECT TO ATTAINMENT STATUS

State	Total No. of foundries[a]	Attainment status[b]: Not meet primary No.	%	Not meet secondary No.	%	Unknown No.	%	Better than national standard No.	%
Iowa	34	7	20.6	7	20.6	4	11.8	15	44.1
Ohio	103	50	48.5	42	40.7	0	0	11	10.7
Oklahoma	6	5	83.3	0	0	0	0	1	16.7
Pennsylvania	63	30	47.6	0	0	11	17.5	22	34.9
Vermont	9	0	0	6	66.7	0		3	33.3
Washington	16	12	75.0	2	12.5	0	0	2	12.5
Total	231	104	45.0	57	24.7	15	6.5	54	23.4

[a] Source: NEDS Printout, June 1979.

[b] Source: Federal Register, Vol. 43, No. 43, March 3, 1978, Part II. pp. 8962-46019. Federal Register, Vol. 43, No. 194, October 5, 1978. pp. 45993-46019.

Davis et al. developed estimates of industry-wide production from various foundry size classifications.[2] They used foundry employment as a basis for the following size categories:

Large	Over 250 employees
Medium	50 to 249 employees
Small	49 or less employees

The Penton capacity data and the assumption that large foundries melt for 16 h/day, medium foundries 8 h/day, and small foundries 4 h/day were used to calculate industry-wide daily capacities for 12 foundry size/furnace-type categories.[1] The results are shown in Table 3-8.

While these data are not particularly useful in developing specific compliance strategies, two general observations can be made. The data in Table 3-8 indicate that over 65% of foundry production capacity is centered in large foundries, which gives further support to foundries being significant sources of air pollution. The data also indicate that almost 75% of foundry melt capacity is from cupolas, further indicating that these furnaces will continue to be a compliance problem.

Obviously, the data most useful in developing specific compliance strategies are actual production rates of individual foundries. However, since these data may sometimes be difficult to obtain and since employment data are generally available from industrial publications, production rates were examined as a function of employment. Using the size classifications and work rates from Davis et al., Penton capacity data (see Appendix D) were used to calculate daily production capacity for each U.S. foundry. The average daily production and the range of production for the various size foundries (as defined by employment on p. 38) were found to be:

Size (based on employment)	Average production (tons/day)	Range of production (tons/day)
Large	820	10.2-9,670
Medium	100	1.5-1,600
Small	20	0.2-138

As can be seen from the extreme range of capacity shown in the table above, foundry employment can not be used as an indicator of production capacity.

TABLE 3-8. HOURLY CAPACITY AND ESTIMATED CAPACITY PER TYPICAL WORKING DAY FOR CAST IRON FOUNDRIES IN THE UNITED STATES

Type of melting furnace	Large foundries (more than 250 employees)		Medium-size foundries (50 to 249 employees)		Small foundries (less than 50 employees)	
	Capacity (tons/hr)	Estimated capacity per Working day[b] (tons/day)	Capacity (tons/hr)	Estimated capacity per working day[c] (tons/day)	Capacity (tons/hr)	Estimated capacity per working day[d] (tons/day)
Cupola	6,239	99,824	5,638	45,104	2,645	10,850
Induction	323	5,168	986	7,888	213	852
Arc	1,940	31,040	408	3,264	163	652
Air[a]	512	512	2,993	2,993	54	54
Total	9,014	136,544	10,025	59,249	3,075	12,138
Percent of total	-	65.7	-	28.5	-	5.8

Source: Davis, J. A., E. E. Fletcher, R. L. Wenk, and A. R. Elsea. Final Report on Screening Study on Cupolas and Electrical Furnaces in Gray Iron Foundries. U.S. Environmental Protection Agency Contract No. 68-01-0611, Task 8. August 15, 1975.

a For air furnaces, the capacity is given in tons per charge, which is assumed to be equivalent to tons per day for this type of furnace.

b Based on average melting period of 16 h/day.

c Based on average melting period of 8 h/day.

d Based on average melting period of 4 h/day.

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9. Federal Register, Vol. 43, No. 194, October 5, 1978. pp. 45993-46019.

4.0 FERROUS FOUNDRY PROCESSES AND EMISSIONS

A ferrous foundry is composed of numerous unit operations, many of which have the potential for the emission of gaseous and/or particulate pollutants to the atmosphere. A basic understanding of these foundry operations and their associated emissions problems is a prerequisite to any analysis of the compliance problems associated with ferrous foundries.

This section briefly describes the ferrous foundry process and summarizes available information on foundry emissions. The discussion is divided into three sections: (a) description of ferrous foundry processes; (b) identification of emissions sources; and (c) inventory of particulate emissions. More detailed information can be found in Appendix A, "Description of Ferrous Foundry Processes," and Appendix B, "Quantification of Particulate Emissions for Major Foundry Emissions Sources."

4.1 DESCRIPTION OF FOUNDRY PROCESSES

A ferrous foundry processes various grades of iron and steel scrap to make cast iron and steel products. The four basic operations present in all foundries are raw materials storage and handling, metal melting, pouring of the molten metal into some type of mold, and removal of solid castings from the mold. Other operations which occur in many foundries are preparation and assembly of sand molds and cores, mold cooling, shakeout, casting cleaning and finishing, sand handling and preparation, and hot metal inoculation.

Six basic operating areas can be found in the typical ferrous foundry. These are:

- Core and mold preparation
- Furnace charge preparation
- Pattern making
- Melting and casting
- Cleaning and finishing
- Sand-handling system

Since pattern-making operations are not significant sources of emissions, this area was not included in the study. A flow diagram for the other five operations in a "typical" foundry is shown in Figure 4-1. The paragraphs below describe the operations that are found in each of these areas. Details of the individual operations are provided in Appendix A.

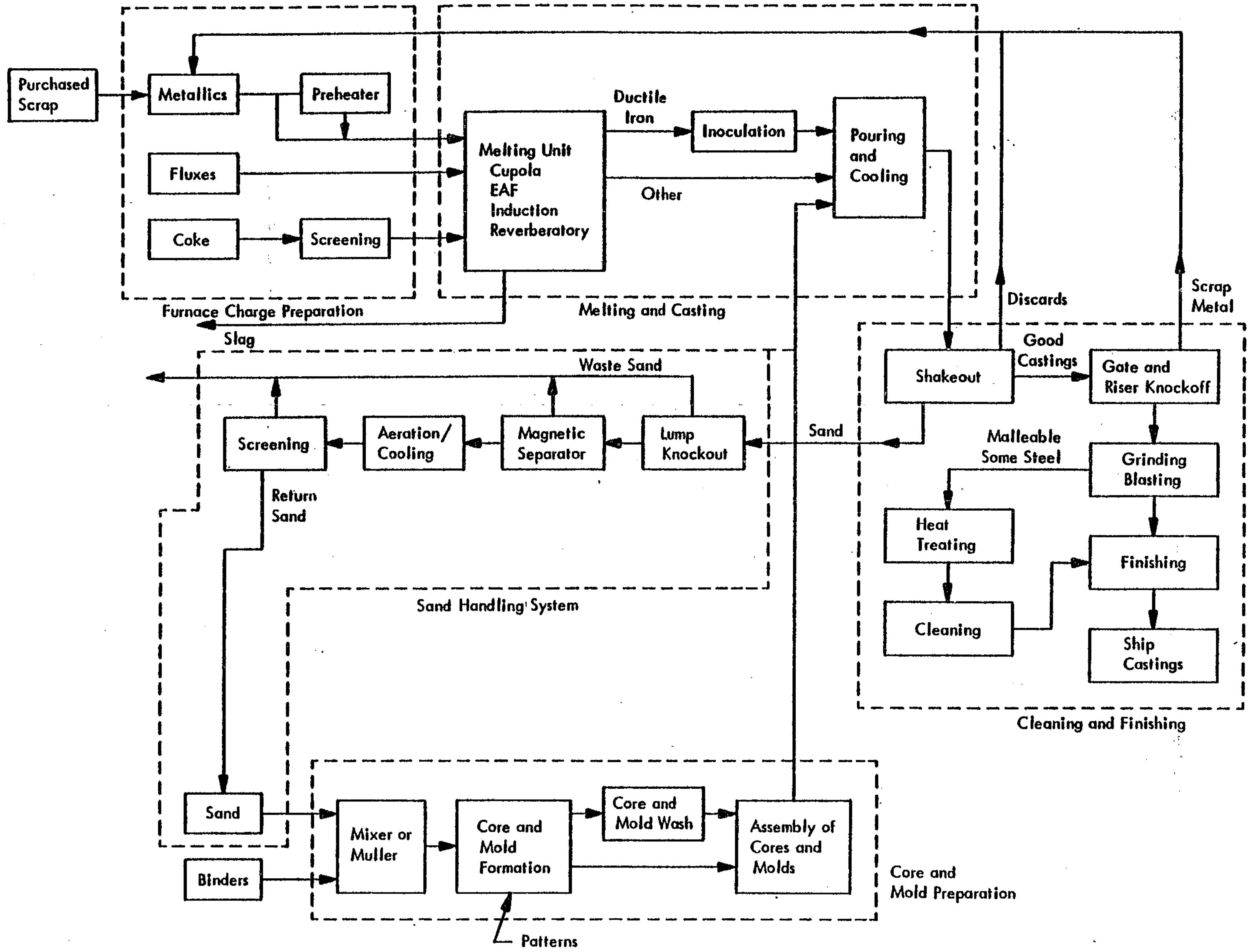

Figure 4-1. General foundry flow diagram.

The basic raw materials which enter the foundry process are: (a) sand and binders for core and mold preparation; (b) metallic materials including iron and steel scrap, borings and turnings, limited quantitites of pig iron, and foundry returns; (c) coke for cupola fuel; (d) fluxing agents; and (e) limited quantities of inoculants and alloying agents. The sand is generally stored in closed silos, and the other materials are stored under cover whenever possible to prevent material degradation.

Upon leaving the storage area, the sand and binders go to the core and mold preparation area. The mold provides the basic exterior form of the casting, and cores are used to form the interior of the castings (e.g., cylinders in an engine block). The most common type of mold used in ferrous foundries is the green sand mold. The sand is prepared by mixing silica sand, water, bentonite clay, and binder materials such as cereal binder (derived principally from corn flour) and sea coal (finely ground coal commonly mixed with foundry sands) in a muller. The damp sand mixture is packed around patterns in one of a variety of molding machines to form the two halves of the mold. A typical green sand mold is shown in Figure A-2 (Appendix A). The cores are then placed in the mold, and the molten metal is poured while the mold is still moist. The cores are generally prepared by a chemical binding process and contain no moisture when the metal is poured.

The production of other types of molds, such as dry sand molds, pit molds, and permanent molds, is described in Appendix A. Another type of mold, the chemically bonded mold, is produced in the same manner as the chemically bonded cores described below.

As with molds, cores are produced by a variety of processes. The traditional method uses oil and cereal binders to maintain the core shape. In this method sand, core oil, and cereal are mixed; the core is shaped; and finally, the core is baked in an oven to solidify it. The oil/core oven method is being replaced by chemically bonded sand processes. These processes work through thermal setting (hot box and shell core systems) or through catalytic reactions (cold box or no-bake processes). These methods are described in detail in Appendix A.

The metallics, coke, and fluxing materials are removed from storage and prepared for charging to the furnace. Coke and fluxing agents undergo minimal processing prior to charging. The amount of metal processed is dependent upon the type of scrap received and the type of melting furnace used. If the scrap received by the foundry is too large to be charged to the furnace, the size is reduced by breaking, abrasive cutting, or torch cutting. Unless an electric induction furnace is used, sizing is the only preparation needed. If an electric induction furnace is used as the primary melting unit, however, the scrap must be clean and dry, or explosions will result. Acceptable scrap is obtained by purchasing high quality scrap and storing it in an enclosed area or by preheating the scrap before it is charged to the induction furnace.

The melting area is the most visible area in the foundry. All melt shops will include a melting furnace and some type of process for pouring the molten iron into a mold and subsequent cooling of the casting. In addition, some foundries have duplexing furnaces (primarily associated with malleable iron) and inoculation stations (associated with ductile iron).

Four types of furnaces are used as primary melting units in ferrous foundries. Currently 75% of all molten iron is produced in cupola furnaces, 17% in electric arc furnaces, 7% in electric induction furnaces, and 1% in other types of furnaces such as gas- or oil-fired reverberatory furnaces. These four types of furnaces are described in Appendix A. Diagrams of these furnaces can be found in Figures A-6 through A-10.

Each of the four types of furnaces receives scrap metal and heats the metal until desired physical and chemical properties are achieved. After the melt is completed, the metal is tapped from the furnace into a hot metal transfer ladle. The metal may then be transferred to a holding furnace, a duplexing furnace, an inoculation station, or directly to the pouring station. In some foundries the metal is transferred to a mixing ladle or forehearth before going to the pouring ladle.

A holding furnace is an electric arc or an electric induction furnace which is used to maintain the metal in the proper condition until the foundry is ready to pour. A duplexing furnace is an electric furnace which is used in malleable iron production to increase the temperature of the metal in the absence of slag. Duplexing is necessary when a cupola is used as the primary melting unit. Iron inoculation is the addition of magnesium (or other inoculants) to gray iron to produce ductile iron. It is generally accomplished in the ladle by one of several methods described in Appendix A (see Figure A-11).

After the above steps have been completed, the molten metal is ready to be poured into the mold. The pouring method used is dependent upon the type of mold, the size of the casting, and the degree of mechanization in the foundry. Various types include permanent mold pouring; floor pouring, in which the ladles are moved to stationary molds; and pouring stations, in which the ladle is held at one place and the molds are moved to the station on conveyors. After pouring is completed, the mold and casting are cooled until the casting is ready for removal from the mold.

The final processing area is cleaning and finishing the casting in preparation for shipping. Cleaning and finishing are accomplished in several steps by a variety of methods. The first step is to remove the casting from the mold. If a sand mold is used, this process is termed shakeout. Shakeout is accomplished in a variety of ways, but the most typical is the use of a vibrating or rotating screen to remove the sand from the castings. The castings are then sorted, and the sprues, gates, and risers are removed. Depending upon the type and size of casting, this may be accomplished through impaction, abrasive cutting, band cutting, or torch cutoff (including air-carbon-arc cutting). After the appendages have been removed, the surface is cleaned by processes such as shot and sand blasting, tumbling, and various types of grinding. Finally, especially with malleable iron and steel, the casting is heat treated and final forming is completed before shipping.

The final area of operation which can be found in all foundries that use some type of sand molding is the sand-handling system. Sand handling comprises a number of transfer and conditioning operations which vary significantly among foundries. The most important processes from the standpoint of compliance are those involving the return sand between the shakeout and the sand mixer or muller. In a mechanized foundry transfer is generally accomplished by conveyor. In smaller, less mechanized foundries much of the sand transfer may be accomplished manually and by front-end loader.

In reviewing the above description of the ferrous foundry relative to compliance with air pollution regulations, it is important to note a "typical" ferrous foundry does not exist. Any given foundry consists of a sequence of unit operations which can be accomplished in a variety of ways. Thus, an agency charged with monitoring the compliance of ferrous foundries should be familiar with the available operations, the relative impact of these operations on air quality, and the limitations in the application of different methods of operation.

It is not within the scope of this study to provide detailed descriptions of every available iron foundry process. But some additional detail is provided in Appendix A. For the reader who desires further information about foundries in general or more details about specific processes, excellent information can be found in References 1 to 9.

4.2 IDENTIFICATION AND CHARACTERIZATION OF EMISSIONS SOURCES

The characteristics and quantity of emissions from the various processes are apparent factors which affect the compliance of ferrous foundries. This section describes those characteristics of emissions sources which can affect a foundry's compliance with various regulations. The major characteristics examined include the types of pollutants emitted by the source, the type of emissions source, e.g., ducted or stack, process fugitive, or open fugitive, and emissions stream properties, such as temperature and moisture that have an effect on the controllability of the source. Emissions quantities are discussed in Section 4.3.

Each of the processes described in Section 4.1 is a potential source of gaseous or particulate emissions. Gaseous pollutants emitted from foundries include carbon monoxide (CO), gaseous hydrocarbons or volatile organic compounds (VOC), and limited quantities of sulfur dioxide (SO_2). Major constitutents of the particulate emissions are fine metallic fume from the molten metal, silica dust from the core and mold sand, metallic oxide, organic particulates, and general dust. Table 4-1 presents a detailed listing of all the foundry operations which are potential emissions points.

Obviously not all the sources listed in Table 4-1 will present a compliance problem at any particular foundry; many are generally minor emissions sources. However, depending on the type of operation, degree of control, attainment status of the area surrounding the foundry, and regulations applicable to the foundry, each of these sources may affect the compliance of some foundries. The number and variety of sources also highlight the complex problem of developing compliance strategies for foundries.

Another characteristic that affects foundry compliance is the nature of the source. Foundry emissions sources can be classified as one of three types: ducted or stack sources, process fugitive sources, and open fugitive

TABLE 4-1. POTENTIAL SOURCES OF EMISSIONS IN FERROUS FOUNDRIES

	Gaseous			Particulate				
	CO	VOC	SO_2	Metal fume	Silica dust	Smoke	Coarse metals	Other dust
Raw material receiving and storage								
Scrap storage								
Transfer to/from pile							X	X
Wind erosion								X
Coke/limestone storage								
Transfer to storage								X
Sand receiving								
Manual or mechanical transfer					X			
Mold and core preparation								
Mixing (mulling)								
Charge to muller					X			X
Dry mixing					X			X
Sand molding					X			X
Shell or hot box core or mold								
Charge shell machine					X			X
Heating	X	X				X		
Cooling pallet		X						
Cold box								
Introduce catalyst		X						
Air sweep		X						
No-bake	X	X						
Oven bake	X	X						
Core washing								
Apply wash	X	X						
Burn off	X	X				X		
Charge preparation								
Metal screening							X	X
Coke screening								X
Sizing								
Abrasive cutting								X
Torch cutting							X	
Preheating	X	X				X		
Melting and casting								
Cupola furnace								
Charging	X	X			X	X	X	X
Melting	X		X	X		X	X	X
Tapping	X							

TABLE 4-1 (continued)

	Gaseous			Particulate				
	CO	VOC	SO_2	Metal fume	Silica dust	Smoke	Coarse metals	Other dust
Electric arc furnace								
Charging						X		X
Melting	X			X				
Oxygen lancing	X			X				
Tapping	X			X				
Electric induction furnace				X				
Ductile iron inoculation				X				
Pouring and cooling	X	X		X		X		
Cleaning and finishing								
Vibrating conveyor to shakeout		X			X	X		
Shakeout		X			X	X		
Appendage removal								
Impact					X			X
Abrasive cutting					X		X	X
Torch removal				X	X	X		
Carbon-air-arc				X				
Surface cleaning								
Abrasive blast					X		X	X
Grinding					X		X	X
Heat treating	X		X				X	X
Painting or coating		X						
Sand-handling system								
All conveyor transfer					X			
Magnetic separator					X			
Aerator					X			
Screening					X			
Reclaimer					X			
Waste disposal								
Sand handling					X			X
Baghouse catch removal					X		X	X
Landfill								
Transfer					X		X	X
Erosion					X		X	X

sources. A ducted emissions source is one in which the emissions are confined within the processing equipment and are released to the atmosphere only through a well-defined duct or stack. Cupola melting is an example of a ducted emissions source. Process fugitive emissions are emitted directly from a particular process to the foundry environment. These emissions reach the atmosphere through windows, doors, wall vents, and roof monitors. To control these emissions some type of capture mechanism must be used to confine the emissions stream to a duct. Iron pouring and electric arc furnaces are examples of process fugitive emissions sources. An open fugitive emissions source is one which is not associated with a particular piece of processing equipment, e.g., storage piles and road dust. Dust generated from movement of equipment on dusty foundry floors can also be considered an open source.

Emissions stream properties, particularly those for fugitive sources, also impact on the compliance status of the foundry. Some of the properties which have the greatest impact are the temperature, moisture content, and flow variations in the gas stream.

For a fugitive source the chance of emissions reaching the atmosphere is directly related to the temperature. Those particles emitted at ambient temperature have a greater chance of settling in the foundry than those released in a bouyant plume. In addition, highly bouyant plumes are difficult to capture.

Moisture content and the variation in gas stream flow also impact on the controllability of an emissions stream. Higher moisture systems are more difficult to control and can cause corrosion problems with control equipment. Ease of control is also dependent on the variation in gas stream flow. A continuous emissions stream can be controlled more easily and much more economically than an intermittent stream. In addition, the determination of compliance status is much easier for a continuous stream than for an intermittent stream.

Table 4-2 characterizes each of the emissions sources identified in Table 4-1 with respect to type of source, temperature, moisture content, and flow variability (both frequency and location). The information in Table 4-2 represents a "best estimate" based on literature review and a limited number of foundry visits; as such, some characteristics may differ for a similar operation at a particular foundry.

4.3 QUANTIFICATION OF FOUNDRY EMISSIONS

The primary goal of this study was to provide an overview of ferrous foundry compliance problems. Given the broad scope of the study, it was not feasible to perform a detailed quantification for each of the sources and pollutants listed in Table 4-1. Since initial contacts with state agencies indicated that their primary concern was particulate emissions, and since earlier studies by MRI indicated that gaseous emissions data are scarce, this study focused only on particulate emissions.

TABLE 4-2. POTENTIAL SOURCES OF EMISSIONS IN FERROUS FOUNDRIES

	Type of source	Temperature	Moisture content	Flow Variability
Raw material receiving and storage				
Scrap storage				
Transfer to/from pile	OF[a]	Ambient	Low	I[b]
Wind erosion	OF	Ambient	Low	I
Coke/limestone storage				
Transfer to storage	OF	Ambient	Low	I
Sand receiving				
Manual or mechanical transfer	S	Ambient	Low	I
Pneumatic transfer	S	Ambient	Low	I
Mold and core preparation				
Mixing (mulling)				
Charge to muller	PF[c]	Ambient	High	I
Dry mixing	PF	Ambient	Low	I
Sand molding	PF	Ambient	73%	I
Shell or hot box core or mold				
Charge shell machine	PF	Ambient	Low	I
Heating	PF	350-450°F	Low	
Cooling pallet	PF	Near ambient	Low	C[d]
Cold box				
Introduce catalyst	S[e]	Ambient	Low	I
Air sweep	S	Ambient	Low	I
No-bake	PF	Ambient	Low	I
Oven bake	S	400°F	Low	C
Core washing	PF	Ambient	Low	SC
Apply wash	PF	Ambient	Low	SC
Dry wash	PP	Ambient	Low	I
Burn off	PP	Above ambient	Low	I
Charge preparation				
Metal screening	PF	Ambient	Low	I
Coke screening	PF	Ambient	Low	I
Sizing				
Abrasive cutting	PF	Ambient	Low	I,M[f]
Torch cutting	PF	High	Low	I,M
Carbon-air-arcing	PP	High	Low	I
Preheating	PF or S	200-1200°F	Low	I
Melting and casting				
Cupola furnace				
Charging	PF	High	Low	I
Melting	S	1400-1500°F	Low	I or C
Tapping	PF	2600-2650°F	Low	I or C

TABLE 4-2 (continued)

	Type of source	Temperature	Moisture content	Flow variability
Electric arc furnace				
Charging	PF	High	Low	I
Melting	PF	High	Low	I or C
Oxygen lancing	PF	High	Low	I
Tapping	PF	High	Low	I
Electric induction furnace	PF	High	Low	I
Ductile iron inoculation	PF	High	Low	I
Pouring and cooling	PF	Moderately High	High	I,M
Cleaning and finishing				
Vibrating conveyor to shakeout	PF	Above ambient	High	I or C
Shakeout	PF	Above ambient	High	I or C
Appendage removal				
Impact	PF	Ambient	Low	I
Abrasive cutting	PF	Ambient	Low	I,M
Torch removal	PF	High	Low	I,M
Surface cleaning				
Abrasive blast	PF	Ambient	Low	C
Grinding	PF	Ambient	Low	I or C
Heat treating	S	High	Low	C
Painting or coating	PF	Ambient	Low	I
Sand-handling system				
All conveyor transfer	PF	Near ambient	Moderate	C
Magnetic separator	PF	Near ambient	Moderate	C
Aerator	PF	Ambient	Moderate	C
Screening	PF	Ambient	Moderate	C
Reclaimer	PF	Ambient	Moderate	C
Waste disposal				
Sand handling	OF	Ambient	Low	I
Baghouse catch removal	OF	Ambient	Low	I
Landfill				
Transfer	OF	Ambient	Low	I,M
Erosion	OF	Ambient	Low	I

a OF - Open fugitive
b I - Intermittent
c PF - Process fugitive
d C - Continuous
e S - Stack
f M - Moveable

In order to further limit the scope with respect to emissions quantification, control technology analysis, and regulatory analysis, initial effort was directed toward identifying these particulate sources which had the greatest emissions potential. Data which had previously been compiled were used to determine emission factors for most particulate emissions sources.[1,10-21] These emission factors were then applied to annual production rates (based on data in Wallace and Cowherd[10]) to estimate the total annual emissions. The results are shown in Table 4-3. The data indicate that the following sources have the greatest potential impact on the environment: (a) cupola; (b) electric arc furnace; (c) pouring and cooling; and (d) shakeout. Other sources that might possibly have a significant impact are the cleaning room (grinding, blasting, and cutting) and the sand system. Each of these sources was considered in detail, and the results are summarized below. Further analysis of emissions data for these sources is presented in Appendix B.

4.3.1 Cupola Emissions

The cupola is the one source of foundry emissions for which extensive data are available. These data indicate that emissions from cupolas vary widely (3.8 to 75.5 lb/ton) and suggest that these variations are due, at least in part, to different design and operating parameters of cupolas. Some of the parameters which have been shown to affect cupola emissions are specific blast rate, blast temperature, melt rate, and in some cases, the coke-to-melt ratio. In some cases, the effects of these parameters have been quantified (see Appendix B).

Two observations from the data in Appendix B are of particular significance when evaluating and enforcing compliance of cupola furnaces. First, the variations in cupola emission factors has a dual impact on enforcement. The wide range of emission factors makes the use of an average emission factor to enforce a process weight regulation questionable. On the other hand, the measured relationship between foundry emissions and operating characteristics can be an enforcement tool. If measured emissions data and associated operating characteristics are available for a particular cupola, control agency personnel can estimate the effect of changes in its operating characteristics on its emissions and in that way make an initial determination of any change in compliance status.

Another observation which may be particularly useful for small foundries is the result of testing at Foundry A shown in Table B-7 in the appendix. At this foundry screening of the scrap and careful handling to prevent charging of loose sand, rust, and coke fines resulted in a 50% reduction in emissions. This practice may be an economically feasible way of reducing emissions in smaller foundries where fabric filter system costs make the system economically infeasible.

The development and installation over the past 10 years of the divided blast cupola is a technological step which has the potential to decrease cupola energy use and emissions. This system, described in Appendix A, has been shown to significantly reduce coke consumption. It is quite likely that the decreased coke consumption will result in lower emissions per ton of iron produced. However, no data are available which quantify this reduction.

TABLE 4-3. PARTICULATE EMISSIONS FROM IRON FOUNDRIES

Emissions source	Source extent tons/yr	Emission factor: Range lb/ton	Emission factor: Best lb/ton	Annual emissions: Range tons/yr	Annual emissions: Best 10^4 tons/yr	Reliability
I. Furnace charge preparation						
Coke storage (outdoor)	4.5×10^6	-	0.02 lb/ton coke	-	0.0045	D
Scrap storage (outdoor)	3.18×10^7	-	0.1 lb/ton scrap	-	0.159	D
Preheating						
Bottom fired	-	0.942-1.47 lb/ton scrap	1.26 } 0.8			B
Top fired } General }	2.32×10^6	0.34-0.53 lb/ton scrap	0.41 } 0.8	139 - 1,705	0.0928	B
General		0.12 lb/ton melt				E
II. Core and mold preparation						
Molding (nobake cont. mixer)	2.43×10^7	-	0.05 lb/ton melt	-	0.608	E
Mulling	2.43×10^7	0.3-2.1 lb/ton melt	1.5 lb/ton melt	0.35-2.6	1.82	E
III. Melting and casting						
Cupola						
Coke fired	2.47×10^7	4.8-66.3 lb/ton metal	20	5.93×10^4 - 8.19×10^5	24.7	A
Cokeless	-	1.28-1.8	1.5	-		B
Electric arc furnace	5.55×10^6	4.0-40	14	1.11×10^4 - 1.11×10^5	3.88	A
Induction furnace	2.21×10^6	0.12-1.5	1.0	133 - 1,660	0.11	B
Reverberatory furnace	5.62×10^5	1.49-2.72	2.1	419 - 764	0.0509	B
Inoculation	4.92×10^6	1.25-12 lb/ton metal treated	2.5	3.08×10^3 - 2.95×10^4	0.615	C
Pouring and cooling	2.43×10^7	0.55-8.3 lb/ton metal cast	6	6.68×10^3 - 1.01×10^5	7.29	B
IV. Cleaning and finishing						
Shakeout	2.43×10^7	3.15-14.1 lb/ton cast	10	3.83×10^4 - 1.71×10^5	12.2	B
Shot blast	2.03×10^7	-	3.1 lb/ton melt	-	3.14	E
Grinding	1.52×10^7	-	0.32 lb/ton melt	-	0.243	E
V. Sand handling						
Conveyor/transfer	-	0.04 lb/ton/transfer	0.04	-	-	D
Dry sand handling	2.43×10^7	-	1.03 lb/ton melt	-	1.25	E
Screening	2.43×10^7	-	1.0 lb/ton melt	-	1.22	E
Drying/reclamation	2.43×10^7	-	0.3 lb/ton melt	-	0.364	E

A - Data are from emissions tests on several full-size operations.
B - Data are from emissions tests at a single full-size operation or tests at pilot or bench scale operations.
C - Engineering estimate based on material balances or stoiciomentric estimates.
D - Engineering estimate based on test data from a similar operation.
E - Method of determination unknown.

4.3.2 Electric Arc Furnace Emissions

Emissions data for the electric arc furnace (EAF) are much more limited than the data for cupolas. It appears that little effort has been made to relate emissions data to EAF operating characteristics. Data compiled during an earlier Environmental Protection Agency (EPA) study indicate that EAF emissions range from 4 to 40 lb/ton with an average of 13.8 lb/ton.[1] All other data identified during this study fall within this range.

Available data indicate that EAF emissions are related to scrap quality and cleanliness. Data presented in Appendix B show increases in emissions of 30 to 100% when dirty or low quality scrap is used. Observations of industry personnel and from past plant visits indicate that visible emissions from charging increase appreciably when dirty, particularly oily, scrap is charged to the furnace.

Limited data (see Appendix B) also indicate that the practice of oxygen lancing in steel foundries also has an impact on EAF emissions. The data indicate that gas temperature, gas flow rate, particulate loading, and CO emissions increase during lancing. These factors are important considerations in the sizing of steel foundry EAF control equipment.

4.3.3 Pouring and Cooling Emissions

The emissions generated from pouring and cooling castings have generally not been considered to be a problem either by foundry personnel or air pollution control agencies. However, limited test data indicate that if sand molds are used, pouring and cooling operations may be a significant source of particulate emissions. Test data show that pouring emissions range from 0.6 to 24 lb/ton of iron poured with an average of about 6 to 10 lb/ton of iron poured. This level is particularly important because most operations are not controlled and may be difficult to control as described in Section 5.0.

Foundry personnel report that the quantity of pouring and cooling emissions is probably related to such factors as mold size, mold composition, sand-to-metal ratio, pouring temperature, and pouring rate. Test data are not sufficient, however, to quantify the effects of these parameters on emissions.

It should be noted that the estimates of emissions are based on limited test data, and some of the data were obtained from pilot scale operations. It is suggested that these data are not sufficiently reliable to use for enforcement purposes.

4.3.4 Shakeout Emissions

The removal of castings from a sand mold releases moisture that has been trapped in the mold, dust from the sand and binders which have dried during pouring, and products of thermal decomposition of the chemical binders as they are exposed to air. Available emissions test data range from 0.17

to 18 lb/ton of iron castings with an average of about 3 lb/ton of iron castings. Limited data indicate the wide variation in the emissions may result from variations in such parameters as sand to metal ratio, length of cooling time prior to shakeout, size of casting, and number of cores in the casting.

4.3.5 Cleaning Room Emissions

As reported in Section 4.1, cleaning room emissions are generated by a number of operations. Available data are not sufficient to quantify emissions from most of these operations, and available data are certainly not sufficient to determine the effect of operating and design parameters on emissions quantities.

The only available cleaning room test data are for sand and shot-blasting operations. These data indicate that uncontrolled emissions range from 27 to 500 lb/ton of castings cleaned, and several tests show emissions in the range of 250 to 400 lb/ton of castings cleaned. It should be noted, however, that most of these emissions were controlled at the 98 to 99+% level.

Limited engineering estimates are available for emissions from grinding wheels. These data indicate that emissions in the range 1.6 to 15 lb/ton of castings cleaned are generated from grinding wheels.

4.3.6 Sand-Handling Emissions

Sand handling, like cleaning, has a number of unit operations which generate particulate emissions, but test data are not sufficient to quantify emissions from these unit operations. Limited test data indicate that emissions from the sand-handling system (starting at the point the sand leaves the shakeout and eanding when it enters the muller) range from 0.6 to 50 lb/ton of sand handled. Given this wide range and the limited quantity of data, it is not possible to estimate an average.

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5.0 EMISSIONS CONTROL TECHNOLOGY

The development and application of emissions control technology for control of foundry emissions is complicated by the wide variance in operations among foundries, the number of emission points within any particular foundry, and the differences in pollutants and gas stream characteristics of these sources. This study was motivated in part by reports that the above factors have resulted in significant technical problems associated with installation of air pollution control equipment at foundries.

The examination of these problems was directed toward two specific objectives. The first was to determine the type of technical problems associated with design or operation of control equipment. The second was to investigate exemplary control systems which had successfully alleviated these problems.

The above objectives were accomplished through five basic activities. First, selected state and local agencies having a number of foundries in their jurisdiction were contacted by Midwest Research Institute (MRI) to obtain information on the types of problems associated with control equipment in ferrous foundries and to identify foundries which had a record of continual compliance. Concurrently, a thorough literature search was initiated, and control device manufacturers were contacted to obtain data on foundry controls. The foundries that were identified by the state and local agencies were contacted by telephone to obtain design and operating data for their control systems. Finally, a limited number of foundries appearing to have the best systems for continual emissions reduction were visited.

It became apparent early in the study that the scope was not sufficient for a detailed analysis of all sources and pollutants. Based on initial contacts with state and local agencies, it was decided to limit the analysis to particulate controls only. The study was further limited to the five operations (see Section 4.0) having the greatest impact: (a) cupola melting; (b) electric arc furnace melting; (c) pouring and cooling; (d) shakeout and sand handling; and (e) the cleaning room.

The review of foundry control technology resulted in the following conclusions:

1. Adequate control technology is available for most foundry emissions sources. The major exceptions are pouring and cooling emissions, emissions from carbon-air-arcing operations and some grinding operations.

2. Concerns of the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) about

the internal foundry sources which result in worker exposure to contaminants as well as fugitive emissions from the foundry have led to the development and implementation of improved capture systems for these sources.

3. Malfunction of control equipment is cited as a major problem by both control agency and foundry personnel.

4. Reduction of malfunctions is possible through improved operation and maintenance procedures and proper equipment design.

The remainder of this section presents the data that form the basis for the above conclusions. The discussion is divided into three parts. The first is a general overview of foundry emissions control. The second summarizes the status of emissions control systems with respect to availability and, when possible, extent of application. (More detailed descriptions of the available control systems are presented in Appendix C.) The final section identifies some of the major malfunction problems that were identified by control agency and foundry personnel and describes some of the design features and maintenance procedures employed by some foundries to reduce malfunctions.

5.1 FOUNDRY EMISSIONS CONTROL

The principal components of an effective emissions control strategy are availability of an effective control system, installation of the control system and operation and maintenance of the system in a manner which ensures continued compliance. The paragraphs below summarize the status of foundry controls with respect to each of these components.

Before discussing the availability of foundry control systems, it is helpful to describe briefly the components of a "typical" foundry control system. The components of the control system depend upon the nature of the emissions source. For a stack or ducted emissions source, the control system consists of a particulate removal device (generally referred to as an air pollution control device) and possibly some type of gas conditioning equipment positioned ahead of the removal device. The primary removal devices used in foundries are wet scrubbers, and fabric filters.

The control system for a fugitive emissions source consists of a capture device which contains the particulate and exhausts it to a duct where it is then collected by a removal device. Some type of gas stream conditioning may also be used with fugitive emissions sources. The primary capture devices are hoods, either close capture or canopy, and enclosures. The removal devices are the same as those for stack sources.

One alternative to the fugitive source control system is preventive measure to reduce or eliminate the generation of emissions. One example might be water sprays at sand conveyor transfer points or the use of the Schumacher system (see Section 5.2.2.2) to inhibit dust generation. Another method for either stack or fugitive sources is to replace one process with another that is less polluting. Other examples are the use of in-mold rather than ladle inoculation of ductile iron and the replacement of a cupola with an induction furnace.

Data from the literature review, industry personnel, and air pollution control agencies indicate that for many foundry particulate sources, both stack and fugitive control systems are available. There are some operations for which, depending on the type of casting (e.g., shakeout of a pit mold) or size of the foundry (e.g., manual sand handling in a small foundry), emission control systems may not be technically feasible and are very expensive. For a limited number of sources, control systems are not available.

The extent of installation of available emissions control systems depends on several factors. The first and most obvious is the size and degree of mechanization of the foundry. Larger foundries and those that are more mechanized tend to have more operations that are controlled and also tend to have a higher level of control. A second factor, especially among small to medium sized foundries, is management attitude. During telephone contacts and plant visits, MRI found that some foundry managers considered the installation of an acceptable level of emissions control to be part of corporate responsibility. Other managers, however, considered air pollution control systems to have an unwanted adverse impact on production. The former shops generally had better overall control. Another factor in the degree of application of emissions control systems is the regulatory stance of local air pollution control officials. MRI visited one foundry which, as a result of aggressive enforcement by the local agency, had installed a well-designed fabric filter system on a cupola. A foundry of similar size in the same state but under the jurisdiction of another agency less than 50 miles away was still operating with an uncontrolled cupola stack.

Both air pollution control agencies and industry personnel indicate that the greatest foundry compliance problem is the malfunction of air pollution control equipment. This is sometimes the result of poorly designed equipment, but more often it is the result of improper operation and maintenance either through lack of knowledge or limited resources.

The following section provides in some detail the available data on control system availability and application. Section 5.3 discusses malfunctions operation and maintenance.

5.2 AVAILABILITY AND EXTENT OF INSTALLATION OF EMISSIONS CONTROL EQUIPMENT

Information from control agency and industry personnel and the literature indicate that adequate control technology is generally available for both stack and fugitive emissions sources in foundries. The discussion below briefly summarizes available control systems for the major foundry emissions sources identified in Section 4.3. More detailed descriptions of these control systems can be found in Appendix C. The discussion is divided into two sections. The first describes melting furnace control, and the second control of all other fugitive emissions sources.

5.2.1 Melting Furnace Controls

MRI examined control technology for two melting furnaces, the cupola and the electric arc furnace (EAF). Cupola control systems generally consist of a wetcap or a system comprising an afterburner, a gas cooler, and a venturi scrubber or fabric filter. The EAF control system consists of a capture device and a particulate collection device.

5.2.1.1 Cupola Controls--

The particulate collection devices most frequently used on cupolas are wetcaps, venturi scrubbers, and fabric filters. Wetcaps which may be either single or double are low efficiency scrubbers which can still be found on some smaller cupolas in nonmetropolitan areas. The wetcap is installed in the cupola stack above the charging door. Flow through the wetcap is maintained by the draft of the cupola without the use of auxiliary fans. The wetcap is effective in controlling the large particles generated from loose dust and sand in the charge but is ineffective in controlling fine particles. In general, single wetcaps control about 50% of the total particulate while double wetcaps control about 85%. A diagram of a wet cap is shown in Figure B-1 (Appendix B).

If a fabric filter or venturi scrubber is used for particulate collection, the typical control system includes an afterburner, a gas cooler, the collection device, and a fan. The afterburner, usually located in the cupola stack above the charging door or just before the gas takeoff duct, is used to oxidize the carbon monoxide and to burn tars and oils. The oxidation of these compounds prevents explosions in the control system and reduces the potential for plugging that can occur in some control systems. The afterburner raises the temperature of the gas stream to about 1200 to 1400°F, which is too high for operation of either a scrubber or a fabric filter. Cooling of the gas stream can be accomplished in one of three ways: evaporative cooling, dilution cooling, or radiant cooling. Evaporative cooling, or quench cooling with water sprays used to cool the gas stream is preferred by most foundries. However, some foundries that have cooler gas streams from other processes that can be mixed with the cupola gas stream use dilution cooling. A few foundries may use a long duct system to obtain radiant cooling. However, a more common form of radiant cooling is the indirect heat exchanger where the heated air is used for cupola blast air. Some systems may have a combination of two of these cooling methods. A fan, which may be located either in front of or behind the collector, is needed to overcome the pressure drop across the collector.

As indicated above the two particulate collection devices most commonly used with ferrous foundry cupolas are fabric filters and venturi scrubbers. Davis et.al.[1] indicate that fabric filters are used more frequently in small and medium sized cupolas while scrubbers are commonly found in larger cupolas. Detailed descriptions of both devices are included in Appendix C. The paragraphs below describe some of the design features identified during the study as factors that might affect on compliance status, such as ease of monitoring and equipment performance and condition.

The major design features that may affect fabric filter compliance are filter material, cleaning method, fan location, and air-to-cloth ratio. Some type of glass or Teflon is usually chosen as the bag material because of the high temperature of the cupola gas stream. These fabrics can withstand temperatures continuously in the 450 to 500°F range and maximum temperatures of about 550°F. The literature does indicate that if fluorspar is used in the charge, the resultant fluorides in the emissions stream will destroy glass fibers.[2] Under these conditions Nomex or Teflon bags or Teflon-coated bags should be used.

Information compiled during the study indicates that both reverse air (including pulse) and mechanical shaker mechanisms are being used for cleaning cupola filters. No particular advantages were identified for any particular cleaning mechanism. However, at least one small foundry, which melts only 3 h/day, did indicate that they have improved bag life by going to daily inspections coupled with manual shaking rather than automatic mechanical shaking.

Typical air-to-cloth ratios for metallurgical furnaces are in the range of 1.5 to 2.5:1, and the air to cloth ratio for a cupola filter should fall in this range. The American Foundrymen's Society (AFS) suggests that the ratio should be 2:1 with the gas volume based on the maximum design volume that occurs during burndown (the end of the heat).

Both positive and negative pressure fabric filters were used on foundry cupola systems. Both appear to operate with equal effectiveness, and neither type system is inherently better. Positive pressure baghouses have the advantage of lower capital cost, greater ease of inspection and maintenance of the bags, and reduced fan noise. Negative pressure baghouses generally have less fan wear and maintenance as well as lower operating costs.

Two other design features were identified during the study which impact on the wear of the bags and the baghouse. First, it is essential that fabric filters be well insulated, especially those located in northern climates. If not, condensation in the baghouse is likely, and the corrosive nature of the condensate will result in early deterioration of both the bags and the housing. Second, it is important to have a mechanism whereby the gas stream bypasses the baghouse if the inlet temperature is above 550°F. The best designs identified during the study have a double fail-safe system. A temperature sensor immediately downstream from the primary cooler controlls a dilution air damper. If the gases leaving the cooler are too hot, the damper opens providing ambient dilution air for cooling. Another temperature sensor is located between the dilution air damper and the baghouse inlet. If the temperature at this sensor is above 525°F, the damper to the baghouse inlet closes and a bypass damper to the atmosphere opens. In addition, an alarm sounds to alert the operator to the problem. One foundry visited installed this type system 2 years ago and has had no problems with bag burnout and has had minimal time in the bypass mode. Since this same system is well insulated, they have also had no corrosion problems and have had extremely good bag life.

Two types of venturi scrubbers are used frequently for cupola control, the typical venturi tube with cross current water introduction and a fixed throat and the variable throat flooded disc scrubber. For both types of scrubbers, the primary design parameters which affect compliance are pressure drop across the scrubber and the material of construction.

It is well established that the fractional efficiency of any wet scrubber is strongly related to the pressure drop across the scrubber. Data in

Appendix B show that the cupola emits significant quantities of fine particulate. Thus, a relatively high pressure drop is needed to effectively control cupola emissions. AFS indicates that scrubber pressure drops of 60 to 90 in H_2O are necessary to attain grain loadings of 0.02 to 0.03 gr/scf.[2] The higher pressure drops are needed for dirty or oily scrap.

Because the emissions from the cupola tend to result in highly corrosive substances in the wet scrubber, choice of construction materials is important. Both the literature and the foundries contacted during the study say that it is imperative that the venturi throat, spray nozzles, and the separator be constructed of stainless steel if maintenance problems are to be avoided. In addition it is suggested that the fan housing be epoxy coated and the fan blade be constructed of stainless steel. It has also been suggested that less efficient self-cleaning paddle wheel fans are often used because they are easily maintained. Foundries contacted that used the materials suggested above had experienced minimal maintenance difficulty.

Information gathered from contacts with control agencies and foundries strongly suggest that the systems with the designs described above can achieve initial compliance with the existing regulations. To achieve continued compliance, further operation and maintenance procedures are available (Section 5.3)

5.2.1.2 Electric Arc Furnace Controls--

Emissions from the electric arc furnace (EAF) are particularly difficult to control since at least some of the emissions are fugitive, i.e., they do not necessarily enter the atmosphere from a well defined duct or stack. As such the emissions control system comprises a capture mechanism to contain the emissions stream and a particulate collection device. The paragraphs below describe the various capture mechanisms that may be used by EAFs. These descriptions are followed by a discussion of particulate collection devices.

Three distinct emissions streams are generated by the various phases of the EAF melt cycle: melting and refining, charging, and tapping. The capture device is generally designed to contain one or more of the streams. Charging and tapping emissions are often captured by one system and the melting and refining by a different system. Melting and refining capture systems are described below, followed by a discussion of charging and tapping systems.

EAF melting and refining emissions are generally controlled by one of three systems: roof hoods; side draft hoods; or direct furnace (or shell) evacuation. Each of the systems controls emissions during melting but does not operate when the roof is removed for charging or during tapping. Two other systems, the furnace enclosure and the close capture hood, have been used on a limited basis. These systems capture charging and tapping emissions as well as melting and refining emissions. These five systems are described briefly below and in more detail in Appendix C. Diagrams of the systems are shown in Figures C-10 through C-16. Typical flow rates and capture efficiencies for each are shown in Table 5-1.

TABLE 5-1. TYPICAL EXHAUST FLOW RATES AND EMISSION CAPTURE EFFICIENCY OF MELTING CONTROL SYSTEMS

	Typical exhaust flow rate for model furnaces, in ft^3/min			Emission capture efficiency (percent)	
	Furnace size				
	4 ton/h	10 ton/h	25 ton/h	Range	Typical maximum
Roof hood	16,300	25,200	63,600	95-100	99
Side draft hood	27,500	60,000	150,000	90-100	99
Direct evacuation	7,000	18,000	45,000	90-100	99
Furnace enclosure	17,000	25,000	60,000	80-100	99
Close capture hood	27,500	42,000	106,000	90-100	99

Source: Electric Arc Furnaces in Ferrous Foundries - Background Information for Proposed Standards (Rough Draft). U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. April 1980, pp. 4-32.

A typical roof hood is mounted directly on the furnace and pulls air through the annular openings around the furnace electrodes. The roof hood is the most effective device for capturing EAF emissions. It has the additional advantage of muffling noise. Its major disadvantages are stress on the furnace roof and supports due to the substantial weight of the hoods and difficulty encountered in maintaining furnace roofs.

The side draft hood is also mounted on the furnace roof but is open on the top and on one side to allow free movement of the electrodes. Since the side draft hood collects emissions after they have escaped from the furnace through the annular openings around the electrodes, it requires greater air volume and is sometimes slightly less efficient than the roof hood. However, the side draft hood is easier to retrofit than the roof hood, places less stress on the roof and supports, and allows easier maintenance of the furnace roof.

Direct furnace (or shell) evacuation is often called fourth hole evacuation because it collects gases from the furnace through a fourth hole in the roof. A heat resistant elbow is mounted above this ventilation hole through which the gases from the furnace are pulled into a duct. This evacuation system provides good emission control and minimizes both the space required on the furnace roof and the gas volume which must be withdrawn. Disadvantages are that the ingress of air to the furnace, although slight, cools the slag, makes control of the temperature difficult, and reduces the carbon level in the melt through formation of carbon monoxide.[3] It has also been suggested that direct evacuation is not applicable to small furnaces because of lack of space for a fourth hole, pressure fluctuations in the furnace which are too rapid for the automatic control dampers and deterioration of the shell refractory because of excess weight on the furnace roof.

A furnace enclosure is a metal shell which completely encloses the furnace and tapping area. It captures emissions from charging, tapping, and melting. The major advantage of this system is that emissions from all phases of the melt cycle are captured. Although there is some speculation that the system may inhibit operations of the charging or tapping cranes, one steel plant using the system has encountered no problems. Only two installations in the United States currently use total enclosure systems. More experience at both facilities is needed before the system can be fully evaluated.

The close capture hood is a collection of hoods connected to an exhaust plenum. Dampers allow the system to regulate the exhaust volume to the appropriate hoods during different phases of the melt cycle. Melting and refining emissions are captured by a rectangular hood which surrounds the electrodes, acting much like a side draft hood. Capture of charging emissions is accomplished by an annular ring hood which has slots on the inside that collect the fumes during charging. Tapping emissions are evacuated through an inverted U-shaped hood that covers the tapping spout.

The advantage of the close capture design is that control of charging and tapping is provided at an exhaust flow rate much less than the flow rate for canopy hoods or furnace enclosures. This significantly reduces the quantity of exhaust gas delivered to the particulate control device, thus cutting costs of gas cleaning. Also, the close capture hoods are simpler and considerably less expensive to install than a furnace enclosure or canopy hood. The disadvantage is that complete control of charging and tapping may not always be provided because the charge/tap hoods do not completely enclose emission sources.[3]

In addition to the furnace enclosure and close capture hooding just described, four techniques are available for capturing charging and tapping emissions. They are: (a) canopy hoods; (b) building evacuation; (c) bay evacuation; and (d) ladle pit enclosure. The exhaust volumes and capture efficiencies of all six systems are shown in Table 5-2.

Canopy hoods are the capture mechanism most frequently employed to collect charging emissions. The canopy hood is suspended at a sufficient height above the furnace to allow clearance for the crane, or it is attached to the foundry roof. If the furnace has a melting emission capture system, the hood is operated only during charging and tapping.

Effective capture of emissions is not always attained by the use of a canopy hood. As the furnace is charged, emissions are sometimes diverted away from the canopy because of impingement on overhead cranes and the charge bucket. Another problem is caused by cross drafts in the shop which lower canopy hood collection efficiency. Upward flow of the emission plume from the furnace is easily disrupted by drafts from openings along foundry walls and doors, passage of shop vehicles, temperature gradients within the shop, and even suction hoods which may ventilate other nearby foundry processes. A canopy hood is not generally as effective for small furnaces because there is less thermal uplift generated. Meteorological conditions may also influence the plume conditions. High pressure systems and low humidity tend to

TABLE 5-2. TYPICAL EXHAUST FLOW RATES AND EMISSION CAPTURE EFFICIENCY OF CHARGING AND TAPPING CONTROL DEVICES AT MODEL FOUNDRIES

	Typical exhaust flow rate for model furnaces in ft^3/min — Model furnace size			Emission capture efficiency (percent)	
	4 ton/h	10 ton/h	25 ton/h	Range	Typical maximum
Canopy hoods, charge and tap[a]	138,000	155,100	171,600	15-90	80
Building evacuation, charge and tap	171,600	193,900	214,000	95-100	99
Furnace enclosure charge				50-80	80
furnace enclosure tap	17,000	25,000	60,000	80-95	90
Close capture hoods, charge and tap	27,500	42,000	106,000	60-90	80[b]
Ladle pit enclosure, tap only	27,500	42,000	106,000	80-100	99

Source: Electric Arc Furnaces in Ferrous Foundires - Background Information for Proposed Standards (Rough Draft). U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. April 1980. pp. 4-7.

a Collection efficiency substantially reduced if cross drafts are present in shop.

b Capture efficiency for tapping operations considerably reduced with increasing alloy additions to ladle; i.e., at steel furnaces.

allow efficient upward flow of the plume to the canopy. However, during periods of low pressure, high humidity, and/or strong winds, thermal uplift may not be sufficient to carry fumes directly into the canopy.[3]

Some iron foundries capture charging and tapping emissions by evacuating the complete melt shop. Since building evacuation systems require greater air flow than do canopy hoods, they are generally used only if the building is not structurally suited for canopy hoods or if there is also a need to collect fugitive emissions from other sources.

A recent modification to the building evacuation system is the bay evacuation system, which is in limited use in foreign steel mills. In the bay evacuation system, each separate shop bay, or furnace area, is isolated from the others by walls with closed doors. A canopy hood is then placed at the top of the bay. While no foundries in the United States have employed this system, it is anticipated that it may eliminate the problems associated with cross drafts that occur when canopy hoods or building evacuation are used.

One steel mill in the United States uses a tapping pit enclosure to capture emissions from EAF tapping. In this system the ladle is placed in the pit with a standard overhead crane. The crane is retracted and a moveable cover seals the pit. Hot metal flows through a closed launder to the ladle, and air is exhausted from the enclosure. This system, which visibly appears to control emissions well, could easily be designed into a new melt shop. However, structural limitations, primarily space around the pit, may limit its retrofit applicability.

The systems described above are considered to be effective in capturing EAF melting emissions; in many cases charging and tapping emissions can also be captured. However, more experience with capture systems for charging and tapping is needed before these systems can be said to assure compliance.

The particulate collection device used with virtually all domestic EAFs is the fabric filter. Industry data indicate that both positive and negative pressure units are used. Newer installations tend to be positive pressure units because of lower capital costs and simpler inspection procedures for detecting damaged bags.[4] Information collected during the study indicates that EAF fabric filters perform satisfactorily and that no major design problems have been identified.

5.2.2 Other Fugitive Emissions Sources

Control systems for the two melting furnaces described above are well developed and have been applied to foundries of all sizes and locations. Such a high degree of availability and application is not found for the other fugitive emissions sources in the foundry, however. This lack of control results in part from two factors. First, unlike melting operations, other foundry processes which produce fugitive emissions vary considerably between foundries. These variations are dependent on a number of factors including foundry size, degree of mechanization, type of product, and size of casting produced. As a result of these process differences, the development of uniform or standard control measures is not possible. A second reason identified during the study is the lack of concern about fugitive emissions on the part of both foundries and many state agencies. Since fugitive emissions from foundries are not perceived to be a major problem, little research or regulatory effort has been directed toward their control.

While fugitive emission controls are not as well developed as melting controls, some fugitive control can be found at almost all foundries. Current control is in part a result of OSHA and state health department pressure to maintain a clean internal environment and in part results from a commitment on the part of many foundries and the American Foundrymen's Society over the last 40 years in developing adequate foundry ventilation systems.

For this study three major areas which contribute to fugitive emissions were examined: (a) pouring and cooling; (b) shakeout and sandhandling; and (c) the cleaning room. The sections below briefly describe the control systems that are available for these three sources. More detailed descriptions can be found in Appendix C. The sections describe alternate processes which reduce the emission of particulate as well as capture/particulate removal combinations which can be used on traditional installations.

5.2.2.1 Pouring and Cooling Controls--

Control systems for pouring and cooling operations are the least developed of all controls in ferrous foundries because of the large volumes of air and low pollutant concentrations. During the course of this study no well controlled pouring and cooling installations were identified even though a significant number of foundry personnel, control agencies, and equipment manufacturers were contacted. However, some systems of limited effectiveness were identified. The paragraphs below describe some of the problems that have inhibited the development of controls for pouring and cooling emissions. In addition the limited controls that are available are described.

If sand molds are used, most pouring operations are one of three types. For large castings, pit molds are often used. These molds are not moveable and the ladles must be moved to the mold. Pouring occurs at a relatively stationary point but in a large area. In small jobbing foundries, floor pouring is generally used. In these foundries molds are placed on the floor in a large room. The ladle is then moved to the molds by overhead conveyor, and the casting is poured and cooled on the floor. In more mechanized foundries producing small to medium sized castings, pouring occurs at a defined station. In this case the ladle is placed in a stationary position (or along a line) and the molds are moved to the ladle by conveyor or rail. After the pouring is complete, the molds move along the conveyor or rail through a cooling line or cooling tunnel. The control problems and control availability are dependent upon the type of pouring operation.

For pit molds, no known capture system exists. Because of the size of the operations, localized hoods cannot be used. On the other hand, canopy hoods or building evacuation are considered not economically feasible and in all likelihood would not provide a high degree of control. Because the thermal rise of pouring emissions is significantly less than the thermal rise of melting emissions, the volumes necessary for control would be cost prohibitive and might well result in such low inlet grain loadings that particulate collection devices would have little effectiveness.

Capture mechanisms for floor pouring operations are limited. Some small nonferrous foundries have installed moveable localized hoods that are attached to the pouring ladle to capture hazardous metal fumes. These ladle hoods are described in Appendix C (see Figure C-19). Based on observations during earlier plant visits, the hooding system visibly appears to control emissions during pouring. In addition, the concentration is sufficiently high to allow good control in a fabric filter. However, the system is limited in that it only controls emissions during pouring. Even small ferrous castings continue to smoke for up to half an hour; and as the data in Appendix B indicate, about 50% of the emissions occur during this cooling period. While systems have been used in nonferrous foundries, no ferrous foundries were identified which use a pouring hood such as the one described above. Because of the differences in emissions from pouring of ferrous and nonferrous castings, this system probably has limited usefulness in ferrous foundries.

The greatest degree of control of pouring and cooling emissions is possible when mechanized pouring lines are used. Several commercial pouring hoods such as those described in Appendix C (Figure C-17) are available. The most effective of these systems use a push/pull air flow which blows air over the top of the molds to contain the emissions and draws the emissions stream to the back of the hood. These pouring hoods are usually coupled with an enclosed cooling tunnel which also exhausts the emissions stream. Data from the literature and from foundry personnel indicate that these systems have been applied to several foundries and that they effectively capture pouring emissions. However, the emphasis of these controls was on the in-plant environment, and no foundries were identified which use a particulate collection device with the pouring hood. Some foundry personnel indicated that particulate collection may be quite expensive with these capture systems.

One alternative that is available to some foundries is the use of permanent molds rather than green sand molds. Permanent molds, made of metal or graphite emit almost no particulate during pouring and cooling. However, current technology for permanent molds is limited with respect to the size of castings that can be produced and is only economical if at least 2,000 copies of the same casting are needed.[5]

5.2.2.2 Shakeout and Sand Handling Controls--

Because of the internal environmental problems caused by the silica dust emissions from shakeout and sand handling, the capture mechanisms for these sources are well developed and have been installed in most foundries. The few exceptions are the nonmechanized jobbing foundries which often perform shakeout and sand handling manually. Since the emissions from sand handling can be quite extensive, most of the installed capture systems are connected to particulate collection devices. The paragraphs below briefly describe the capture systems used on shakeout and sand handling and the associated particulate collection devices. The last paragraph describes an alternative sand handling system which can be used to reduce emissions from the process.

Three types of hoods are used to capture emissions from shakeout: total enclosure, side draft, and double side draft (see Figures C-19, C-20, and C-21). If the size of casting permits, the preferred capture method is to enclose the shakeout operation with openings for the mold to enter and the casting to exit. Details on flow rates and design parameters are given in Appendix C. Based on visual observations during plant visits, a properly operating enclosure is nearly 100% effective in capturing the shakeout emissions.

If the size of a casting or the foundry operating characteristics do not permit the use of an enclosure, side draft or double side draft hoods can be used to capture shakeout emissions. Because the emissions from the plume are somewhat buoyant, the side draft hood is most effective if it is placed at an angle above and to one side of the operation. The double side draft hoods should be placed as closely as practical on either side of the shakeout grate.[6] The two side draft hoods observed during the study were not effective in capturing the emissions stream. In both cases it appeared that the hoods were too small and did not extend far enough above the shakeout. However, Kane suggests that a properly operating side draft hood captures 90% of the emissions.[7]

Both low energy wet scrubbers (8- to 10-in. pressure drop) and fabric filters are used to collect the particulate from shakeout. Because the emissions stream often has a high moisture content, the scrubber is more frequently used. No particular design problems were identified for either control system. However, if a fabric filter is used, it is suggested that it be well insulated to avoid condensation and bag blinding.

Once the sand leaves the shakeout hopper, a portion of the sand that was near the mold/metal interface is dry, and there is a high potential for dust emissions. It is essential for reduction of emissions in both the internal and external environment that the handling and transfer operations be hooded as well as possible. Hooding systems for the various operations are well defined and widely implemented and are not described here. As with shakeout emissions, particulate emissions from sand handling may be collected in either a fabric filter or a low energy scrubber.

An alternative concept (U.S. Patent No. 3,461,941) has been developed which has the potential to control fugitive dust emissions from most sand handling operations other than shakeout by reducing rather than capturing emissions. The process is called the Schumacher Sand Process System. The normal sand-to-metal ratio in a green sand foundry is between 5 and 7:1. The Schumacher process uses a sand processed to metal ratio of 20:1. This is the quantity of sand put through the muller. However, the extra sand is not used to produce molds, but is diverted to an inundator. Here the hot dry sand taken off the shakeout is mixed with the moist sand from the muller to produce a moist cool sand. This sand is then taken through the normal sand handling processes. However, the now moist sand presents no emissions problems.

No problems with either the design or operation of control equipment for shakeout and sand handling were identified during the study by either foundry or control agency personnel. Thus, there is no evidence to suggest that these operations should have an uncorrectable adverse effect on foundry compliance.

5.2.2.3 Cleaning Room Controls--

As with shakeout and sand handling, no control agency or foundry personnel identified the cleaning room as a compliance problem. In addition, the limited data suggest that emissions from the cleaning room are less significant than those from the other sources. As a result of these considerations, no effort was made to obtain any information on the cleaning room controls that was not readily available in the literature. The limited information that was obtained is summarized in Appendix C and is not repeated here.

The one factor regarding cleaning room controls that may impact on future foundry compliance is the increased concern about the industrial health hazards of the cleaning room. These concerns are likely to result in pressure on foundries to improve their cleaning room capture and ventilation systems. However, since many of the particles generated in the cleaning room are relatively coarse, control should not present a problem.

5.3 MALFUNCTION OF CONTROL EQUIPMENT

The major control problem identified by state agencies and confirmed by foundry personnel is the malfunction of control equipment, particularly cupola control systems. As a result of these concerns, effort was made to identify the problems which led to the malfunctions and to examine possible ways to reduce the incidence of malfunction. MRI efforts were directed primarily toward cupola controls, although some of the findings are applicable to other control systems.

Based on a number of telephone contacts with foundry personnel and a limited number of plant visits, MRI concludes that extensive malfunctions of cupola controls are avoidable. They are a result of improper design and, more frequently, of improper operation and maintenance of the control equipment. Section 5.2.1.1 described some of the design considerations that have an impact on malfunctions; this section describes operation and maintenance practices that can help reduce the incidence of malfunction.

The discussion is divided into three sections. The first two cover proper operation and maintenance of wet scrubbers and fabric filters. Material is summarized that was compiled in a previous Environmental Protection Agency (EPA) study of operation and maintenance of control devices for iron and steel processes.[9] More detailed information from this EPA study is included in Appendix D. While these procedures were not developed specifically for the cupola, they were developed for processes with similar emissions stream characteristics and are applicable. The third section summarizes the information obtained from those foundries experiencing a low incidence of malfunctions.

5.3.1 Operation and Maintenance of Venturi Scrubbers

The typical scrubber system associated with ferrous foundry cupolas consists of a gas prequencher to reduce the temperature of the cupola exhaust, a flooded disc or fixed throat venturi scrubber, a mist eliminator with sump, recirculation pumps, and an induced draft fan. Each of these components can be a source of malfunctions; however, the main problems identified during the study were fan bearing and wiring failure, feedwater nozzle plugging, and corrosion and erosion of the venturi throat and mist eliminator. It appears that proper operation and maintenance of the scrubber can reduce the occurrence of these problems. The sections below describe typical operating procedures that can be used during startup, normal operation, and shut down and some routine maintenance procedures that can be used to improve equipment performance.

5.3.1.1 Operating Procedures--

Before initial startup, all major equipment including fan, pumps, control and safety systems, connecting pipes, and utility feed systems should be inspected and cleaned. All fluid flow systems should be checked for leaks and instabilities, and an initial water test should be run on newly installed systems to ensure that all items, particularly monitoring instruments and the control safety system, are operating properly. After the preoperational checks are completed, the system can be started using procedures outlined in the designer's operating manual. Typical startup procedures and preoperational checks are included in Appendix D.

During normal operation, the operator should monitor the system to ensure that control variables such as pressure drop, recycle pump rate, makeup water rate, slurry density and purge rate, and sump level are operating within prescribed ranges. An alarm system should be used to notify the operator of abnormal conditions. An interlock system that can be operated both automatically and manually to open a bypass and shut down the scrubber in cases of major failure should be available.

After a melt is complete, the system is shut down again using the procedures described in the operator's manual. In particular, care should be taken to flush and drain water lines and slurry lines to reduce the possibilities of corrosion and plugging. More complete shutdown procedures are covered in Appendix D.

5.3.1.2 Inspection and Maintenance During Normal Operation--

Many items checked before operation should be inspected during routine maintenance; this generally includes unplugging lines, nozzles, pumps, etc.; replacement of worn equipment parts, erosion/corrosion prevention liners, and instruments (level indicators, density indicators, etc.); and repairing damaged components (when practical from the standpoint of labor and materials). In addition, the crossover duct between the cupola stack and cupola should be checked for wear and corrosion and fan mufflers should be checked on a weekly basis.

Table 5-3 indicates the manpower requirements for maintenance due to scaling and plugging for both the wet approach and liquid injection venturi scrubbers.

TABLE 5-3. MAINTENANCE FOR PLUGGING AND SCALING VENTURI SCRUBBER (From interview with P. Wechselblatt, Chemico)

Type of venturi scrubber	Type of problem: Plugging — Mechanical cleaners	Plugging — Cylinder cleaners	Scaling — Chemical cleaning	Scaling — Hand cleaning
Wet approach	1 man/shift/mo	1 man/shift/mo	3 men/shift/wk	1 man/shift/wk
Liquid injection	1 man/shift/mo	1 man/shift/mo	3 men/shift/wk	1 man/shift/wk

Source: Szabo, M., and R. W. Gerstle. Operation and Maintenance of Particulate Control Devices on Selected Steel and Ferroalloy Processes. EPA-60012-78-037. U. S. Environmental Protection Agency, Research Triangle Park, North Carolina. March 1978.

Table 5-4 lists maintenance requirements for two ranges of pressures and various lining materials and gas characteristics. This table should be useful in the selection of scrubber liners or venturi units for the various iron and steel applications, including iron foundry cupolas and sand system scrubbers.

The incidence of malfunction can be reduced by periodically checking the system and performing the necessary preventive maintenance. Major items which should be checked are scaling, corrosion and erosion of all internal surfaces, nozzle plugging or erosion, improper operation of the mist eliminators, fan balance and power requirements, and instrumentation. A proper inventory of spare parts should also be maintained to allow quick correction of problems identified during the check. A more detailed inspection checklist and spare parts inventory are included in Appendix D.

5.3.2 Operation and Maintenance of Fabric Filters

The typical fabric filter control system applied to a ferrous foundry cupola consists of a cooling mechanism, usually a prequencher, to cool the gas stream to about 450°F, the fabric filter (or baghouse) including its cleaning mechanism, a fan which may be either upstream or downstream from the baghouse, and a dust removal system to handle the captured dust. As with the scrubber system, each of the components of the fabric filter system is subject to breakdowns which can lead to a malfunction of the entire system and excessive emissions from the cupola. Proper operation and maintenance of the system will reduce the frequency of the malfunctions to low levels (in some cases 1 to 2% of the operating schedule).

This section describes operation and maintenance procedures for the fan, fabric filter, and dust removal systems. The section is divided into three parts: (a) preoperational checks and startup; (b) shutdown; and (c) maintenance during normal operation.

TABLE 5-4. SCRUBBER MAINTENANCE
(From Interview with P. Wechselblatt, Chemico)

Type of liner	Pressure drop > 30" ΔP: Life cycle, years	Pressure drop > 30" ΔP: Repair time	Pressure drop < 30" ΔP: Life cycle, years	Pressure drop < 30" ΔP: Repair time	Gas characteristics: Corrosive	Gas characteristics: Abrasive	Gas characteristics: Corrosive and abrasive	Comments
Ceramic								
Silicon carbide	3-4	2 men/wk	10	2 men/wk	Poor	Excellent	Good (mildly corrosive)	
Cement	1	2 men/wk	4	2 men/wk	Poor	Poor	Good (mildly corrosive)	
Rubber	1	2 men/2 wk	5	2 men/2 wk	Excellent	Good	Good	For cutting type particles for erosive but not sharp particles.
Rubber	5	2 men/2 wk	10	2 men/2 wk	Excellent	Good	Good	
Plastic			Indefinite	1 day				Patchable lining.
Steels								
Carbon	2-6	Patchable	6	Patchable	Poor	Fair	Fair	Good for chlorides.
316	2-6	Patchable	6	Patchable	Excellent (arid)	Fair	Fair-good	Not good on chlorides.
304	2-6	Patchable	6	Patchable	Good (arid)	Fair	Good	Except for SO_3 and Cl^-.
Inconel 625	2-6	Patchable	6	Patchable	Good	Good	Good	
Hastoloy	2-6	Patchable	6	Patchable	Excellent	Good	Good	

Source: Szabo, M., and R. W. Gerstle. Operation and Maintenance of Particulate Control Devices on Selected Steel and Ferroalloy Processes. EPA-60012-78-037. U. S. Environmental Protection Agency, Research Triangle Park, North Carolina. March 1978.

5.3.2.1 Preoperational Checks and Startup--

Once started, the operation of a fabric filter system is often completely automatic. However, preoperational checks, startup, and shutdown are critical. As with the scrubber, fabric filter operational problems can often be avoided with a detailed preoperational check. This check should ensure that the bag cleaning mechanism (air line or shaker) and dust removal system are operating properly. Bag installation should be checked and the baghouse compartments cleaned. Finally, all control instrumentation should be checked. A more detailed complete checklist is included in Appendix D.

At the first startup of the system, and also whenever new bags have been installed by the maintenance crew, the bags should be checked after a few hours of operation for correct tension, leaks, and expected pressure differential. Initial temperature changes or the cleaning cycle can pull a bag loose or burst it. It is wise to record at least the basic instrument readings on new bags during this startup period for ready reference and comparison during later startups.[10]

During any startup, transients in the dust-generating process and surges to the filter house are probable and ought to be anticipated. Unexpected temperature, pressure, or moisture has often badly damaged a new installation. In particular, running almost any indoor air or combustion gases into a cold filter can cause condensation on the walls and cloth, leading to blinding and corrosion. Condensation in the filterhouse, in fact, may void the manufacturer's guarantee. Condensation can be avoided by preheating the filter or the gas.[10] Another problem associated with cool baghouses is sulfate condensation. Some of the sulfur in the coke is emitted from the cupola as gaseous sulfate. This sulfate condenses at 320°F to 350°F and reacts with water vapor in the gas stream to form "acid dew." This "acid dew" can result in both bag blinding and rapid corrosion of metal surfaces. Since most cupolas operate on an intermittent basis, it is necessary to heat the cupola gases above the water and sulfate dewpoint in a bypass mode during each startup. The filter can then be brought on line.

5.3.2.2 Shutdown--

The main precaution in shutting down the filter system is prevention of moisture in the filterhouse. Condensation can occur due to cooling of gases containing moisture, particularly combustion gases, if they are not completely purged from the filter system and replaced with drier air before the filter cools down. This can also happen with air at ambient moisture levels if the filter is in a colder location. To prevent condensation, the systems should be purged carefully on shutdown and then sealed off completely. Alternately, a flow of warm air can continue to pass through the filter during the shutdown, which also helps prevent condensation when the system is started up again. A shutdown procedure is summarized below:

1. After the process has been stopped and emissions have ceased, allow baghouse to track through one complete cleaning cycle; this will purge system of process gas and collected dust.

2. Stop main fans.

3. Stop separate reverse air fan if used.

4. Allow material removal system to operate for 1 h or until system is purged of collected material. This is imperative for a fabric filter on a shakeout as the combination of moisture and binders may result in bag blinding or hopper plugging if the systems not cleaned prior to shutdown.

5.3.2.3 Maintenance During Normal Operation--

Maintenance of fabric filters in the iron and steel industry centers around the bags and the moving mechanical parts in the hostile interior of the baghouse (i.e., dampers, screw conveyors, and shaker linkages). The same maintenance procedures can be applied to baghouses operating on electric arc furnaces or cupolas in ferrous foundries.

Plant personnel must learn to recognize the symptoms that indicate potential problems in their fabric filter, determine the cause of the problem, and remedy it either by in-plant action or by contact with the manufacturer or another outside resource.

For example, high pressure drop across the system is one symptom for which there could be many causes, e.g., difficulties with the bag cleaning mechanism, low compressed-air pressure, weak shaking action, or loose bag tension. Many other factors can cause excessive pressure drop, and several options are usually available for corrective action appropriate to each cause. Thus, the ability to locate and correct malfunctioning baghouse components is important and requires a thorough understanding of the system. A detailed list of troubleshooting and corrective measures is given in Appendix D.

Table 5-5 presents the frequency of failure of basic fabric filter parts, including the frequency of inspection, the inspection time, and the time required for repairs.

Some of the major fabric filter components requiring routine maintenance and the problems frequently encountered include:

- Inlet ducting - abrasion, corrosion, and plugging of the duct.
- Blast gate and flow control - Hydraulic system failures and bad seals.
- Fans - Wear from corrosion or abrasion, balance, and bearing failure.
- Hoppers - Plugging caused by caking or bridging of dust.
- Bags - Collar wear, poor tension, burnout.
- Shaker mechanism - Bearing failure, improper amplitude or frequency.
- Reverse air mechanism - Line blockage from moisture.

Maintenance procedures for these components are described in Appendix D.

TABLE 5-5. BAGHOUSE COLLECTOR MAINTENANCE

Item	Frequency of breakdown	Frequency of inspection	Time required to perform inspection	Time to repair	Type of[d] person to repair	Comments
INSIDE BAG COLLECTION						
Bags						
5 in. ϕ 14 ft	Monthly	Monthly	1.5-3 man-h/100 bags[a]	10-30 min/bag[b]	Laborer[c]	Complete replacement
8 in. ϕ 22 ft	Monthly	Monthly	2-4 man-h/100 bags[a]	15-45 min/bag[b]	c	2 years same
12 in. ϕ 30 ft	Monthly	Monthly	2.5-5 man-h/100 bags[a]	20-60 min/bag[b]	c	Same
Door seals	2-4 yr	Monthly	5 min/door	1 h/door	c	
Cleaning mechanism						
Shaker	6 mo	Monthly	5 min/row	30 min/row	Maint. man	
Reverse air	2 yr	Monthly	15 min	2 hours	Maint. man	
Dust removal system						
Screw conveyors	1-2 yr	6 mo	1 hour	2-4 hours	Maint. man	
Air locks	1-2 yr	6 mo	30 min	1-2 hours	Maint. man	
Pneumatic	2-3 yr	6 mo	1 hour	8 hours	Maint. man	
Baffle plate	4 yr	1 yr	30 min	8 hours	Maint. man	
Damper valves	2-3 yr	Monthly	15 min/valve	1-24 hours	Maint. man	
OUTSIDE BAG COLLECTION						
All bags	Monthly	Monthly	0.6 man-h/100 bags	6-10 min/bag	Laborer	Assume top bag removal
Cleaning mechanism						
Pulse jet	2 yr	Monthly	2 min/row	30 min	Maint. man	
Pulsing plenum	2 yr	Monthly	2 min/row	1 hour	Maint. man	

(continued)

TABLE 5-5. (concluded)

Item	Frequency of breakdown	Frequency of inspection	Time required to perform inspection	Time to repair	Type of person to repair	Comments
Door seals	2-4 yr	Monthly	5 min/door	1 h/door	Laborer	
Dust removal system						
Screw conveyors	1-2 yr	6 mo	1 h	2-4 h	Maint. man	
Air locks	1-2 yr	6 mo	30 min	1-2 h	Maint. man	
Pneumatic	2-3 yr	6 mo	1 h	8 h	Maint. man	
Baffle plates	4 yr	1 yr	30 min	8 h	Maint. man	
Damper valves	2-3 yr	Monthly	15 min/valve	1-24 h	Maint. Man	

Source: Szabo, M. and R. W. Gerstle. Operation and Maintenance of Particulate Control Devices on Selected Steel and Ferroalloy Processes. EPA-60012-78-037. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. March 1978.

a 1.5 man-h/bag for 24 inch reach, 3.0 man-h/100 bags for 36 inch reach (time may be cut by 70% if rejection of fluorescent particles and black light are used).

b Low value is total changeout/bag and high value is individual bag change.

c Three-man crew minimum.

d Some industry personnel have suggested that all of these operations should be performed by maintenance men rather than laborers.

5.4 FOUNDRY EXPERIENCE WITH OPERATION AND MAINTENANCE OF CONTROL EQUIPMENT

Since most state agencies and some industry personnel indicated that malfunction of control equipment was the major foundry control problem, one facet of this study was to contact well-controlled foundries to identify the types of procedures they used to minimize malfunctions. In order to identify exemplary foundries, 13 state and local agencies were contacted. These agencies identified 36 foundries that had exemplary control. Of these 36 foundries, 30 were contacted by telephone and six which appeared to have well-developed operation and maintenance programs were visited.

This section summarizes the results of these contacts. The section is divided into three parts. The first part presents an overview of the results of the survey. The next two parts describe practices at two plants which have had particularly good success in avoiding malfunctions.

5.4.1 Conclusions of the Foundry Survey

A limited number of foundries were contacted for this survey and a wide variety of responses were obtained. Therefore, it was not possible to develop general conclusions about technology availability, equipment design problems, or equipment maintenance procedures. (For example, the number of hours spent on preventive maintenance ranged from 0 to 160 h/week.) The discussion that follows is a digest of the information gathered from these foundries.

- The majority of foundries disclaimed the need for improved technology. However, the following concerns were addressed: (a) a need for more data on the possibilities of combining gas streams from two processes (e.g., hot cupola gases with cool shakeout gases) in a single collector; and (b) a need for a cupola control system that would allow heat recovery for space heating. This same concern has been raised related to the use of heat in captured fugitive streams.

- Malfunctions of control equipment are frequently a result of lack of training of operators in the proper operation and maintenance, or the inability to motivate workers to properly operate and maintain the equipment, rather than the result of inherent problems in the process or control equipment system.

- Generally, larger foundries practices greater surveillance of the control system during operation and do more preventive maintenance. However, one of the best operated and maintained cupola control systems identified during the study was at a small jobbing foundry that only melts 3 h/day.

- At least one foundry contacted considers the operation and maintenance requirements of the equipment in comparison to the capability of foundry personnel as a factor in choosing both the control equipment and equipment supplier.

- Maintenance procedures usually evolve in-house and make use of initial input from control device suppliers. The degree of follow-up help varies widely among different suppliers. Maintenance people are generally trained on-the-job although some larger companies with multiple facilities have their own training centers and some obtain help from the Cast Metals Institute.

• The sources of malfunctions frequently identified are: (a) plugged water spray nozzles on both wet scrubbers and evaporative coolers; (b) bag blowout and overheating; (c) fan bearing failure; and (d) corrosion of the throat and mist eliminator. Each of these problems can be minimized with the proper design, operation, and maintenance of the control equipment.

• Some of the features at the foundries visited during the study which might be incorporated to minimize malfunctions are: (a) automatic air dilution and filter by-pass controls to avoid bag overheating; (b) periodic check of all fan motors with an amprobe to detect possible failures; (c) periodic calibration of monitoring and control instrumentation; (d) daily check of bag hoppers and weekly to biweekly internal checks of bag condition; (e) periodic cleaning of quencher spray nozzles; and (f) post-startup and shutdown procedures in operating room similar to those described in Appendix D. It is apparent that the practices in these foundries include many of the elements described in 5.1 and 5.2.

• Most contacts indicated that stainless steel parts in the scrubber throat, mist eliminator, and fan are essential if malfunctions are to be minimized.

The results presented in the above paragraphs lead to the following conclusions:

1. Malfunction of control equipment can be minimized (to as little as 1 to 2%) through proper operation and maintenance.

2. Training of personnel is a prerequisite to proper operation and maintenance.

3. Such training is available through some vendors and, if not available from the vendor, can be supplied by the Cast Metals Institute. The foundry should consider the cost of such training as a part of the cost of the control equipment package.

These conclusions (especially item 1) are supported by information presented in the following sections. These sections describe successful operation and maintenance practices at two foundries of different types. The first is a small jobbing foundry which has a cupola with a fabric filter that operates 3 h/day. The second is a large production foundry, again with a cupola and fabric filter.

5.4.2 Operation and Maintenance on Cupola and Shakeout Controls at a Small Jobbing Foundry

One of the six foundries visited was a small jobbing foundry that produces primarily grates and manhole covers for streets. Although the foundry was the smallest and least mechanized that was visited during the study, the preventive maintenance program for the control equipment was more extensive than at any of the other foundries. The paragraphs below describe the foundry control equipment and operation and maintenance procedures.

The shakeout had a side draft hood which vented to a pulse-jet fabric filter. Based on visual observations during the visit, the hood adequately captured the dust from the shakeout; no emissions were visible from the exhaust. The system was designed with an easily accessible manometer and pulse indicator to allow frequent monitoring. Key elements of the maintenance protocol include these steps:

- Pressure drop, fan, and rotor lock are checked daily.

- Bags are checked and manually cleaned every 3 weeks.

- The bags are pulsed manually each morning before system startup to eliminate blinding.

- The only spare part inventoried is a spare motor for the screw conveyor which has caused problems in the past. One-hour service is available on the fan motor.

The muller has a shaker-type fabric filter. There were no visible emissions at either the muller or the stack. The maintenance protocol was similar to that on the shakeout.

The control system for the cupola included an evaporative chamber for gas cooling and a Pangborn shaker-type fabric filter. The system design was conducive to good preventive maintenance with easily accessible monitoring instrumentation and a double backup system for the evaporative cooler to avoid overheating of the bags. Features of the system which aid in preventive maintenance include:

- Automatic temperature-controlled damper which admits dilution air to the exhaust stream if the evaporative cooler exhaust is above 450°F.

- Automatic temperature-controlled damper system which results in bypass of the fabric filter if inlet gas temperature is too high.

- Pressure and temperature guages located inside the foundry in a control room for easy monitoring.

- A flow meter on the evaporative cooler water line located in the control room. A booster pump is used to increase flow in case water pressure on the city line drops.

The maintenance foreman monitors the cupola emission control system continuously during melting to ensure proper operation of the equipment. The foreman can manually operate the dampers and booster pump described above. In addition, a rigorous preventive maintenance program is followed to ensure continual compliance. Features of the maintenance program include:

- Startup procedures include heating of the system and manual shaking of all bags before melt each day.

- Fan and grease bearings are checked daily before start of melt. Fan is checked periodically during melt.

- Honeywell calibrates electrical controls and monitoring devices once every 3 months.

- Nozzles in the spray chamber are cleaned monthly.

- Bags are checked for leakage once every 2 weeks by injecting agricultural lime into the exhaust duct 30 ft upstream of the fabric filter inlet.

The foreman agreed that the procedures described above are expensive. However, he felt that the procedures are cost effective from the standpoint of equipment life and minimized downtime. During the time the system has been in operation (about 2 years) the only downtime was caused by a frozen air line which locked the inlet to the fabric filter closed for two shifts. This is judged to be important as the company is fined $150 per day when operating with the filter down. The procedures have also resulted in excellent bag wear with the lifetime expected to be 2-1/2 to 3 years.

The foreman did indicate that they have had problems with shrinkage of the Nomex bags; some bags have shrunk as much as 5 to 6 in.

5.4.3 Operation and Maintenance on a Cupola Fabric Filter at a Large Foundry

Another foundry visited was a medium- to large-sized foundry which melts on one shift at the rate of 30 ton/h. In contrast to the foundry described above, this foundry tended to react to problems rather than to spend time on preventive maintenance. However, the process and control system is carefully monitored, and maintenance is performed quickly to limit downtime to about 1-1/2%. The paragraphs below describe the control equipment and monitoring practices at this foundry.

The effluent stream from the cupola passes through a conical bottom chamber, gas-fired afterburners, air/air heat exchanger, two water prequenchers and into the baghouse. The heat exchanger heats ambient air to approximately 900°F at 11,000 CFM, which is recycled to the cupola for hot blast. No space heating is attempted. The water lines to prequenchers are equipped with filters to avoid plugging the nozzles. The cupola gas stream enters the baghouse at approximately 500°F and is filtered through fiberglass bags. Bags are replaced as needed (approximately five bags/week) and can be changed with the system on-line by shutting off a given baghouse segment. Mechanical shakers clean the bags approximately every 3 minutes.

The control room consists of two large panels. One panel is a schematic flow diagram for the system showing the location of numbered thermocouples. The second panel consists of a circular chart recorder for flow rate, a selector switch and digital readout for the thermocouples, and a bank of lights, each labeled with a given operation segment. In the event of trouble, a warning buzzer sounds and the appropriate light flashes to indicate the source of the problem. Amp meters for the various motors are also displayed on the panel, which is under constant surveillance by the operator.

The system is designed in such a manner that both broken bags and malfunctioning nozzles can be changed with the system on-line if a malfunction occurs.

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6.0 STATE AND LOCAL AIR POLLUTION CONTROL REGULATIONS AND IMPLEMENTATION POLICIES

An important aspect of an analysis of factors affecting compliance of ferrous foundries is the identification of applicable regulatory strategies. These include both legal requirements and enforcement policies; as they related intrinisically to the structure of those state and local agencies with major enforcement responsibility for foundries. One subtask of this study comprised an analysis of both the regulations available to state and local agencies and the implementation policies of these agencies.

This subtask was directed to two specific objectives: (a) the identification of state and local regulations that establish emissions limitations for ferrous foundries (in particular particulate emission limitations for cupolas, electric are furnaces, pouring and cooling operations, and shakeout and sand handling); and (b) the identification of state and local implementation policies with specific reference to enforcement problems and solutions used by enforcement officials in applying regulations. These objectives were addressed through three basic activities: a survey of relevant regulations for all states and selected local agencies; a simultaneous telephone survey of agency personnel assigned implementation responsibility for those regulations; and a subsequent analytical phase to identify how agencies actually apply regulations to ferrous foundry processes, areas that agencies perceive to be problems in apllying the regulations, and solutions to these problems.

The results of these activities are summarized in four sections. The first section identifies the regulations that are available and the degree to which they are applied. The second section is a brief discussion of the strengths and weaknesses of these regulations. The third section identifies some major problem areas and, when possible, describes solutions identified by some agencies for these problems. The final section presents some issues raised by the surveys which deserve further study. Each of these topics is discussed in greater detail in Appendix E.

The data presented below should be examined and used with some caution, as they result from single telephone contacts with agency personnel. The conclusions presented in these sections are based on the authors analyses of the data compiled during these contacts and were not tested through further contacts with either control agency or foundry personnel.

6.1 REGULATIONS APPLIED TO PARTICULATE EMISSIONS FROM FOUNDRY PROCESSES

Two distinct aspects of emissions control must be addressed by state and local regulations applied to ferrous foundries. First, the regulations must result in the installation of appropriate control equipment on foundry emissions sources. Second, the regulations must be capable of ensuring operation of the installed equipment in a manner that results in continued compliance. In general, agencies surveyed felt that regulations were adequate and had been used sufficiently to require the installation of all necessary control equipment. Statements about the status of foundries with respect to continued compliance were not as positive. Several states identified malfunction of foundry control equipment as a major regulatory problem.

State and local regulations used to require installation and operation of controls for ferrous foundries vary widely both from state to state and within states. Factors such as foundry location, type of process, foundry size, date of startup, available legal structure, and previous experience with the public, the foundry industry, and the court systems all influence the choice of regulation.

The four general types of regulations used to control emissions from foundry processes which are surveyed during the study are mass emission, visible emission, fugitive emission, and nuisance-related regulations. Other important regulations identified during the study but not surveyed are the malfunction regulation operation and maintenance (O&M) regulations, and operating permit regulations. These regulations may be used individually or in combination to ensure appropriate control of foundry emissions.

The paragraphs below briefly describe each of the major types of regulations. These descriptions are followed by a summary of the availability of the regulations surveyed to the states and the degree to which the states apply the regulations. More detail is provided in Appendix E.2.

Mass emissions regulations specify the quantity of particulate that can be emitted from a foundry process or group of processes. As such they allow for the relatively precise prediction of particulate emission necessary for the calculation of air quality impact and, thus, are valuable in the development of (SIPs) for the attainment and maintenance of National Ambient Air Quality Standards (NAAQS). Three major types of mass emissions regulations were identified during the study: (a) the process weight regulation which limits the total mass of hourly emissions based on the hourly raw material input; (b) the concentration regulation which limits the mass of particulate in a specified volume of undiluted gas; and (c) the removal efficiency regulation which specifies the efficiency that must be attained by the control device on a foundry process. Some of the regulations identified were written for general industrial processes while others were written for specific foundry processes.

Visible emissions (VE) regulations generally limit the opacity of the emissions plume. (Opacity is the degree to which the plume limits an observer's view of the background.) Unlike mass emissions regulations, VE regulations cannot be used to limit precisely the quantities of particulate emitted to the atmosphere and hence are not as valuable in developing SIPs. However, VE regulations have the advantage of being more easily and economically enforceable than mass emission regulations. This is especially true in the ferrous foundry where many of the emissions are fugitive and are difficult to test precisely.

Fugitive emissions regulations differ from the above categories in two major respects. First, they often involve no specific, quantitative standards; rather, they invite the discretion of the responsible agency official to determine the levels of fugitive emissions and control to prevent such emissions that are reasonable in a given situation. A second difference is that fugitive emission regulations vary according to significantly different models: some are preconditioned on the determination that a nuisance exists; some are preconditioned on the determination that ambient concentrations at the property line exceed an established limit; others require that reasonable precautions be taken to prevent any fugitive emissions; and finally, some restrict visible emissions at the property line. Because fugitive emissions are an air pollution problem commonly associated with foundries, fugitive emissions regulations may play an important role in enforcement strategies. They may be used in establishing in-plant capture systems for fugitive total suspended particulates (TSP), as well as aiding enforcement of the performance of those in-plant capture systems.

Nuisance-related regulations have their basis in common law. The three general types of nuisance regulations surveyed during the study were: (a) a general proscription against emissions that harm persons or property; (b) a proscription against air pollution which causes a nuisance; and (c) regulations which proscribe air pollution causing odors. These nuisance-related regulations have proven helpful in some states because state courts have acted favorably on action brought under these regulations due to their historical basis and also because they provide an avenue for action based on citizens' complaints.

Malfunction regulations were not originally included for consideration in this study. However, it quickly became apparent that these regulations are a two-edged sword which might be used on the one hand to excuse excessive emissions as a malfunction, and on the other hand to better ensure continuous compliance at ferrous foundries. Essentially, most malfunction regulations require that a source report a malfunction (defined differently in different states) to the local agency. The foundry must then present a plan for correcting (and sometimes preventing) the malfunction. Much greater detail is provided in Appendix E.2.6.

The paragraphs below and Table 6-1 summarize the degree to which the states apply the regulations described above.

Mass emissions regulations applicable to ferrous foundries are primarily process weight and concentration (grain loading) limitations. Forty-three states have process weight regulations, and 23 states have concentration limitations that are or could be applied to one or more of the ferrous foundry processes. Only two states (New Mexico and Utah) have no general mass emission limitation that would be applicable to ferrous foundries.

Of the 43 states with process weight regulations, 41 have limitations that apply to sources in general, including foundries, but only 14 have limitations that apply specifically to foundry operations (usually the melting process). Similarly, of the 23 states with concentration limitations, 19 have regulations that apply to sources in general, including foundries, but only 9 have regulations that apply specifically to foundry processes.

TABLE 6-1. APPLICATION OF REGULATIONS TO FERROUS FOUNDRIES

Type of authority	States where authority exists	States not interviewed	States interviewed with no foundries	States which use authority
Process weight Regulations	43	7	4	31 (97%)
Grainloading regulations	23	3	1	18 (95%)
Visible emission limitations	50	9	5	36 (100%)
Fugitive emission limitations	43	9	4	23 (77%)
Nuisance-related authority	38	6	3	11 (38%)
General prohibition	20	4	1	5 (33%)
Odor	25	3	2	5 (25%)
Nuisance	16	1	2	5 (38%)

Mass emissions regulations have generally been used to require installation of control equipment, particularly on the melting furnaces. Because of the cost of emissions testing, mass emissions regulations are not used frequently to ensure continued compliance.

Virtually every state has a visible emissions regulation that would apply to foundry operations; and a large majority (43) have a fugitive emissions regulation that could be applied. However, very few if any of these regulations are specifically designed to regulate foundry emissions. Fewer states (37) have nuisance-related authority (nuisance, odor, or a general prohibition against air pollution) specified in their air pollution statutes and regulations (although it is possible that additional nuisance-related authority exists elsewhere in the state code). This authority also seems designed to aid in the regulation of air pollution sources in general, but not foundries specifically.

VE regulations have been used both to require the installation of control (particularly on shakeout and sand handling) and in the enforcement of continued compliance. In fact many of the states use the drive-by VE inspection as their primary enforcement tool. Little information was gathered on the specific uses of nuisance-related authority. However, theoretically this authority can be used to require installation and regulate continued compliance.

Since the malfunction, O&M, and operating permit regulations were not included as a part of the original survey, data on the extent of their availability and application are not available. However, it is known that in a few states, these regulations do form the backbone of continual compliance efforts.

6.2 STRENGTHS AND WEAKNESSES OF VARIOUS TYPES OF REGULATIONS

Each of the regulations described has certain strengths and weaknesses when applied to the foundry processes that were identified during the telephone survey. The paragraphs below briefly summarize these strengths and weaknesses for four basic types of regulations: process weight, concentration, fugitive emissions, and visible emissions.

As a mass emissions standard, the process weight regulation was perceived by respondents to have two advantages: (a) it establishes a fixed quantity of allowable particulate subject only to a change in the process weight; and (b) it varies stringency with the size of the source. This second factor is particularly important for the foundry industry where many small jobbing foundries have a very low profit margin and cannot afford sophisticated control systems.

On the other hand, two major criticisms were leveled at the process weight regulation. Foremost was the practice of applying a single process weight curve or table to a wide variety of processes. The intrinsic differences in quantities and controllability of emissions may result in an inequitable burden on some industrial categories. A second criticism that is particularly true of foundries is the difficulty of determining the input weight. For example is the shakeout input weight simply the weight of castings or is it the combined weight of castings and sand.

The advantage most often cited for concentration regulations is that they rely only on measured emissions and do not depend on determination of input weights. As a result it is easier to determine compliance on many of the fugitive emissions sources. In particular, emissions from roof vents and ventilation ducts can be monitored.

The two major criticisms of the concentration regulation are that the regulations do not generally vary allowed emissions according to source capacity (a few states do have such variance) and that the regulation may be subject to circumvention. The importance of the first criticism, especially with respect to jobbing foundries, was described above. The second criticism is based on the assertion that it is possible to infiltrate large quantities of air and circumvent the regulation. However, it seems that if the process were properly monitored during testing, the potential for such circumvention is slight. Survey respondents, in fact, did not indicate that this potential problem actually occurs.

In discussing fugitive emissions regulations, respondents had fewer strong statements about the strengths and weakness of these regulations than they had about the mass emissions regulations. This is probably the result, at least in part, of a lack of concern about fugitive emissions by many of the respondents. For those persons concerned about fugitive emissions, the primary advantage of the regulation is that it often provides a better vehicle to control fugitive sources than either mass emissions regulations or the visible emissions regulation.

The major disadvantage of most fugitive emissions regulations is their subjectivity. This subjectivity invites dispute on the part of the industry and makes violations much more difficult to prosecute. Although many states have retreated from enforcement of such regulations because of their subjectivity, other states have attempted to reduce this subjectivity by providing more objective criteria. Fourteen states, for example, prohibit any visible emission at the property line; four states prohibit any fugitive emission that exceeds 20% opacity; and six states establish ground level ambient concentration standards. In addition, several states shift the burden to the source to demonstrate the need for fugitive emissions or the reasonableness of the in-plant control equipment installed, thus providing the state an edge in any dispute that may result. Another disadvantage of fugitive emissions regulations that require property line measurements, is that these measurements are difficult to obtain and consume a large amount of agency resources.

As indicated earlier, visible emissions regulations form the basis for ferrous foundry regulatory activity in many states. Visible emissions regulations are often used because they are more easily applied than other regulations available to the agency. Visible emissions "tests" can be performed with almost no planning and with a minimal commitment of resources.

Survey respondents had two major criticisms of visible emissions regulations as applied to foundries. First, it is likely that a visible emissions standard (especially a 40% opacity standard) is significantly less restrictive for emissions stacks than is a mass emissions standard. Thus, sole reliance on the visible emissions standard results in an overly lenient enforcement posture. The second disadvantage of the visible emissions standard is that it often does not adequately apply to foundry fugitive sources. Since the emissions from these sources exit from a large number of windows and doors, acceptable method 9 readings are often not possible, and it is not likely that the emissions from any one exit will exceed the opacity limit.

6.3 SELECTED PROBLEMS AND SOLUTIONS INVOLVING FERROUS FOUNDRY REGULATIONS AND THEIR APPLICATION BY STATES AND LOCALITIES

One major objective of the regulatory analysis in this study was to identify solutions to particular regulatory problems that inhibit effective enforcement of ferrous foundries. Most state contacts reported, however, that there are few, if any, significant problems encountered in the regulation of ferrous foundries. Foundries thought generally to be in compliance with applicable emission limitations; when out of compliance they have been willing to comply voluntarily; and the development of specific investigation or enforcement strategies to deal with ferrous foundries has been considered unnecessary. While most survey respondents could recall isolated instances in which compliance problems had occurred, few were willing to state that theoretical problems in the applicability or effectiveness of particular types of regulations were to blame.

In contrast, a few respondents related their concern over a multiplicity of compliance and regulatory problems involving ferrous foundries. Federal regulators and technical experts associated with private consulting and engineering firms also expressed many of the same concerns. This discrepancy in opinion is not fully explainable. In some cases, such as the control of fugitive emissions, it is conceivable that the majority of state regulators do not yet recognize compliance problems that must be addressed in the future and, therefore, have not yet experienced certain regulatory and enforcement strategy problems that are inevitable. In other cases, it is possible that certain matters are not considered problematical because the problems have already been resolved.

Whatever the case, it has been possible to identify a limited number of regulatory and strategic problem areas of actual or potential significance and explain how these have actually been resolved by some states. As a general observation, problems tend to fall into the following broad categories: (a) the unavailability of an appropriate regulation; (b) problems involving the type of emission limitation included in the regulation; (c) problems involving vagueness or overbreadth in the regulation; (d) problems involving a lack of adequate resources to implement regulations; and (e) problems in the design of surveillance or enforcement strategies. Solutions, also, tend to fall into broad categories: (a) the adoption of new types of regulations; (b) changes in existing regulations; (c) reliance on alternative regulations; (d) reinterpretation of existing regulations; and (e) formulation of new surveillance or enforcement strategies.

These problems and solutions are identified and discussed briefly in the following paragraphs. It should be noted that certain of the problems may be less prevalent or less substantial and certain of the solutions may be less desirable or even inappropriate in particular states. No attempt has been made to analyze or evaluate either the problems or the solutions presented in this section.

6.3.1 The Process Weight Regulation Problem

Major problems voiced and solutions identified during the survey include:

Problem: The rate was not designed for foundries and therefore results in an inequitable burden on specific segments of the foundry industry. Specifically, certain small or intermittently operating foundries must meet limitations that are too restrictive; and certain large foundries escape with a more relaxed emission limitation.

Solutions Mentioned

1. Adopt regulations specifically designed for ferrous foundries. These may be process weight rates (see, for example, Pennsylvania's regulation, Appendix E, Table E-3) or concentration limitations (see, for example, Michigan's regulations, Appendix E, Table E-3).

2. To prevent certain foundries from taking advantage of a more relaxed mass emission limitation, as well as to relieve the burden of a more stringent mass emission limitation, a collection efficiency regulation may be superimposed (in the first case, to apply if more stringent; in the second, as an alternative if less stringent) (see, for example, Connecticut's and New York's regulations, Appendix E, Table E-3).

Problem: General process weight rates result in grossly inefficient control of shakeout and sand handling emissions.

Solutions Mentioned

1. Adopt a separate regulation for shakeout sand handling (see, for example, Pennsylvania's regulations, Appendix E, Table E-3).

2. Rely on the visible emission regulation if its application would result in more stringent control.

3. Rely on the process weight regulation to obtain initial installation of control equipment; then rely on other regulations that pertain primarily to operation and maintenance to ensure effective, continuous control. Such regulations may include visible emission regulations and collection efficiency regulations as well as operation and maintenance regulations, permit regulations, malfunction regulations, and even nuisance and odor regulations.

4. Rely on nuisance, odor, ambient air quality, or some other authority to obtain initial control, then on operation and maintenance regulations to ensure continued control.

Problem: Process weight rates are difficult to apply because of problems in estimating input and ensuring representative testing conditions.

Solutions Mentioned

1. Adopt a concentration limitation.

2. Use the process weight rate to obtain initial control that should achieve the emission limitation with an ample cushion; then rely primarily on permit regulations, operation and maintenance requirements, and similar regulations to ensure that the control equipment is operating properly.

Problem: Process weight rates are difficult to apply to the cupola because of problems in accounting for fugitive emissions when measuring emissions during stack testing.

Solutions Mentioned

1. Adopt either of the solutions described in the problem immediately above.

2. Measure fugitive emissions from appropriate points (e.g., roof vents) and/or during appropriate portions of the operating cycle (e.g., during charging, melting, and tapping). These emissions are then included as a part of the allowable emissions from the melting operation. At least one state has derived a similar factor for pouring and cooling emissions and has included these emissions as a part of the allowable melting emissions.

6.3.2 Regulating Fugitive Emissions

Major problems voiced and solutions identified during the survey include:

Problem: Existing regulations do not allow for adequate control of fugitive emissions. Fugitive emission regulations are too vague, too subjective, or too complex.

Solutions Mentioned

1. Adopt a fugitive emission regulation that prohibits all fugitive emissions unless reasonable control measures are adopted; then define reasonable control measures in terms specifically responsive to typical foundry problems. The state should have the power to insist on any of the enumerated control measures at any point within the foundry that contributes to fugitive emissions whenever fugitive emissions are observed or measured at a point of exit from the foundry enclosure without regard for whether they are observable or measureable at the property line. The source has the burden to demonstrate that the measures are, in fact, unreasonable.

2. Require as a condition of an operating permit that measures be adopted to prevent fugitive emissions. These measures should be specified in the permit as conditions for issuance and would be specifically enforceable without regard to whether it could be demonstrated that there was an actual violation of the underlying fugitive emission regulations.

Problem: Mass emission regulations do not allow for the control of fugitive emissions.

Solutions Mentioned

1. One state estimates the contribution to fugitive emissions from certain activities associated with melting (e.g., charging, tapping, pouring, and cooling) and accounts for these emissions during stack testing by adding them to the measured stack emissions to determine whether the melting operation is in compliance with a process weight rate.

2. An emissions concentration limitation may be applied at any exit point depending on the definition of "source" in the state regulations or air pollution statute. If defined broadly so that roof vents, windows, and other openings are incorporated, the emissions concentration regulation could be applied to require further control of in-plant processes; however, the effectiveness of such a regulation would depend on its relative stringency compared to the actual emissions experienced at individual points. It would also depend greatly on the susceptibility of the exit point to emission measurement techniques.

Problem: Visible emissions regulations do not allow for effective control of fugitive emissions because they are not easily applied around buildings or from nonrectangular stacks. They also do not effectively address the problem of emissions from multiple roof vent emissions.

Solutions Mentioned

1. There was disagreement relating to the feasibility of conducting accurate readings exiting from the sides of buildings. A spokesperson explained that such readings are feasible if certain precautionary measures are taken and adequate allowance for background opacity is made.

2. It may be necessary to revise the test method for determining compliance with visible emissions regulations to use these regulations as part of a strategy to respond to fugitive emission problems.

6.3.3 Post-Installation Enforcement

Major problems voiced and solutions identified during the survey include:

Problem: Regulations do not provide effective authority for ensuring continued compliance after the initial compliance demonstration. The primary problem is that to demonstrate a violation requires time-consuming and expensive stack testing which is usually nonrepresentative of actual operating conditions.

Solutions Mentioned

1. Adopt operation and maintenance regulations which are independently enforceable. The most effective of these regulations allows for the state to require preventive steps without documenting an actual emissions violation.

2. Adopt and enforce malfunction regulations which require self-surveillance and reporting whenever control equipment (including capture equipment) is down. The most effective of these regulations requires immediate corrective action, reporting to the state within a reasonable time frame, and subsequent preventive action according to a plan approved by the state and enforced as an independently enforceable requirement (in the form of a permit condition, variance, or enforcement order). Malfunction reports should be used to assist in the development of investigation and enforcement priorities, and they should be constructively evaluated when determining whether the source has made good faith attempts to comply.

3. Adopt and use operating permit requirements. The most effective of these requirements allows for the state to impose reasonable operation and maintenance conditions to prevent violations of all applicable regulations (including fugitive emission regulations) according to a plan prepared by the source and subject to the state's approval. Permit conditions should be independently enforceable without a need to demonstrate actual emissions violations. The permit should be renewable on a periodic basis, and the state should have the authority to impose new conditions prior to renewal.

Problem: States may not have effective investigation strategies.

Solutions Mentioned

1. Proper detection of actual and potential fugitive emission violations require in-plant inspections. Drive-by inspections are an insufficient indicator of fugitive problems because of the difficulty of observing significant fugitive emissions at a distance. It is also thought that any significant potential for fugitive emissions may be detected during an in-plant inspection and effectively prevented.

2. States tend to rely primarily on complaints and secondarily on inspection prioritization as a basis for dealing with the lack of surveillance resources. Effective additional strategies are: (a) to "capture" other investigation resources by coordinating with the Occupational Safeguard and Health Administration (OSHA), or the state equivalent, and local health inspectors; and (b) to educate the public and solicit public assistance in surveillance.

3. States that must rely on stack tests to initiate effective enforcement should explore the potential for an abbreviated version that would be considered equivalent within the meaning of state regulations that allow for equivalent alternatives to specified test methods. An abbreviated version may be sufficient to shift the burden to the source to demonstrate compliance or may convince the source that a stack test would show noncompliance and therefore serve as an incentive to comply voluntarily with the state requests in issue.

4. States may wish to use other techniques that show probable noncompliance, including: (a) establishing a rough correlation between visible emissions and particulate mass emissions during stack testing; and (b) inspecting control equipment (including capture equipment) for signs of physical deterioration. Such methods would serve as indicators of noncompliance and would therefore be used primarily as leverage for pre-enforcement negotiation.

6.4 UNRESOLVED ISSUES REGARDING FOUNDRY REGULATIONS

As indicated at the beginning of Section 6.0, one of the major objectives of the control agency survey was to identify enforcement problems and solutions experienced by agencies in applying regulations to ferrous foundries. Because of the limited effort and relatively broad scope of the study and the wide variation in responses from agencies, it was not possible to conclusively address all issues raised during the study. The major question which is still unanswered is whether the current methods of evaluating ferrous foundry compliance adequately address foundry emissions problems. Three possible problem areas which impact on this questions are: (a) fugitive emissions; (b) malfunction of control equipment; and (c) the contribution of ferrous foundries to NAAQS nonattainment. The following paragraphs review the findings of the study with regard to the major question and the surrounding areas of concern.

Data in Appendix E indicate that the vast majority of state contacts feel that ferrous foundries are generally in compliance with applicable emission limitations and are rarely found in violation. Hence, these agencies see no need for the development of enforcement strategies to deal with ferrous foundries. The bases for these views are threefold. First, it has been the experience of most agencies that foundries have installed the control equipment necessary to come into compliance upon request; or, if the cost of control was not feasible, the foundry closed. Thus, most foundries have completed the installation phase of control, and that phase appears to be perceived by state agencies as most important. Second, most states use process weight rates to regulate foundry emissions. For some foundry processes such as shakeout and sand handling, the input weight is so large that the allowable emissions can be attained by equipment operating inefficiently. Thus, these sources are not perceived to be compliance problems. Finally, many of the foundries which have inadequate controls are small jobber foundries located in economically deprived rural areas. These foundries are seen as essential to the economy of the community and not as major emissions problems. As a result they are not given enforcement priority.

The findings described above appear to be in conflict with the opinions voiced during the study by federal regulators who indicated that ferrous foundries are a problem source category. Some of the information obtained from the state agencies substantiate this view. It is particularly worthy of note that almost a third of the respondents indicated that the majority or almost all foundries had inadequate control equipment. In addition, the majority of the respondents indicated that malfunction of foundry control equipment is a problem. These responses suggest that the current methods of evaluating compliance are not adequate.

Given the inconsistent responses described in the above paragraphs, it is not possible to draw conclusions about the importance of ferrous foundry compliance problems. Additional information from three areas (fugitive emissions, malfunctions, and the impact of foundries on attainment of NAAQS) may help resolve the issue. However, unanswered questions remain about each of these areas. The following paragraphs highlight available information and unresolved questions regarding each of these issues.

As described in Section 4.0, many ferrous foundry processes are sources of fugitive emissions. The responses of the majority of the agencies contacted suggest that these fugitive emissions sources are not a major concern. But this conclusion is not supported by the limited fugitive emissions data in Section 4.0 and Appendix B, which suggest that fugitive emissions sources may account for the majority of emissions from ferrous foundries. Further, the data gathered during the survey indicate that the regulatory authority for addressing fugitive emissions problems (particularly continual compliance) is problematical and sometime totally inadequate. Even if the regulatory authority for control of fugitive emissions exists, Section 5.0 indicates that control technology for these sources is not always adequate. Given the above concerns, it appears that a more detailed analysis of fugitive emissions quantities, controls, and regulations would provide a better indication of the impact of fugitive emissions on foundry compliance.

One problem that was identified by almost all persons contacted, both control agency and foundry personnel, is the malfunction of control equipment. However, the attitude most frequently conveyed by those agencies contacted was that the malfunction of control equipment is inevitable. The resultant position of the agencies is that enforcement actions are not warranted.

The assumption that malfunctions are inevitable is not consistent with the findings presented in Section 5.3. These findings indicate that the incidence of malfunction can be minimized with proper operation and maintenance of control equipment. However, even though practices appear to be available to minimize malfunctions, the study does not clearly indicate that states have the regulatory structure to prevent malfunctions.

Because of the costs of testing, process weight and concentration regulations are not a good tool for the prevention of malfunctions. Opacity regulations may be of some value if the malfunction results in excessive concentrations at a control device outlet. However, if the malfunction causes decreased capture efficiency at a fugitive emissions source, the opacity regulation may not be violated. Three types of regulation were identified during the study which may be useful in reducing malfunctions and promoting continued compliance. These regulations include malfunction regulations, operation and maintenance regulations, and operating permit regulations. However, because these regulations were not originally a part of the survey, data are not sufficient to determine the degree to which these regulations are available to states and their effectiveness in reducing malfunctions. Thus, the degree of reduction of malfunctions that can be attained is an unresolved issue.

The final factor which affects the question of whether ferrous foundries are a problem source is the impact of uncontrolled or noncompliance ferrous foundry emissions on the nonattainment of NAAQS. Since almost all states indicated that SIP revisions would have no impact on foundry controls, it is assumed that states consider foundries to have minimal impact on nonattainment. The scope of this study did not permit examination of the impact of foundry emissions on ambient air quality. However, since Section 3.0 does indicate that the majority of foundries from a sampling of six states are located in particulate nonattainment areas, the issue deserves further study.

In summary, the following unanswered questions were raised during the survey:

1. Do foundry emissions resulting from lack of control (either uncontrolled sources, insufficiently controlled sources, or malfunctioning control equipment) contribute significantly to the nonattainment of NAAQS?

2. Are current technology and regulations sufficient to control foundry fugitive emissions?

3. Are current regulations sufficient to reduce the incidence of malfunction to an acceptable level?

Answers to the above four questions would allow a much clearer determination of whether important compliance problems exist in ferrous foundries.

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16. ABSTRACT

The report presents an overview of the ferrous foundry characteristics and state and local regulatory practices which affect the evaluation of foundry compliance with air pollution regulations. Ferrous foundries are described with respect to size, location, investment trends, and process equipment. Particulate emission factors are developed for cupolas and electric arc furnaces as well as the process fugitive emissions sources. Techniques are described for controlling emissions from cupolas, electric arc furnaces, pouring and cooling, shakeout, sand handling and the cleaning room. Emphasis is placed on identification of malfunction problems associated with these control measures, and operation and maintenance practices that can be used to reduce the incidence of malfunctions. The regulations which are applied to ferrous foundries by state and local agencies are identified. Problems which have been encountered in regulating foundries and solutions which some agencies have found for these problems are described.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Iron and Steel Industry Foundries Furnace Cupolas Electric Arc Furnaces Air Pollution Control Equipment Emissions Regulations	Pollution Control Stationary Sources Particulate Operation and Maintenance	

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