United States Environmental Protection Agency

National Emission Standards for Hazardous Air Pollutants (NESHAP) for Iron and Steel Foundries - Background Information for Proposed Standards

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National Emission Standards for Hazardous Air Pollutants (NESHAP) for Iron and Steel Foundries-- Background Information for Proposed Standards

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LIST OF ACRONYMS

AB	Afterburner
A/C	Air-to-cloth [ratio]
AFS	American Foundrymen's Society
APCD	Air pollution control device
BID	Background information document
BLS	Bureau of Labor Statistics
CAA	Clean Air Act
CAS	Chemical Abstract Service
CEMS	Continuous emission monitoring system
CERP	Casting Emission Reduction Program
CIST	Casting Industry Supplier Association
CO_2	Carbon dioxide
CO	Carbon monoxide
CPMS	Continuous parameter monitoring system
CRF	Capital recovery factor
DEC	Direct evaluation control
D/F	Dioxin and furan
DMEA	Dimethylethylamine
EAF	Electric arc furnace
EID	Electric induction furnace
EPA	U.S. Environmental Protection Agency
ESP	Electrostatic precipitator
FCCU	Fluid catalytic cracking unit
HAP	Hazardous air pollutant
ICR	Information collection request
lb/ton	pound(s) per ton
MACT	Maximum achievable control technology
MSDS	Material safety data sheet

LIST OF ACRONYMS (continued)

NAICS . . . . North American Industry Classification System

NESHAP . . . . National Emission Standard for Hazardous Air Pollutants

ng/dscm . . . . nannograms per dry standard cubic meter

NO_x . . . . Nitrogen oxide

NSPS . . . . New source performance standard

O_2 . . . . Oxygen

OAQPS . . . . Office of Air Quality Planning and Standards

PCS . . . . Pouring, cooling, and shakeout

PeCDF . . . . Pentachlorinated dibenzofuran

PCDD/PCDF . . . . Polychlorinated dibenzo-p-dioxins/Polychlorinated dibenzofurans

PH . . . . Preheater

PM . . . . Particulate matter

POHC . . . . Principal organic hazardous compound

POM . . . . Polycyclic organic matter

ppmb . . . . Parts per billion by volume

ppmv . . . . Parts per million by volume

QA . . . . Quality assurance

RATA . . . . Relative accuracy test audit

SIC . . . . Standard Industrial Classification Code

SO_2 . . . . Sulfur dioxide

SO_x . . . . Sulfur oxide(s)

TAC . . . . Total annualized cost

TCI . . . . Total capital investment

TEA . . . . Trimethylamine

TEF . . . . Toxic equivalency factor

THC . . . . Total hydrocarbon concentration

VOC . . . . Volatile organic compound

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1.0 INTRODUCTION

This document summarizes the basic background information used in the development of maximum achievable control technology (MACT) standards for the iron and steel foundries source category. References and technical memoranda in the docket provide supplementary information on those steps in the standards development process not covered within this document.

The balance of this chapter summarizes the statutory basis for MACT standards and the selection of the source category. Chapter 2 provides an overview of the industry. Chapter 3 discusses foundry production processes in detail and describes hazardous air pollutant (HAP) emissions from each operation. Emission control technologies and their performance are summarized in Chapter 4. Chapter 5 presents baseline emissions and control options. Control costs (for use in estimating potential impacts) and options for emission control and monitoring are discussed in Chapter 6. Nationwide environmental and energy impacts are estimated in Chapter 7.

Appendix A lists the foundries reporting in a 1998 survey conducted by the U.S. Environmental Protection Agency (EPA) to obtain the information needed to develop the National Emission Standards for Hazardous Air Pollutants (NESHAP) for iron and steel foundries. Estimated HAP emissions from mold- and core-making operations appear in Appendix B. Appendices C through G provide detailed information on the development of emission factors for foundry processes and source test data for cupola baghouses, electric induction furnaces (EIFs), electric arc furnace (EAF) baghouses, and pouring, cooling, and shakeout (PCS) lines, respectively.

1.1 STATUTORY BASIS

Section 112 of the Clean Air Act (CAA) requires the development of NESHAP for the control of HAPs from both new and existing major sources or area sources. The statute requires the standard to reflect the maximum degree of reduction in emissions of HAPs that is achievable, taking into consideration the cost of achieving the emission reduction, any non-air-quality health and environmental reduction, and energy requirements. This level of control is commonly referred to as MACT.

Reductions in HAP emissions may be achieved by applying a variety of measures, processes, methods, systems, or techniques, including, but not limited to:

- Implementing process changes, substituting materials, or making other modifications to reduce the volume of, or to eliminate emissions of, such pollutants;
- Enclosing systems or processes to eliminate emissions;
- Collecting, capturing, or treating such pollutants when released from a process, stack, storage, or fugitive emissions point;
- Implementing design, equipment, work practice, or operational standards (including requirements for operator training or certification) as provided in subsection (h); or
- Employing a combination of the above [section 112(d)(2)].

1.2 SELECTION OF SOURCE CATEGORY

Section 112 specifically directs the EPA to develop a list of all categories of all major and area sources that emit one or more of the HAPs listed in Section 112(b). The EPA published an initial list of source categories on July 16, 1992 (57 FR 31576) and may amend the list at any time. An original schedule for promulgation of standards for each source category was published on December 3, 1993 (58 FR 63941).

Iron foundries and steel foundries are two of the categories on the initial list. As defined by the EPA, the iron foundries category consists of plants engaged in producing final shape castings from grades of iron (EPA, 1992). This source category includes the following production steps: (1) raw materials handling and preparation, (2) metal melting, (3) mold and core production, and (4) casting and finishing. The steel foundries category includes any facility engaged in producing final shape steel castings by the melting, alloying, and molding of pig iron and steel scrap. This source category also includes raw materials handling, metal melting, mold and core production, and casting and finishing. Because of the similarity in processes, emissions, and controls, we are presenting information for these two categories together under the rubric of "Iron and Steel Foundries."

The listings for iron foundries and steel foundries were based on the EPA Administrator's determination that these plants may reasonably be anticipated to emit several of the listed HAPs in sufficient quantity to be designated as major sources. The EPA schedule for promulgation of the Section 112 emission standards required MACT rules for the iron and steel foundries source category be promulgated by November 15, 2000. If MACT standards for this source category were not promulgated by May 15, 2002 (18 months after the promulgation deadline), Section 112(j) required States or local agencies with approved permit programs to issue permits or revise existing permits containing either an equivalent emission limitation or an alternative emission limitation for HAP control.

1.3 HAP HEALTH EFFECTS

Several HAPs have been identified that may be present in air emissions in significant enough quantities to be of concern. The metal HAPs emitted from melting furnaces include cadmium, chromium, lead, manganese, and nickel. Aromatic organic HAPs produced by mold- and core-making lines, melting furnaces, and PCS lines contain acetophenone, benzene, cumene, dibenzofurans, dioxins, naphthalene, phenol, pyrene, toluene, and xylene. The nonaromatic organic HAPs emitted are formaldehyde, methanol, and triethylamine. The known health effects of these substances are described in the *EPA Health Effects Notebook for Hazardous Air Pollutants-Draft* (EPA, 1994).

Of the HAPs listed above, benzene is a known human carcinogen of moderate carcinogenic hazard. Cadmium, 2,3,7,8-TCDD (dioxin), formaldehyde, lead, and nickel are classified as probable carcinogens. Chromium can exist in two valence states. Chromium VI is a known human carcinogen of high carcinogenic hazard if inhaled. (Note: Chromium III and Chromium VI by oral pathways are classified as Group D “not classifiable as to carcinogenicity in humans.”) Acute effects of some of the HAPs listed above include eye, nose, and throat irritation, nausea, vomiting, drowsiness, dizziness, central nervous system depression, and unconsciousness. Chronic effects include respiratory symptoms (such as coughing, asthma, chronic bronchitis, chest wheezing, respiratory distress, altered pulmonary function, and pulmonary lesions); gastrointestinal irritation; liver injury; and muscular effects. Reproductive effects include menstrual disorders, reduced incidence of pregnancy, decreased fertility, impotence, sterility, reduced fetal body weights, growth retardation, slowed postnatal neurobehavioral development, and spontaneous abortions.

Note that the degree of adverse effects on health experienced by exposed individuals can range from mild to severe. The extent and degree to which the health effects may be experienced depends on:

- Pollutant-specific characteristics (e.g., toxicity, half-life in the environment, bioaccumulation, and persistence);
- The ambient concentrations observed in the area (e.g., as influenced by emission rates, meteorological conditions, and terrain);
- The frequency and duration of exposures; and
- Characteristics of exposed individuals (e.g., genetics, age, pre-existing health conditions, and lifestyle), which vary significantly with the population.

1.4 REFERENCES

U.S. Environmental Protection Agency, 1992. *Documentation for Developing the Initial Source Category List.* Office of Air Quality Planning and Standards, Research Triangle Park, NC. EPA-450/3-92-030.

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2.0 INDUSTRY DESCRIPTION

A foundry is a facility that makes metal castings, which are near final shape products that may be complex in form. A casting is made by pouring molten metal into a cavity that has the shape of the product. Many metal products can be made much more effectively by casting than by other methods such as machining or forging.

The metal casting industry makes an enormous variety of products according to end users' specifications. Castings are used in virtually every industry that is critical to the nation's economic health and strategic capability. Castings can be made from a wide variety of metals, including iron, steel, aluminum, brass, bronze, and superalloys. Approximately 3,000 foundries currently operate in the United States in virtually every State. Of these, approximately 750 pour iron or steel. More than $25 billion worth of castings, used in 90 percent of manufactured goods, are produced annually. A primary feed material for foundries is scrap metal, 15 to 20 million tons of which are consumed annually. The foundry industry is thus a major recycler of primary metals. The size of foundries varies widely, from facilities that employ more than 1,000 persons, to those that employ fewer than 10. A significant number of foundries are operated by companies that employ 500 or fewer persons and are therefore small businesses.

This chapter presents a brief overview of the metal-casting industry, with a specific focus on the iron and steel foundry sector. Facilities are typically categorized by the type of metal used in the castings as either ferrous (iron and steel) or nonferrous (e.g., aluminum, copper, zinc, brass, and bronze). The source categories that are the subject of this report (Iron and Steel Foundries) are ferrous foundries categorized by the Office of Management and Budget (OMB) under the general North American Industry Classification System (NAICS) code of 33151. They are also categorized under the general Standard Industrial Classification (SIC) code of 332. More specifically, iron and steel foundries are categorized by the NAICS code according to the type of iron or steel casting operations as follows:

- NAICS 331511 - Iron Foundries,
- NAICS 331512 - Steel Investment Foundries, and
- NAICS 331513 - Steel Foundries (Except Investment).

The specific SIC codes that apply are:

- SIC 3321 - Gray and Ductile Iron Foundries,
- SIC 3322 - Malleable Iron Foundries,
- SIC 3324 - Steel Investment Foundries, and
- SIC 3325 - Steel Foundries Not Elsewhere Classified.

2.1 BACKGROUND

The foundry or metal-casting industry is an old industry, with bronze castings dating back to 3,200 B.C. Iron was discovered in 1,500 B.C., and the first iron casting was made in 600 B.C. In North America, the first iron foundry started producing castings in 1642. The first steel castings date back to 500 A.D., but the technology was lost and did not reappear until 1750. The first U.S. cast steel foundry started production in 1818 (Lessiter and Kotzin, 1996).

About 13 million tons of castings are produced every year in the United States. Most of these castings are produced from recycled metals. Thousands of different cast metal products are made, many of which are incorporated into other products. Almost 90 percent of all manufactured products contain metal castings. It is estimated that, on average, every home contains over a ton of castings in the form of pipe fittings, plumbing fixtures, hardware, and furnace and air conditioner parts. Automobiles and other transportation equipment use 50 to 60 percent of all castings produced. Castings for this purpose include engine blocks, crankshafts, camshafts, cylinder heads, brake drums and calipers, transmission housings, differential casings, universal joints, suspension parts, flywheels, engine mount brackets, front wheel steering knuckles, hubs, ship propellers, hydraulic valves, locomotive undercarriages, and railroad car wheels. The defense industry also uses a large portion of U.S.-produced castings. Typical cast parts used by the military include tank tracks and turrets and the tail structure of the F-16 fighter. Other common castings include pipes and pipe fittings, valves, pumps,

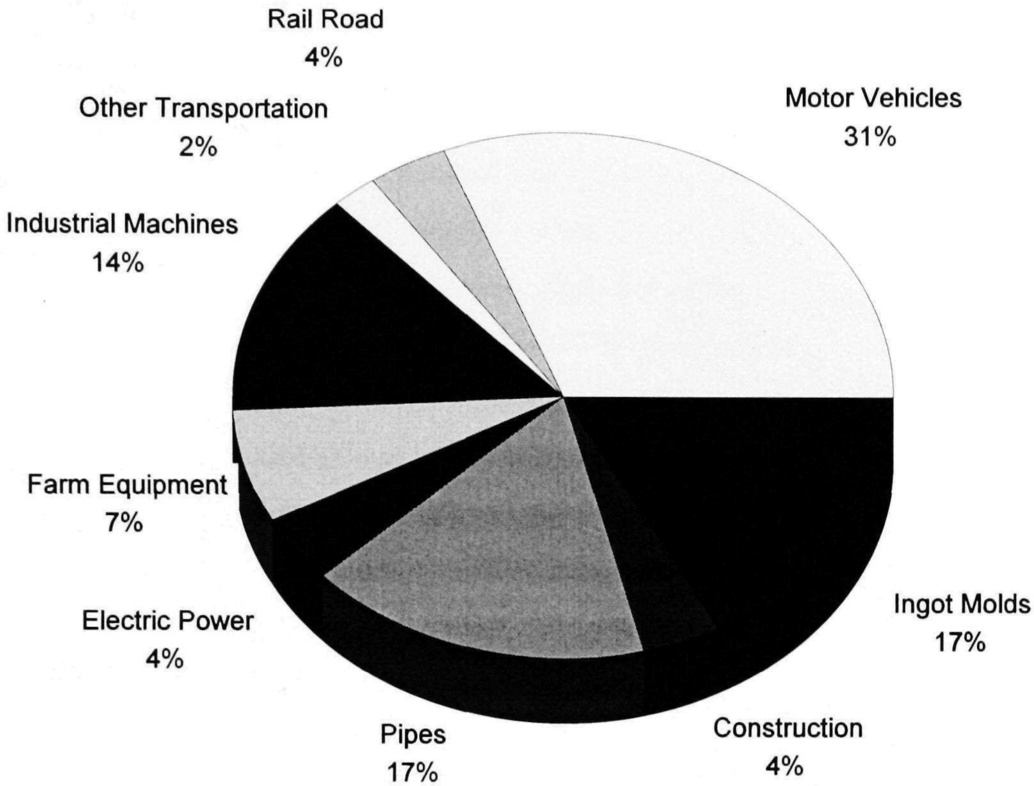

Figure 2-1. Uses of U.S. Cast Metal Products (EPA, 1997).

pressure tanks, manhole covers, and cooking utensils (EPA, 1997). Figure 2-1 shows the uses of various types of castings produced in the United States.

Most foundries manufacture castings for sale to other companies (EPA, 1997). These are referred to as jobbing foundries. Important exceptions are the relatively few (but large) captive foundries operated by original equipment manufacturers such as General Motors, Ford, Chrysler, John Deere, and Caterpillar. Captive foundries account for a large portion of all castings produced and employ a significant portion of the industry's workforce.

Gray and ductile iron make up almost 75 percent of all ferrous and nonferrous castings by weight (see Figure 2-2). Gray iron contains carbon in the form of flake graphite and has a lower ductility than other types of iron. It is used extensively in the agricultural, heavy equipment, engine, pump, and power transmission industries. Ductile iron has magnesium or cerium added to change the form of the graphite from flake to nodular, resulting in increased ductility, stiffness, and tensile strength (EPA, 1997).

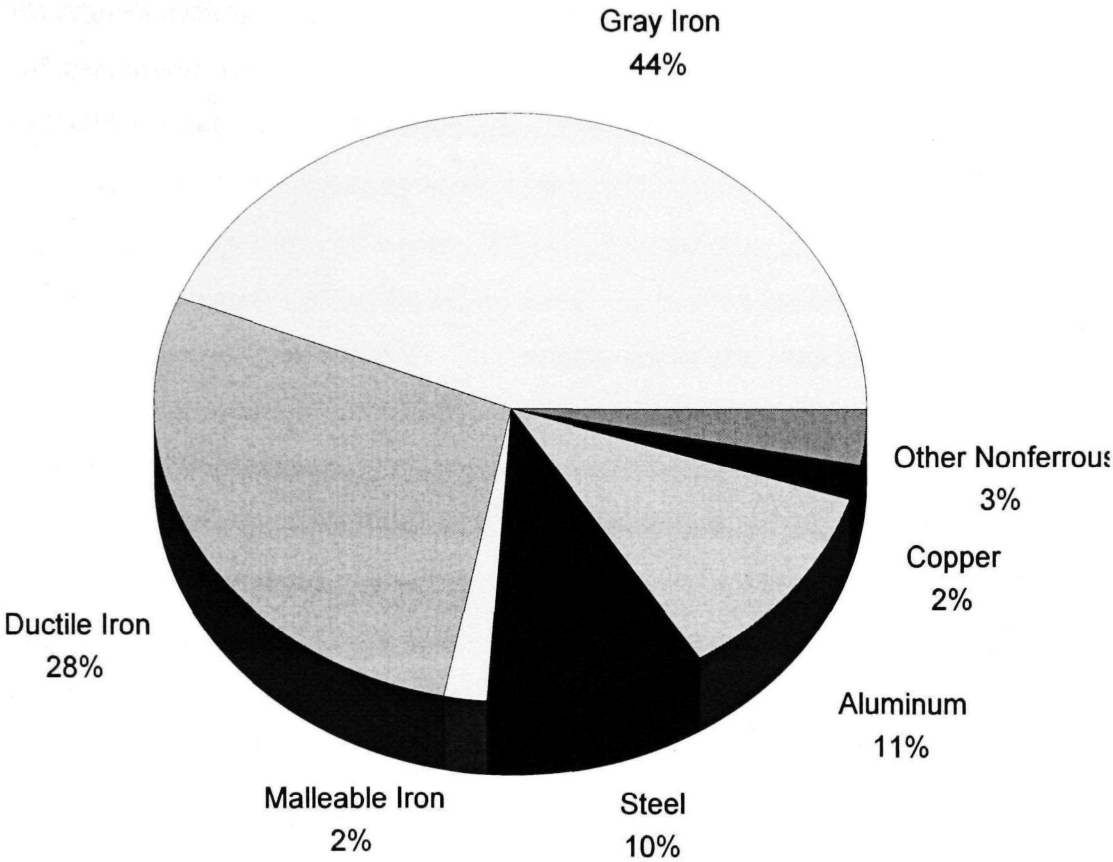

Figure 2-2. Types of Metal Cast (EPA, 1997).

Malleable iron foundries produce only about 2 percent of all castings. Malleable iron contains small amounts of carbon, silicon, manganese, phosphorus, sulfur, and metal alloys to increase strength and endurance. Malleable iron has excellent machinability and a high resistance to atmospheric corrosion. It is often used in electrical power, conveyor and materials handling, and railroad industry equipment.

Compared to steel, forms of iron are all relatively inexpensive to produce and easy to machine, and they are widely used where the superior mechanical properties of steel are not required (EPA, 1997). Steel castings make up about 10 percent of all ferrous foundry products. In general, steel castings have better strength, ductility, heat resistance, durability, and weldability than iron castings. There are a number of different classes of steel castings (based on carbon or alloy content) with different mechanical properties. A large number of different alloying metals can be added to steel to increase its strength, heat resistance, or corrosion resistance (EPA, 1997). The steel investment casting method produces high-precision castings, usually smaller products. Examples of steel investment castings range from machine tools and dies to golf club heads.

2.2 INDUSTRY SIZE AND GEOGRAPHIC DISTRIBUTION

According to the *1992 Census of Manufactures*, there were approximately 2,813 metal-casting facilities operating under SIC codes 332 and 336 in that year. The payroll for 1992 totaled $5.7 billion for a workforce of 158,000 employees, and the value of shipments totaled $18.8 billion (U.S. Census Bureau, 1992). The industry's own estimates of the number of facilities and employment for 1994 are somewhat higher, at 3,100 facilities employing 250,000. The industry predicted shipments of 14.5 million tons valued at $28.8 billion in 1999.

The *Census of Manufactures* data indicate that the industry is labor intensive. The value of shipments per employee, a measure of labor intensity, is $119,000, which is less than half of the value for the steel manufacturing industry ($245,000 per employee) and less than 7 percent of the value for the petroleum refining industry ($1.8 million per employee).

The EPA surveyed the industry in 1998 for information needed to develop the NESHAP for Iron and Steel Foundries (EPA, 1998a). A comprehensive questionnaire, the MACT Standards Development Questionnaire for Iron and Steel Foundries, was submitted to approximately 750 foundries. A total of 595 facilities responded with detailed information on size and type of operations, number of employees in the facility and its parent company, and descriptions of air pollution control measures employed, including whatever information was available on pollutants emitted and control efficiencies. A complete list of facilities submitting information and a summary description of their type and scope of operation is compiled in Appendix A.

According to the survey data, most ferrous metal-casting facilities in the United States are small. About 70 percent of the facilities reporting employed 200 or fewer people (see Table 2-1). These smaller facilities were generally jobbing foundries. Captive foundries tended to be larger and to have correspondingly higher production. As seen in Table 2-1, approximately 50 percent of the ferrous metal castings in the United States are produced by roughly 10 percent of the facilities, which have the highest number of employees. Smaller facilities also appear more likely to produce both iron and steel castings than do larger facilities.

The geographic distribution of the metal-casting industry resembles that of the iron and steel industry. Historically, locations for metal-casting establishments were selected for their proximity to raw materials (iron, steel, and other metals), coal, and water (for cooling, processing, and transportation). Traditional metal-casting regions included the Monongahela River Valley near Pittsburgh, PA, and along the Mahoning River near Youngstown, OH. The geographic concentration of the industry is changing as facilities are built where scrap metal and electricity are available at a reasonable cost and where there are local markets for cast products (EPA, 1997).

A summary of the number of facilities and the metal production rate for each State, according to the EPA survey of iron and steel foundries, is provided in Table 2-2 (EPA, 1998b). The top States by number of facilities, in order, are Ohio (61), Wisconsin (55), Pennsylvania (54), Alabama (39), Indiana (38), Michigan (37), and California (35). Approximately 30 percent of the iron and steel foundries in the United States are in the top three States (Ohio, Wisconsin, and Pennsylvania). The top States by annual production rate (tons metal poured) are Ohio (17 percent of the nationwide total), Wisconsin (14 percent), Michigan (11 percent), Indiana (9.3 percent), and Alabama (8.5 percent). These five States account for over 60 percent of the iron and steel castings produced in the United States.

2.3 ECONOMIC TRENDS

Between the 1970s and 1990s, the metal-casting industry suffered a long-term decline in production. In an 18-year period, the industry witnessed a production decrease of 10.6 million tons, from a high of 21.9 million tons in 1973 to a low of 11.3 million tons in 1991. In these years, over 1,000 metal-casting facilities closed due to the loss of the ingot market, which resulted from rising steel production, the lightening of cars (shift to smaller cars), and product substitution (use of aluminum castings, plastics, ceramics, and other composites) (EPA, 1997). The metal-casting industry is now growing at a modest rate for a mature industry. By 2007, shipments are expected to increase to 16.3 million tons, for an annual growth rate of 1.4 percent. Sales are projected to grow at a rate of 4.2 percent per year to $38.7 billion, reflecting increased sales of lighter and higher priced castings (Kirgin, 1998). Sales of aluminum castings are expected to reach $10.6 billion in 2006, or 29 percent of the total metal-casting revenue.

TABLE 2-1. FACILITY SIZE DISTRIBUTION FOR THE IRON AND STEEL FOUNDRY INDUSTRY

Number of employees at the facilities	Number of facilities	Percentage of facilities, %	Combined annual production rate, tons/yr	Percentage of annual production rate, %	Number of facilities casting iron only	Number of facilities casting steel only	Number of facilities casting both iron and steel
1-20	67	11	28,488	0.2	39	15	13
21-50	124	21	239,821	1.4	64	36	24
51-100	101	17	471,640	2.7	53	31	17
101-200	122	20	1,949,896	11	63	35	24
201-300	56	9	2,190,761	13	39	14	3
301-400	43	7	1,806,949	10	23	13	7
401-500	30	5	2,672,478	15	21	8	1
501-1,000	38	6	3,906,555	22	26	10	2
1,001 or more	12	2	4,222,334	24	10	2	0
Not reported	2	0.3	10,439	0.06	1	1	0
Total	**595**	**100**	**17,499,360**	**100**	**339**	**165**	**91**

Source: EPA, 1998b.

TABLE 2-2. PRODUCTION DATA FOR IRON AND STEEL FOUNDRIES BY STATE

State	No. of facilities	Percentage of facilities, %	Iron, tons/yr	Steel, tons/yr	Total metal, tons/yr	Percentage of total, %
AL	39	6.6	1,246,361	242,366	1,488,727	8.5
AR	4	0.7	31,402	0	31,402	0.2
AZ	5	0.8	86	29,892	29,978	0.2
CA	35	5.9	201,359	53,202	254,561	1.5
CO	5	0.8	30,634	1,400	32,035	0.2
CT	5	0.8	2,480	2,552	5,032	0.0
FL	6	1.0	59,635	836	60,471	0.3
GA	4	0.7	156,779	0	156,779	0.9
IA	19	3.2	591,608	177,307	768,915	4.4
IL	21	3.5	748,254	105,430	853,684	4.9
IN	38	6.4	1,516,791	105,265	1,622,056	9.3
KS	7	1.2	96,533	132,506	229,039	1.3
KY	2	0.3	86,021	0	86,021	0.5
LA	6	1.0	21,112	5,534	26,646	0.2
MA	10	1.7	41,706	1,984	43,690	0.2
MD	3	0.5	12,503	1,099	13,602	0.1
ME	2	0.3	2,702	0	2,702	0.02
MI	37	6.2	1,866,899	63,881	1,930,780	11
MN	15	2.5	164,796	34,590	199,385	1.1
MO	12	2.0	34,097	14,196	48,293	0.3
MS	4	0.7	3,433	28,422	31,855	0.2
MT	1	0.2	1,161	806	1,967	0.01
NC	5	0.8	195,598	0	195,598	1.1
NE	6	1.0	37,636	12,608	50,244	0.3
NH	5	0.8	1,600	14,394	15,994	0.1
NJ	5	0.8	335,058	0	335,058	1.9
NV	1	0.2	0	730	730	0.004
NY	7	1.2	73,396	1,434	74,830	0.4
OH	61	10.3	2,619,454	305,924	2,925,378	17
OK	11	1.9	144,879	7,717	152,596	0.9
OR	9	1.5	17,952	81,390	99,342	0.6
PA	54	9.1	748,062	144,773	892,835	5.1
RI	3	0.5	3,055	0	3,055	0.02
SC	8	1.3	88,517	4,962	93,479	0.5
SD	1	0.2	3,975	0	3,975	0.02
TN	17	2.9	881,272	17,450	898,722	5.1
TX	33	5.6	496,066	102,783	598,848	3.4
UT	5	0.8	103,694	2,109	105,803	0.6
VA	9	1.5	546,660	517	547,177	3.1
VT	3	0.5	22,484	163	22,647	0.1
WA	14	2.4	24,235	31,854	56,089	0.3
WI	55	9.3	2,313,289	170,055	2,483,341	14
WV	3	0.3	21,995	4,000	25,996	0.1
Totals	**595**	**100.0**	**15,595,229**	**1,904,131**	**17,499,360**	**100.0**

Source: EPA, 1998b.

Increases in production have come primarily from increased capacity utilization at existing facilities rather than from an increase in the number of facilities. In fact, the American Foundrymen's Society (AFS) estimates that the number of metal-casting facilities decreased by over 200 between 1990 and 1994 (EPA, 1997). Table 2-3 shows the projected capacity utilization estimates for 1998.

TABLE 2-3. CAPACITY UTILIZATION PROJECTIONS FOR 1998

Metal	Capacity, tons/yr	Utilization, %
Iron	12,592,00	86
Steel	1,650,000	84
Aluminum	2,110,000	84
Copper-base	400,000	82
Magnesium	45,000	82
Zinc	420,000	88
Other nonferrous	50,000	92
Investment casting	210,000	81
Total	17,467,000	85

Source: Kirgin, 1998.

Ferrous casting shipments, which dropped to their lowest level (9.5 million tons) in 50 years in 1991, were expected to grow in the short term to 11.5 million tons in 1997 and 12.2 million tons in 1998. Shipments of gray iron castings were expected to increase slightly, to 6 million tons in 1997, and then to peak in 1998 and 1999 to annual levels of 6.4 million tons. If current trends hold, ductile iron is expected to pass gray iron in sales in 2004 and to become the shipment leader for ferrous metals (Kirgin, 1998).

In 1972, only 5 percent of all castings were aluminum. Today, aluminum accounts for over 11 percent of the market. Aluminum castings are steadily comprising a larger share of the market as their use in motor vehicle and engine applications continues to grow. To produce lighter weight, more fuel-efficient vehicles, the automobile industry is in the process of redesigning the engine blocks, heads, and other parts of passenger cars and light trucks for aluminum. Cast aluminum is expected to increase from 140 pounds per vehicle in 1995 to 180 pounds per vehicle in 2004. This increase is primarily at the expense of gray iron, which will decrease from 358 pounds per vehicle in 1995 to 215 pounds in 2004 (EPA, 1997).

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3.0 FOUNDRY PROCESSES AND EMISSIONS

This chapter discusses the production processes used at iron and steel foundries and the HAPs they emit. It also addresses the factors affecting emissions (where information is available). The chapter first provides a brief overview of the production of ferrous castings, and then describes the processes and emissions associated with the primary foundry operations, which include:

- Pattern making;
- Mold and core making;
- Scrap preparation;
- Metal melting;
- Pouring, cooling, and shakeout (PCS);
- Sand handling;
- Mechanical finishing; and
- Cleaning and coating.

3.1 GENERAL OPERATIONS

Figure 3-1 is a diagram of the process flow at a typical ferrous foundry that uses sand molds to produce castings. It shows potential emission points of HAPs, which are almost exclusively in the forms of metals or organic compounds, including volatile organic compounds (VOCs). Some of the operations illustrated in Figure 3-1 are present in all foundries, whereas others depend largely on the casting specifications and the type of casting process used. The basic operations in all ferrous foundries are pattern and mold making, metal melting, pouring of the molten metal into some type of mold, cooling of the casting, and separation of the solid casting from the mold. Other operations may include scrap preparation, finishing and cleaning, sand handling, and metallurgical treatment of the molten metal such as nodularization and inoculation.

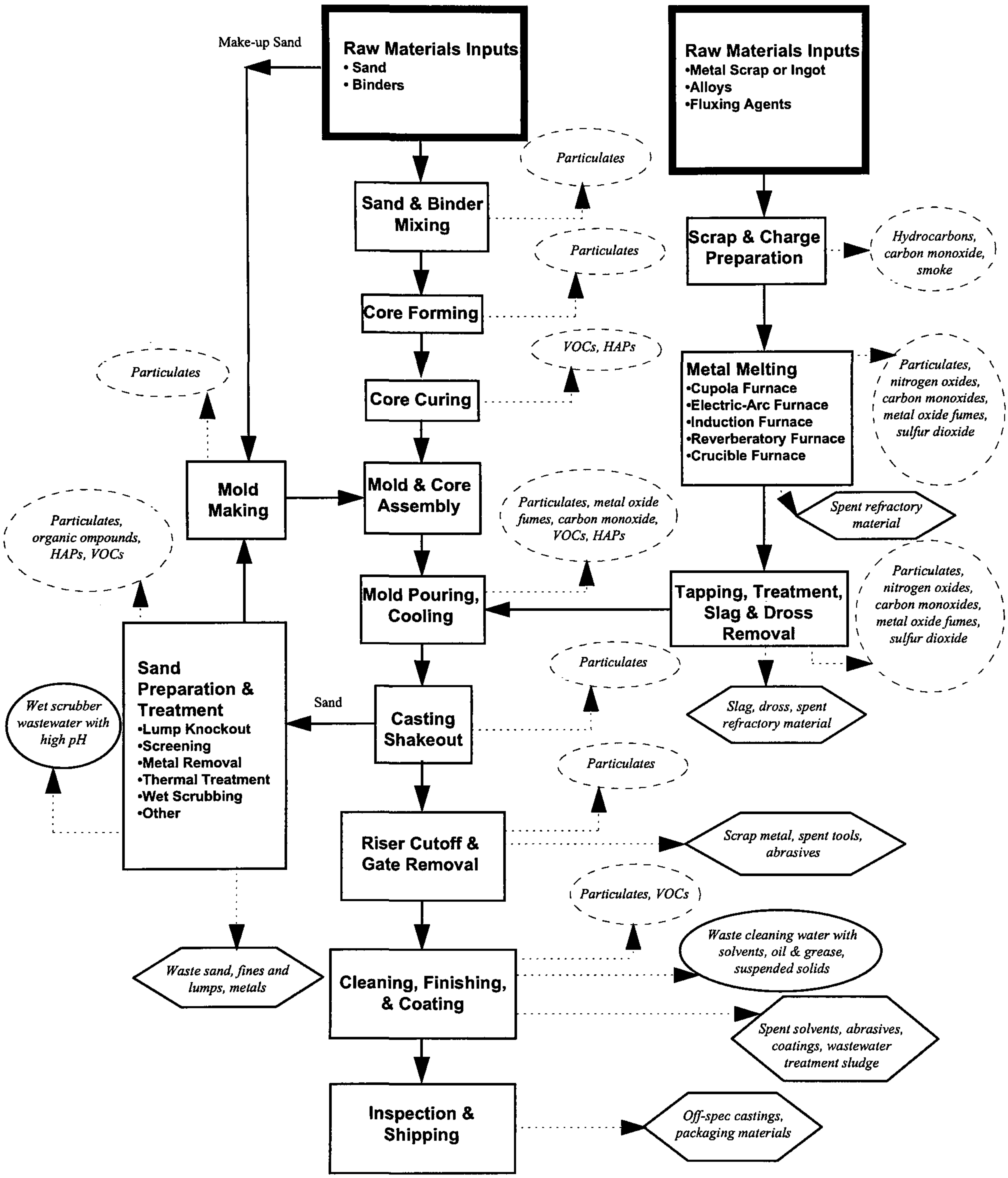


Figure 3-1. Process Flow for Typical Green Sand Foundry (EPA, 1997a).

The first step in the production of castings is making a pattern, which is a replica of a finished casting. Patterns are typically made of metal, wood, or plaster, and are used to create molds into which molten metal is poured. Molds are made from a variety of materials, including clay-bonded or chemically bonded sand, metal, or refractory material. A mold gives the casting its basic exterior shape, while cores are used to form the internal shape, e.g., the cylinders in an engine block. Cores are made from chemically bonded sand, plaster, collapsible metal, or soluble salts.

The next step in the production of castings is preparing and melting metal. Foundries typically use recycled scrap metals as their primary source of metal. They employ metal ingots as a secondary source when enough scrap is not available or when specifications for the metal are strict. Scrap metals typically undergo some type of preparation prior to melting such as sizing, cleaning, and drying.

After preparation is complete, the scrap is charged to a furnace for melting. The molten metal is poured from the furnace (tapped) into either a holding furnace or a transfer ladle. In some operations, particularly the production of ductile iron, inoculants and/or nodularization substances are then added. The molten metal is transported in a ladle, generally by overhead rail, to the pouring location.

Upon reaching the pouring area, the molten metal is poured into a mold. After the metal has solidified and cooled, it is separated from the mold. The casting is then transferred to a finishing and cleaning area. Specific finishing and cleaning operations will vary depending on the type of metal cast, the type of mold used to produce the casting, and casting specifications. Finishing typically involves mechanical operations such as abrasive cleaning (shot, sand, or tumble blast), torch cutoff, air-carbon arc cleaning, chipping, core knockout, and grinding. Cleaning usually involves the use of organic solvents to remove scale, rust, oxides, oil, grease, and dirt from the surface of the casting. In addition to finishing and cleaning, some castings may be given a coating to inhibit oxidation, resist deterioration, or improve appearance.

3.2 PATTERN MAKING

A pattern is a replica of a finished casting. Patterns are used to create hollow molds into which molten metal is poured. Most patterns are reusable and are typically made of metal, wood, or plaster. Other patterns are made from wax or polystyrene. These types of patterns are expendable in that they are used only once per casting.

Because the level of activity required for making permanent/reusable patterns (i.e, those made from metal, wood, or plaster) is very low, HAP emissions produced during their manufacture are not significant. Emissions arise primarily from the use of solvents and are almost entirely a workplace consideration. Emissions of HAPs from the manufacture of expendable patterns are discussed in Section 3.3.4.

3.3 MOLD AND CORE MAKING

The predominant casting operations at ferrous foundries include sand mold, centrifugal, permanent mold, investment, and expendable pattern casting. Sand molds are bonded using resin-like chemicals or clay plus other materials. Permanent and centrifugal casting operations use metal molds, and investment casting operations use molds made from refractory material. Expendable pattern casting uses molds of unconsolidated sand. A variety of cores can be used with each type of mold. Most cores are made from chemically bonded sand. Others are made from plaster, collapsible metal, or soluble salts.

The EPA surveyed the iron and steel foundries industry in 1998 when the MACT Standards Development Questionnaire for Iron and Steel Foundries (EPA, 1998a) was submitted to approximately 750 foundries. A total of 595 foundries reported their production based on type of casting operation. Table 3-1 lists the annual production of iron and steel by casting operation type as reported in responses to the survey (EPA, 1998b).

TABLE 3-1. ANNUAL PRODUCTION BY CASTING OPERATION TYPE (tons of metal poured)

Casting operation	Iron	Steel
Sand casting		
Green sand molds*	11,612,540	610,244
Chemically bonded sand molds*	1,422,995	564,358
Total sand	13,035,535	1,174,602
Centrifugal casting*	1,639,963	48,929
Permanent casting*	578,192	614,930
Investment casting	679	57,748
Expendable pattern (lost-foam) casting	63,609	7,922
Totals	15,317,978	1,904,131

*May involve the use of chemically bonded sand cores.
Source: EPA, 1998b.

The following sections briefly describe mold-making operations associated with sand mold, permanent mold, centrifugal, investment, and expendable pattern casting processes. Core-making processes are also described, but the discussion is limited to cores that use chemically bonded sand, the most prevalent type of material used to make cores. Potential HAP emissions associated with each mold- and core-making process are also discussed, as well as factors affecting these emissions.

3.3.1 Sand Mold and Core Making

In a typical sand-casting line, molding sand is shaped around two pattern halves in metal boxes, or flasks. The pattern halves are then removed, leaving two mold halves. If the mold halves are made of chemically bonded sand, additional steps are needed to harden the sand. Hardening, or curing, occurs through a chemical reaction that takes place at ambient temperature, at elevated temperature, or by catalysis. After the mold halves are formed, cores, if used, are placed inside the halves and then the upper half (the cope) and the bottom half (the drag) are fastened together. A continuous mold-making line operates in a similar manner, except that the two halves of the mold are joined in a vertical rather than a horizontal plane, and the molds are assembled in a continuous line without being enclosed by flasks.

To direct molten metal into the mold, vertical channels called sprues are cut into the mold. Runners connect the sprues to the bottom of the mold cavity. Risers are often cut into the mold above the cavity to provide a reservoir of molten metal to areas of the casting that solidify last and also to collect gas and debris such as loose sand.

Most sand molds are made from clay-bonded sand, which is commonly called green sand. The term "green" denotes the presence of moisture in the molding sand and indicates that the mold halves are not baked or dried prior to assembly. Green sand consists of approximately 85 to 95 percent sand, 4 to 10 percent bentonite clay, 2 to 5 percent water, and 2 to 10 percent carbonaceous materials such as seacoal (powdered bituminous coal), petroleum products, corn starch, or wood flour (EPA, 1997a). The clay and water act as the binder, holding the sand grains together. Carbonaceous materials reduce mold wall movement and create a reducing atmosphere that prevents the metal from oxidizing while it solidifies (EPA, 1992). Carbonaceous materials also facilitate the separation of the mold and the casting, which promotes good surface finish.

Some sand molds and virtually all sand cores are made from chemically bonded sand. Chemical bonding systems work by polymerization reactions that occur at ambient temperature or are induced by heat or catalysis. The major types of binder systems used for core making are the oil-bake, shell, hot-box, warm-box, no-bake, and cold-box systems. The major system used for mold making is the shell system (EPA, 1997a).

The oil-bake system is an older method used to produce cores. The system uses oil and cereal binders mixed with sand. The core is shaped in a core box and then baked in an oven to harden it. Oils used can be natural, such as linseed oil, or synthetic resins, such as phenolic resins. The oil-bake system was used almost exclusively before 1950 but has now been almost entirely replaced by other chemical binding systems (EPA, 1981).

The shell core system uses sand mixed with synthetic resins and a catalyst. The resins are typically phenolic or furan resins or mixtures of the two. Often the shell core sand is purchased as precoated sand. The catalyst is a weak aqueous acid such as ammonium chloride. The sand mixture is shaped in a heated metal core box. Starting from the heated surface of the core box, the heat cures the sand mix into a hard mass. When the outside 1/4 to 5/8 inches of sand has been cured, the core box is inverted, and the uncured sand is poured out, leaving a hard sand shell behind. The shell is then removed from the core box and allowed to cure for an additional few minutes, after which it is ready for placement in the mold (EPA, 1997a). The system has the advantage of using less sand and binders than other systems; however, precoated sand is more expensive than sand used in other mold-making processes.

The shell mold system is similar to the shell core system, but it is used to construct molds instead of cores. In this process, metal pattern halves are preheated, coated with a silicone emulsion release agent, and then covered by the resin-coated sand mixture. The heat from the pattern halves cures the sand mix, and the mold is removed after the desired thickness of sand is obtained. The silicone emulsion acts as a mold release, facilitating removal of the shell from the pattern after curing (EPA, 1997a).

The hot-box system uses sand mixed with a phenolic or furan resin and a weak acid catalyst. The major difference between this system and the shell system is that the core box is heated until the entire core solidifies. The system has the advantage of very fast curing times and a sand mix consistency that allows the core boxes to be filled and packed quickly. The system is therefore ideal for automation and the mass production of cores. The disadvantage is that more sand and binder are used in this system than in the shell core system (EPA, 1997a).

The warm-box system is essentially the same as the hot-box system, but it uses a catalyst that allows the resin binders to cure at a lower temperature (300 to 400 °F, compared to 450 to 550 °F for the hot-box system). As with the hot-box system, this system uses phenolic and furan resins. Either copper salts or sulfonic acids are used as catalysts. The advantage of the warm-box system over the hot-box system is that the former uses less energy for heating, which translates into lower costs (EPA, 1997a).

The cold-box system is relatively new to the foundry industry. It uses a catalytic gas to cure the binder at room temperature. A number of different systems are available, including a phenolic urethane binder with dimethylethylamine or triethylamine gas as the catalyst. Other systems include a sodium silicate binder with carbon dioxide (CO_2) gas as the catalyst and epoxy or furan binders with sulfur dioxide (SO_2) gas as the catalyst. Compared to other chemical systems, cold-box systems have a short curing time (less than 10 seconds) and therefore are well suited to mass production techniques (EPA, 1997a). In addition, the absence of costly oven heating can result in substantial energy savings. Because they are not consumed in the chemical reactions, the catalytic gases must be collected after they are purged from the core box.

The no-bake or air-set binder system allows curing at room temperature without the use of reactive gases. The no-bake system uses either acid catalysts or esters to cure the binder. The acid catalysts are typically benzene, toluene, or sulfonic or phosphoric acids. Binders are either phenolic resins, furan resins, sodium silicate solution, or alkyd urethanes. This type of system has the advantage of substantial savings in energy costs, but it typically requires more curing time than the other systems (EPA, 1997a).

Green sand mold making is not a source of significant HAP emissions because the process does not involve heating or curing. In chemically bonded sand mold- and core-making processes, however, the mixing and curing of the binder may generate substantial HAP emissions. The potential for HAP emissions varies between binder systems, depending on the amounts of HAP used in the formulation and the extent to which they react in the curing process. For example, certain HAPs, such as methylene diphenyl diisocyanate (CAS No. 101-68-8), phenol and formaldehyde in the original binder formulations, are polymerized during the reaction process. Other HAP chemicals may be present as solvents, stabilizing agents, or catalysts that do not participate in the polymerization reaction. Portions of these chemicals evaporate during the mold- and core-making process; the unevaporated portion remains in the chemically bonded mold or core sand. This remaining portion may either (1) pyrolyze as molten metal is poured into the mold (true particularly for chemical near the inner mold surface); (2) evaporate during cast cooling as the temperature of the mold sand further from the molten metal increases; or (3) evaporate during shakeout and subsequent sand handling, when a greater surface area of sand is exposed to the atmosphere.

After chemically bonded molds and cores are cured, they are often coated with a finely ground refractory material to provide a smoother surface finish on the casting. The refractory material is applied as a slurry. After coating, the liquid component of the slurry is either allowed to evaporate or, if it is a flammable substance such as alcohol, is eliminated by ignition (the light-off process).

Little information is available on emissions from the mold- and core-coating process. If molds or cores are coated after forming and curing, the liquid component of the slurry will either evaporate or be destroyed, to some extent, by incineration, if the light-off procedure is used. Most coatings used by foundries do not contain HAPs because they are either water based or isopropanol based. One HAP commonly used in coating slurries is methanol. If the coating is simply dried, all of the HAP in the liquid will be emitted. If the coating is ignited, emissions will be reduced by the amount of HAP consumed by the light-off flame unless other HAPs are generated as combustion products.

3.3.2 Permanent and Centrifugal Mold Preparation

Permanent mold and centrifugal casting operations use reusable molds made from cast iron, graphite, or steel. Although the molds eventually deteriorate, they can be used to make thousands of castings before being replaced. These operations may also incorporate sand cores. The amount of sand used, however, is small compared with the amount used in a sand mold with the same amount of metal poured. Permanent molds offer advantages over sand molds, including a more uniform shape, a higher degree of dimensional accuracy, and a more consistent quality of finish on the castings. The process though is more expensive than using sand molds and is generally not employed for very large castings. Some of the largest steel foundries use this process to make castings for the railway industry, such as wheels for railcars.

In centrifugal casting, the molten metal is introduced into a mold that is rotated during solidification of the casting. The centrifugal force shapes and feeds the molten metal as it is forced into the designed crevices and details of the mold. This process is ideally suited to the casting of cylindrical shapes such as pipe.

Metal molds undergo specific preparation steps prior to pouring, including an initial cleaning of the mold followed by preheating and the spraying or brushing on of a mold coating. Coatings are typically mixtures of sodium silicate and either vermiculite, talc, clay or bentonite (EPA, 1997a). They may also consist of acetylene soot. The coatings insulate the molten metal from the relatively cool, heat-conducting mold. This allows the mold to be filled completely before the metal begins to solidify. The coatings also help produce a good surface finish, act as a lubricant to facilitate casting removal, and allow any air in the mold to escape via space between the mold and coating.

Emissions of HAPs from permanent and centrifugal mold-making preparation come primarily from the making of sand cores where used. These cores are often made using the shell system described previously. Materials used to coat permanent and centrifugal molds generally do not contain significant amounts of HAPs.

3.3.3 Investment Casting Mold Making

The investment casting process uses a pattern around which a mold made of a refractory material is formed. Pattern materials are most commonly wax or polystyrene. Waxes can be synthetic, natural, or a combination of materials.

The mold-making process begins with the production of the patterns, which are usually mass produced by injecting liquid or semiliquid wax or plastic into a die (a metal mold). Multiple patterns are attached to a gating system (a sprue and runners) constructed of the same material to form a tree assembly. The assembly is coated with a specially formulated heat-resistant refractory slurry mixture that is allowed to harden around the assembly, thus forming the mold (EPA, 1997a).

In the flask molding method, the assembly is placed in a flask and then covered with a refractory slurry, which is allowed to harden. In the more common shell method, the assembly is dipped in a refractory slurry, then coarser grained refractory is sifted onto the slurry-coated pattern assembly and the slurry is allowed to harden. This two-step process is repeated until the desired shell thickness is reached (EPA, 1997a). In both methods, the wax assembly is then melted out of the shell and the shell is subsequently heated to remove any residual pattern material and to further cure the binder system. The shell is then ready for the pouring of molten metal into the central sprue; the metal is channeled through the runners into the individual molds.

Although usually not necessary, cores can be used in investment casting for complex interior shapes. The cores are inserted during the pattern-making step. The cores are placed in the pattern die and pattern wax or plastic is injected around the cores. After the pattern is removed from the die, the cores are removed. Cores used in investment casting are typically collapsible metal assemblies or soluble salt materials, the latter of which are leached out with water or a dilute solution of hydrochloric acid or citric acid.

The refractory slurries used in investment casting are comprised of binders and refractory materials. Refractory materials include silica, aluminum silicates, zircon, and alumina. Binders include silica sols (very small silica particles suspended in water), hydrolyzed ethyl silicate, sodium and potassium silicate, and gypsum type plasters. Ethyl silicate is typically hydrolyzed at the foundry by adding alcohol, water, and hydrochloric acid to the ethyl silicate as a catalyst (EPA, 1997a).

Emissions of HAPs from investment casting include polystyrene vapors from the melting of wax in making patterns, pyrolysis products of wax formed during pattern meltout and shell curing, and hydrochloric acid fumes emitted from core-leaching operations.

Vapors from wax melting and acid leaching are, at most, a workplace consideration. Emissions from meltout are commonly incinerated by an afterburner. Wax remaining in the shell after meltout is about 20 percent of the total at most and may typically be less than 10 percent. Limited data show that emissions of paraffin are less than 0.1 percent of the wax input to the furnace, and emissions of particulate (not characterized) may be as high as 1.5 percent (Investment Casting Institute, 1995). One foundry estimates its annual emission of VOCs at 0.05 tons and its annual emission of particulate matter at 0.07 tons. Emissions from this process therefore do not appear to be significant enough to warrant further consideration.

3.3.4 Expendable Pattern Making

Expendable pattern casting, also called the lost-foam process, is a relatively new process that is gaining increased use. A one-piece expendable pattern is made by assembling polystyrene forms, which are made from polystyrene beads blown into a cast aluminum mold and consolidated by heating. The mold for the casting is created by placing the pattern into a container, pouring sand around the pattern, and compacting the sand by vibrating the container. When hot metal is poured into the mold, it replaces the foam and creates a casting of the same shape. The foam is converted into vapor, which escapes through the sand. Emissions of HAPs from expendable pattern making consist of polystyrene vapors. Expendable patterns are typically made outside the foundry and therefore do not constitute a source of foundry emissions.

3.4 SCRAP PREPARATION

Foundries use recycled scrap metals as their primary source of metal and resort to metal ingots as a secondary source when scrap is not available. Scrap metals typically require some type of preparation prior to melting such as cutting or sizing, shot or sand blasting to remove coatings, cleaning with organic solvents to remove oils and grease, and drying. The degree of scrap preparation is generally dictated by furnace type. Most cupolas and electric arc furnaces (EAFs) require minimal scrap preparation (typically only sizing) (EPA, 1981). The presence of water or oil can cause an explosion in electric induction furnaces (EIFs); therefore, scrap is frequently cleaned and preheated before being charged to these furnaces. Oily or wet scrap does not cause explosions in cupolas or EAFs (EPA, 1981). A total of 117 foundries responding to the 1998 industry survey reported using preheaters, and all of these foundries used EIFs. Most (111 of 117) used EIFs exclusively as their melting furnace. The six other foundries used EIFs in conjunction with EAF or cupola melting furnaces. However, these foundries generally indicated in their survey responses that the scrap preheater was specifically associated with the EIF (EPA, 1998b).

The use of scrap preheaters is tied not only to the type of furnace used. It also depends on the type of scrap metal processed. Approximately 98 percent of the foundries that reported using preheaters in 1998 melted iron. Roughly 80 percent of all iron melted in EIFs was first preheated, whereas only about 10 percent of the steel melted in EIFs was first preheated (EPA, 1998b).

Mechanical processes associated with scrap preheaters (e.g., loading of scrap) generate particulate matter (PM) emissions that are of concern only in the work area. Scrap preheating itself can produce both PM and organic emissions. Over 90 percent of preheaters are direct-fired with natural gas. Metal HAP content of the PM is expected to be a function of the composition of the scrap. Data presented by Shaw (1982) indicate that manganese was the major HAP from preheaters used in iron foundries in the early 1980s. Shaw reported that manganese was about 2 percent of the PM from a top-firing preheater and 0.1 percent from a bottom-firing preheater. The only other HAP metal reported at a significant level was chromium at 0.5 percent of the PM from bottom firing and 0.1 percent from top firing. Organic HAP emissions, which arise from oil and grease contaminants, are assumed to include products of incomplete combustion, but these organic HAP emissions have not been characterized.

3.5 METAL MELTING

Table 3-2 shows the annual production of iron and steel reported in the 1998 survey (EPA, 1998b). While the number of EIFs was nine times greater than the number of cupolas and eight times greater than the number of EAFs, approximately 60 percent of the total annual production of iron was melted in cupolas. Approximately 83 percent of the total annual production of steel was melted in EAFs. Based on the survey responses, foundries that exclusively used furnaces other than cupolas or EAFs tended to be smaller in terms of tons of metal melted. Large production iron foundries typically melted with cupolas, while large production steel foundries typically melted with EAFs.

Table 3-3 lists the usage of melting furnaces reported at ferrous foundries (EPA, 1998b). The types of melting furnaces were, in decreasing order of number of foundries using them: EIFs (445 foundries), cupolas (111 foundries), EAFs (81 foundries), reverberatory furnaces (5 foundries), crucible furnaces (2 foundries), and electrical resistance furnaces (2 foundries). A total of 594 foundries identified melting furnace type; 545 (92 percent) of these foundries used only one type of furnace. All of the remaining 49 foundries used only two types.

In addition to melting furnaces, ferrous foundries also used holding furnaces and duplexing furnaces. A holding furnace is an EAF or EIF used to maintain the molten metal in the proper condition until the foundry is ready to pour. A duplexing furnace 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.

The following sections briefly describe the predominant types of melting furnaces at ferrous foundries (cupola, electric induction, and electric arc) and emissions associated with each type.

TABLE 3-2. REPORTED ANNUAL PRODUCTION BY TYPE OF FURNACE

Type of melting furnace	Number of furnaces	Production, tons/yr			Percentage of annual production, %		
		Iron	Steel	Total metal	Iron	Steel	Total metal
Cupola	143	9,175,505	10,298	9,185,803	59.9	0.5	53.3
Electric induction	1,397	5,564,270	319,998	5,884,268	36.3	16.8	34.2
Electric arc	163	571,525	1,573,441	2,144,966	3.7	82.6	12.5
Other	15	6,679	394	7,073	0.04	0.02	0.04
Total	1,718	15,317,979	1,904,131	17,222,110	100	100	100

Source: EPA, 1998b.

TABLE 3-3. TYPES OF MELTING FURNACES REPORTED BY FOUNDRIES

Type(s) of melting furnaces	Number of foundries with furnace type(s)			
	Iron only foundries	Steel only foundries	Iron and steel foundries	Total No. of foundries
Cupola only	93	0	1	94
Electric arc only	3	38	8	49
Electric induction only	216	104	74	394
Other furnace type (reverberatory; crucible) only	6	1	0	7
Total number of foundries with one furnace type	**318**	**143**	**83**	**544**
Electric induction and cupola	16	0	0	16
Electric induction and electric arc	3	20	8	31
Electric induction and other	2	2	0	4
Total number of foundries with multiple furnace types	**21**	**22**	**8**	**51**
Total number of foundries	**339**	**165**	**91**	**595**

Source: EPA, 1998b.

3.5.1 Cupolas

Figure 3-2 shows a schematic of a cupola. The cupola is a hollow vertical refractory-lined or water-cooled steel cylinder. Hinged doors at the bottom allow the furnace to be emptied when not in use. When charging the furnace, the doors are closed and a bed of sand is placed at the bottom of the furnace, covering the doors. A charge consisting of coke for fuel, scrap metal, alloying materials, and flux is the loaded into the furnace.

Flux, often chloride or fluoride salts, is added to the furnace to remove impurities. The flux unites with impurities to form dross or slag, which rises to the surface of the molten metal and helps to prevent oxidation of the metal. The presence of coke in the melting process raises the carbon content of the metal to the casting specifications. Heat from the burning coke melts the scrap metal and flux, which drip to the bottom. A hole that is level with the top of the sand bed allows molten metal to be drawn off, or tapped. A higher hole allows slag to be tapped. Additional charge is added as needed (EPA, 1997a).

3.5.1.1 <u>HAP Emissions From Cupolas</u>. While emission factors for PM (all three furnace types) and VOCs (EAF only) are well documented (EPA, 1995), little information is available for HAP emissions. To partially fill this information gap, in 1997 the EPA conducted source tests on exhaust gases from two cupolas, one controlled by a baghouse and one by a wet scrubber. Both cupolas were also equipped with afterburners, used primarily to combust carbon monoxide (CO), a major reaction product of burning coke. The afterburners also serve to incinerate other organic emissions such as products of incomplete combustion of oil and grease contaminants on the scrap metal. In both tests, PM and HAP metals were measured at the control device inlets and outlets using EPA Method 29. Semivolatile HAPs were measured at the outlets using SW-846 Methods 0010 and 8270, and dioxin and furan (D/F) emissions were measured at the outlets using Method 23. Also, volatile organic HAPs were measured at the wet scrubber outlet using a direct interface gas chromatography/mass spectroscopy method.

A summary of the test on the cupola controlled by a baghouse can be found in the EPA's published report on the test (EPA, 1997b). Prior to entering the baghouse, the exhaust passed through a solids settler, afterburner, and heat recuperator. At the baghouse inlet, metal HAPs were on average 4.08 percent of the PM, for which the average mass flow rate was 322 pounds per hour (lb/hr) and the PM emission factor was 7.26 lbs/ton of metal melted. Manganese and lead represented 51 and 47 percent, respectively, of the metal HAP content. The total of

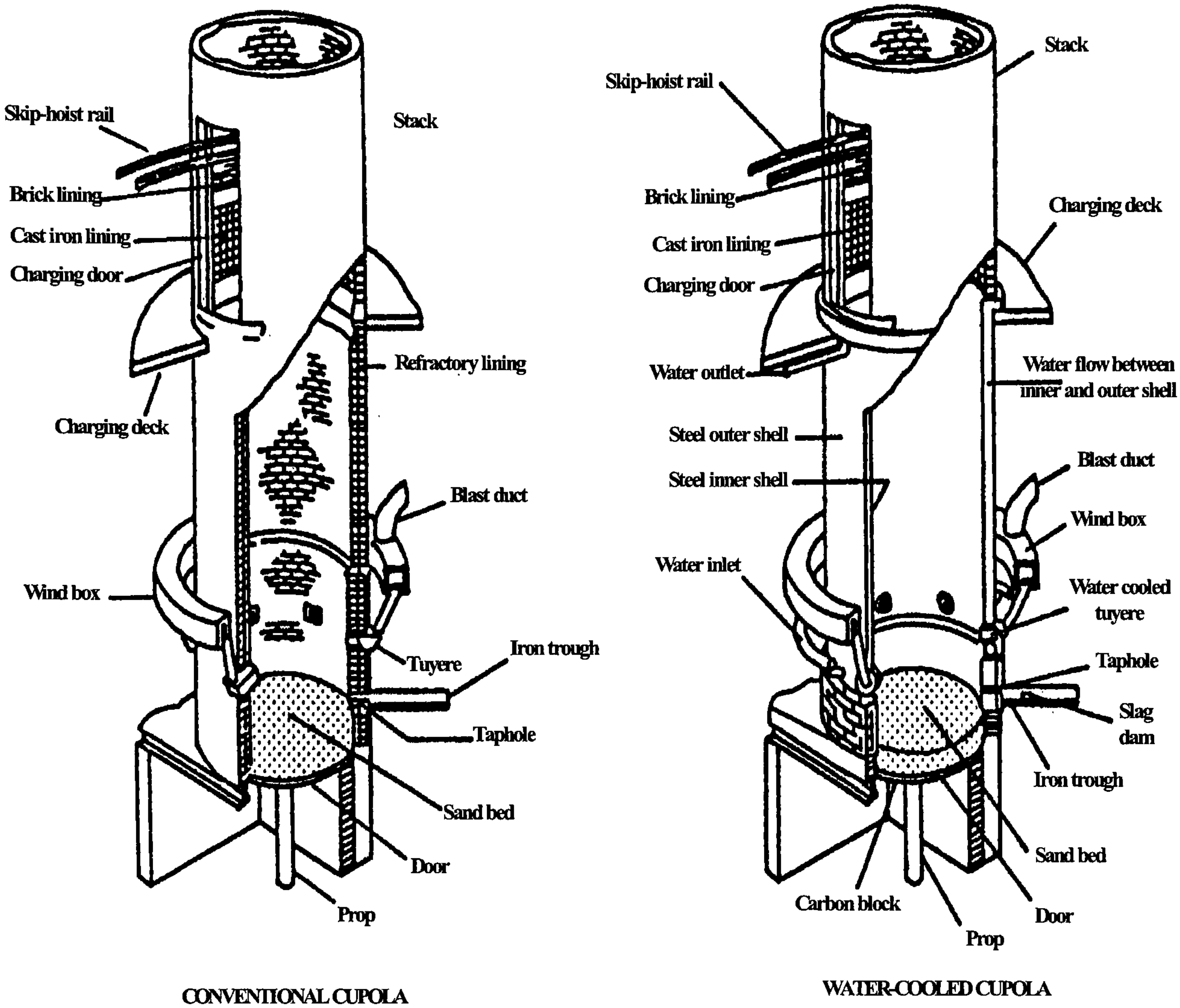


Figure 3-2. Conventional and Water-Cooled Cupolas.

semivolatile HAPs, of which only acetophenone, bis(2-ethylhexyl)phthalate, naphthalene, phenol, and 2,4,6-trichlorophenol were detected in amounts above the quantitative limit, was on average 0.00311 lb/hr at the baghouse outlet. The total D/F at the baghouse outlet was on average 275 micrograms of toxic equivalency (μg TEQ) per hour.

A summary of the test on the cupola controlled by a wet scrubber can be found in the EPA's published report on the test (EPA, 1997c). Prior to entering the scrubber, the cupola exhaust passed through an afterburner, recuperator, and quencher. At the scrubber inlet, metal

HAPs were, on average, 5.69 percent of the PM, for which the mass flow rate was 123 lb/hr and the PM emission factor was 4.16 lb/ton. Manganese and lead represented, on average, 83 percent and 16 percent, respectively, of the metal HAP content. No volatile organic HAPs and no significant quantities of semivolatile organic HAPs were measured at the outlet. The total D/F at the scrubber outlet was on average 18.8 μg TEQ per hour.

Cowen (undated) indicated that manganese ranged from 1 to 2 percent of the cupola baghouse catch, and the EPA (1990) reported manganese as the major HAP at 4.5 percent of the catch. Data for total metal HAP included 5.2 percent (EPA, 1990) and 6.5 percent (Euvrard and Jackson, 1992) of the PM.

Measurements of polycyclic organic matter (POM) after controls were reported as 0.0035 lb/ton of metal melted, and D/F measurements (after a baghouse) were on the order of 10^{-7} to 10^{-10} lb/ton (Emcom, 1990; Normandeau Associates, Inc.,1992). Benzene (after an electrostatic precipitator [ESP]) was 0.0003 lb/ton. Baldwin (1982) reported 0.18 lb/ton of total organics from a baghouse controlling a cupola. Information was unavailable on the HAP content of the organics.

3.5.1.2 <u>Factors Affecting Emissions From Cupolas</u>. Organic vapors from cupolas vary with the oil and grease content of the scrap and with the efficiency of afterburning. Particulate emissions will vary according to the type of coke burned, type of metal melted, melting temperature, and a number of operating practices. The following factors affect particulate (and thus metal HAP) emissions from cupolas (EPA, 1981):

- Unlined furnaces generally have higher emissions than lined furnaces.
- Screening charge materials and other precautions to limit the amount of loose sand, rust, and coke fines charged to the furnace result in a 40- to 60-percent reduction in emissions.
- The use of briquettes and oily scrap increases emissions.
- Oxygen enrichment increases the PM concentration, but any increase in emissions may be offset by shorter melting times.
- Melting metal at a higher rate produces a higher loading of fine particles.
- An increase in the blast rate increases emissions.

A major factor in reducing organic substance emissions is the use of efficient afterburning. When properly designed and operated, afterburners provide high destruction efficiencies (typically more than 99 percent) of organic compounds (EPA, 1991).

In summary, emissions of HAP metal compounds, particularly manganese and lead, from cupolas can be substantial. Emissions of organic HAPs from cupolas with efficient afterburners appear to be low.

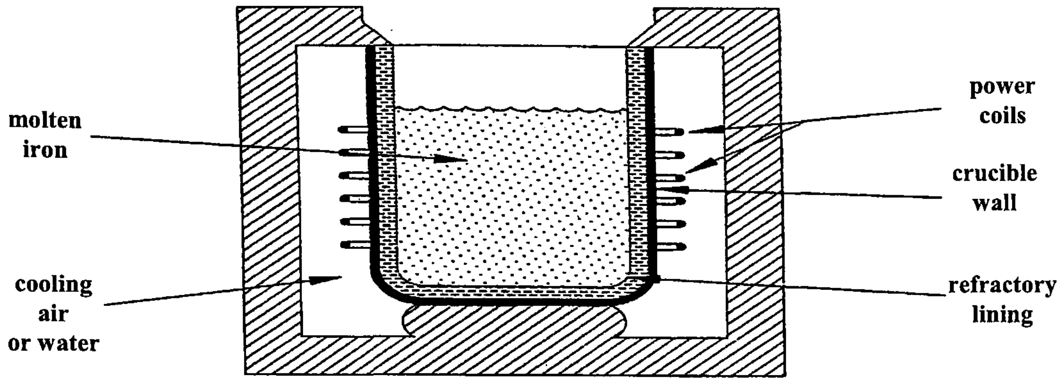
3.5.2 EIFs

An EIF operates by passing an electric current through a coil either around or below the main body of the furnace. Furnaces with the coil around the furnace body are called coreless induction furnaces, and those with the coil below the body are called channel induction furnaces. Both types are shown in Figure 3-3. An alternating electric current through the coils generates an alternating magnetic field, which in turn creates a current in the metal charge. The metal is melted by resistance heating produced by the current. Consequently, EIFs may also be referred to as electric resistance furnaces. The coils carrying the electric current are typically cooled with water. An EIF requires cleaner scrap input than EAF, but an EIF can make more precise adjustments to the metallurgical properties of the metal (EPA, 1997a).

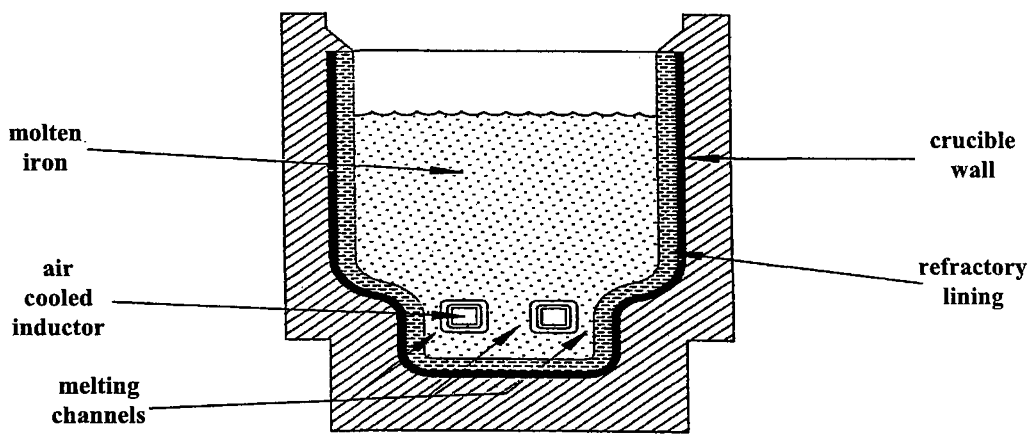
The coreless furnace can melt cold charges; however, most foundries maintain a heel of molten metal in the furnace to increase efficiency and to lower thermal shock to the refractory lining. Power inputs for furnaces used in the foundry industry range from less than 100 to 17,000 kilowatts for coreless furnaces and up to 4,000 kilowatts for channel furnaces. As previously noted, the presence of water or oil can cause an explosion in EIFs, therefore, metal scrap (specifically iron scrap) is frequently preheated to drive off these substances before being charged to these furnaces.

Shaw (1982) provides a review of emission test results for uncontrolled PM emissions from EIFs. The review includes numerous studies that were performed to characterize these emissions and the factors that affect them. The emission factors ranged from 0.26 to 1.5 lb/ton, and most were in the range of 0.26 to 0.77 lb/ton.

Another study (EPA, 1981) reported a range of 0.12 to 1.5 lb/ton, with a best estimate of 1.0 lb/ton. These emission factors include emissions from charging, melting, superheating, and pouring, and in some cases, emissions from nodularization using magnesium alloy. One of the studies found that 45 percent of the emissions came from melting, 25 percent from charging, and 30 percent from pouring and slagging. The AP-42 (EPA, 1995) emission factor is given as 0.9 lb/ton for uncontrolled emissions and 0.2 lb/ton after baghouse control.



Coreless induction furnace



Channel induction furnace

Figure 3-3. Types of EIFs.

The EPA (1990) reported that manganese was the major metal HAP in dust from EIFs, at 1.7 percent, followed by lead, at 0.5 percent, with total metal HAPs at 2.4 percent. Shaw (1982) reported that EIFs producing malleable and ductile iron generated dust that contained chromium (0.5 to 0.75 percent) and manganese (0.5 percent), with total metal HAPs at 1.1 to 1.3 percent (nickel, lead, and cobalt were also detected). The dust generated by EIFs melting steel is expected to contain more HAP metals than the dust from iron melting because of the use of alloys, especially for stainless steel.

The following factors have been found to affect particulate emissions from EIFs (EPA, 1981):

- Whether or not the metal scrap is preheated prior to charging to the furnace (cold charging produces more emissions than hot charging);
- The type of metal used (nodular iron produces greater emissions than malleable iron); and
- The presence of alloying metals such as chromium and nickel (PM emissions will contain higher fractions of these metals).

3.5.3 EAFs

Figure 3-4 shows a schematic of an EAF. EAFs are used almost exclusively to melt steel. The EAF is a refractory-lined cylindrical vessel made of heavy welded steel plates and having a bowl-shaped hearth and a domed-shaped roof. For alternating current furnaces, three graphite electrodes are mounted on a superstructure above the furnace and can be raised and lowered through holes in the furnace roof. A direct current furnace uses only one electrode and provides stable electrical current to the metal scrap with less electrode consumption. Of the 168 EAFs described in EPA's 1998 questionnaire, 139 were alternating current and 25 were direct current furnaces; 4 furnaces were unspecified (EPA, 1998b).

Melting is accomplished in EAFs by heat from direct radiation from arcs formed between the electrodes of the furnace and the metallic charge, by direct radiation from the furnace lining, and by the resistance of metal between the arc paths. Metal-melting operations in an EAF may include: (1) furnace charging, in which metal, scrap, alloys, carbon, and flux are added to the furnace; (2) melting, during which the furnace remains closed; (3) backcharging, which is the addition of more metal and possibly alloys after the initial charge is melted; (4) refining by single-slag (oxidizing) or double-slag (oxidizing and reducing) operations; (5) oxygen lancing by injecting oxygen into the molten steel to adjust the chemistry of the metal and speed up the melt; and (6) tapping the molten metal into a ladle or directly into molds. Raw materials may be charged to an EAF by removing the roof and adding the materials via a bucket suspended from an overhead crane, through a chute opening in the roof, or through a door in the side of the furnace.

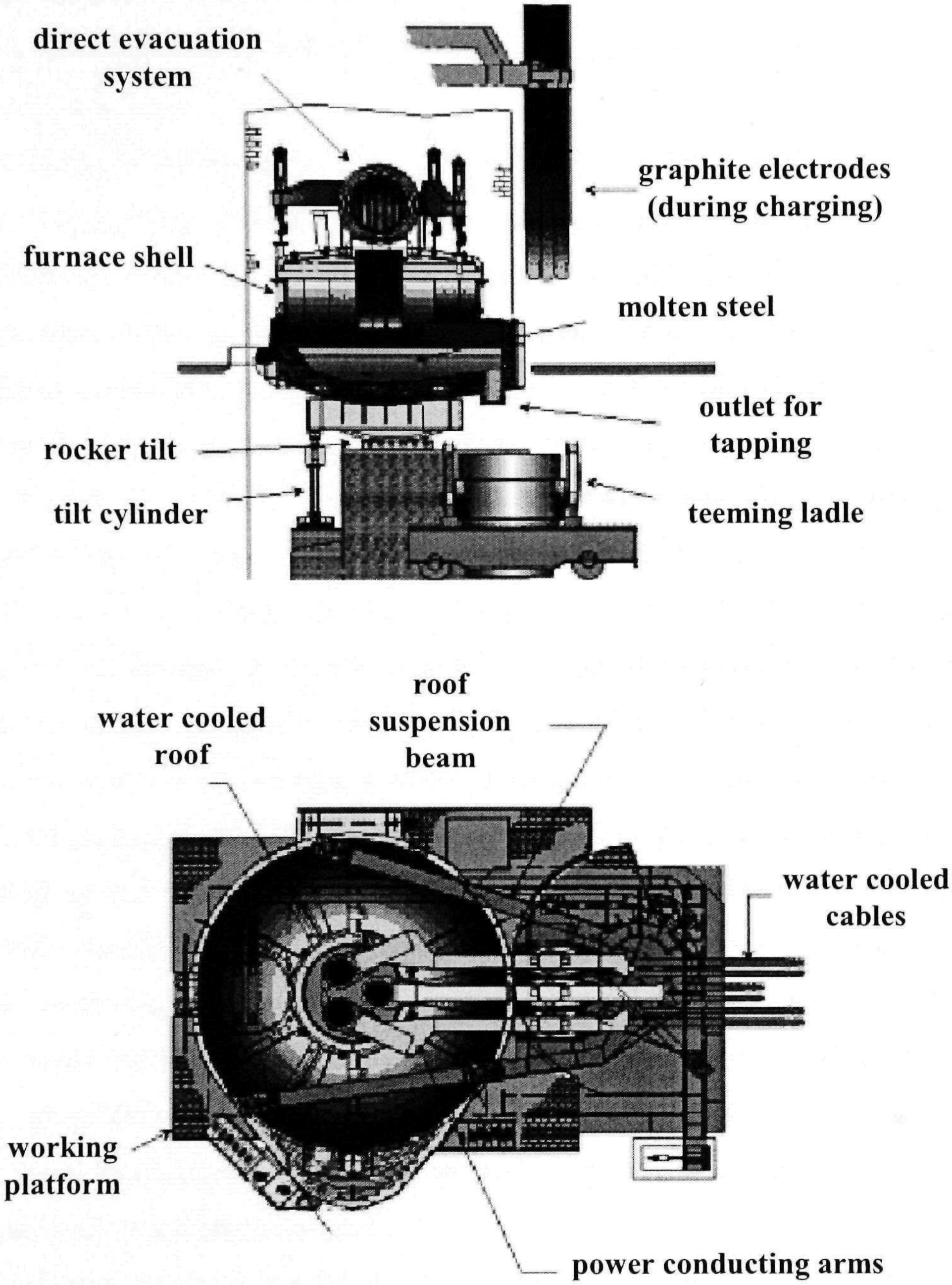


Figure 3-4. Side and Top View of an EAF.

In steel foundries, PM may contain varying amounts of metal HAPs such as zinc, lead, nickel, cadmium, and chromium. Carbon steel dust can be high in zinc as a result of the use of galvanized scrap, while stainless steel dust is high in nickel and chromium. Painted scrap can result in PM high in lead.

Test data for HAP emissions from a baghouse on an EAF showed total metal HAP emissions at 0.0047 lb/ton, with the major HAPs as lead (0.0029 lb/ton) and manganese (0.00066 lb/ton) (Ecoserve, Inc., 1990). HAP metals reported in lower concentrations included antimony, arsenic, cadmium, chromium, mercury, nickel, and selenium.

Calspan Corporation (1978) reported manganese as the major HAP in dust from an EAF melting steel, at 3.4 to 4.3 percent of the dust, with lower levels of lead (0.8 to 2.4 percent) and chromium (0.1 to 0.27 percent). The sum of the metal HAPs ranged from 4.5 to 6.8 percent. The EPA (1990) has also reported manganese as the major HAP (8.7 percent) with total metal HAPs at 12.3 percent for an EAF melting steel. Bates and Scheel (1974) reported that the fumes from five alloy and stainless steel heats in an EAF contained 8.8 percent chromium compounds (Cr_2O_3) and 2.8 percent manganese compounds (MnO), with total metal HAPs at 12.2 percent. The analysis of dust at three other plants showed manganese to be the major HAP, with a range from 0.2 to 5.0 percent, followed by chromium at 0.1 to 3 percent. Total metal HAPs were found to range up to 3.6, 4.8, and 9 percent for the three plants (Bates and Scheel, 1974).

In 1980, the EPA (1980b) presented data for dust analyses from EAFs melting iron. Manganese was the major metal HAP at 2 percent, and total metal HAPs for three foundries were 2.5, 3, and 4.2 percent, respectively. Other metal HAPs included lead, nickel, and chromium. These data on dust analyses indicate that the composition of EAF dust is affected by the type of metal that is produced, with higher HAP concentrations reported for steel than for iron, especially alloy and stainless steel.

No information was found for organic HAP emissions from EAFs. Baldwin (1982) reported 0.35 lb/ton of total organics from the baghouse of an EAF, but information was unavailable on the HAP content of the organics. The EPA (1993) reports total VOC from an EAF as 0.06 to 0.3 lb/ton, but again there is no indication of the HAP component.

The following factors have been found to affect particulate emissions from EAF:

- Emissions are higher from scrap that contains oil, oxidation (rust), and sand particles from casting returns (EPA, 1981).

- Oxygen lancing, used for adjustment of chemistry, speeding up of the melting process, and superheating, increases emissions (EPA, 1981).
- Alloys such as chrome may be added to the furnace just prior to tapping. The addition of the alloys increases particulate emissions during tapping (EPA, 1983).
- Backcharging produces a large eruption of fumes with a strong upward thermal driving force. The emissions during backcharging are higher than during charging due to the heat of the molten steel bath in the furnace (EPA, 1983).
- Adding raw materials to the furnace by removing the roof generates more emissions than adding the materials through a chute or side door (EPA, 1983).

3.6 POURING, COOLING, AND SHAKEOUT

According to the 1998 survey, most metal is poured into sand molds as shown in Table 3-4, which lists the amounts of metal poured in the different types of casting lines. Pouring operations vary widely depending upon the type of mold used and the degree of mechanization in a particular foundry.

TABLE 3-4. METALS POURED BY TYPE OF CASTING OPERATION

Casting Operation	Metal Poured, tons/yr
Sand Casting	
Green sand molds*	12,222,784
Chemically bonded sand molds*	1,987,353
Centrifugal Casting*	1,688,892
Permanent Casting*	1,193,122
Investment Casting	58,428
Expendable Pattern (lost-foam) casting	71,531

*May involve the use of chemically bonded sand cores.
Source: EPA, 1998b.

3.6.1 Sand Casting

The two principal types of pouring operations are (1) floor or pit pouring, in which ladles are moved to stationary molds, and (2) pouring stations, in which the ladle is held at one place and the molds are moved to the station on conveyors. After molten metal has been ladled into the mold and begins to solidify, the molds are transported to a cooling area where the casting solidifies before being separated from the mold. Larger, more mechanized foundries generally use automatic conveyor systems to transfer the casting and mold through a cooling tunnel on the way to the shakeout area, where castings are separated from sand or refractory molds. Less mechanized foundries and foundries that produce very large castings allow the castings to cool on the shop floor. In the shakeout area, molds are typically placed on vibrating grids or conveyors to shake the sand loose from the casting. In some foundries, the mold may be separated from the casting manually (EPA, 1981).

3.6.1.1 HAP Emissions from PCS. The majority of HAP emissions from PCS operations are organic HAP emissions created by incomplete combustion of organic material in the mold and core sand. Metal fume emissions may occur during pouring, and PM, primarily sand with trace amounts of metal HAPs, is emitted during shakeout. Results of investigations on organic and metal HAP emissions are discussed in the following sections.

3.6.1.2 Summary of Research Findings on Organic HAPs. In one laboratory experiment (Scott, Bates, and James, 1976), researchers analyzed pouring and cooling emissions during the manufacture of 40-kilogram castings. Metal was poured into 12 different types of sand molds, most of which were made using chemical bonding systems. Emission sampling was started approximately 1 minute after pouring and continued for 1 hour. Measured HAP included hydrogen cyanide, formaldehyde, acrolein, C_2-C_5 aldehydes, benzene, toluene, xylene, naphthalene, and phenol. (Note: Other HAPs may have been present that were not analyzed.) Prior work by these researchers showed that hydrocarbon emissions peaked approximately 6 minutes after pouring; a second peak occurred during shakeout (castings were cooled for approximately 25 minutes prior to shakeout). The results suggest that organic emissions during shakeout can be of the same order of magnitude as those generated shortly after pouring. During shakeout, hot metal and sand contact cooler sand that contains binder material and other organics, which can result in additional volatilization and thermal decomposition.

Baldwin (1979) measured total organics at an operating foundry using green sand molds with phenolic isocyanate cores and phenol-formaldehyde shell molds. The resulting emission factors for total organics were 0.14 lb/ton of metal poured from pouring and cooling combined, 1.2 lb/ton from shakeout before a scrubber, and 1.0 lb/ton after a scrubber (Baldwin, 1979; EPA, 1980a).

Euvrard and Jackson (1992) reported measurements of total organic emissions from a gray iron foundry using green sand molds with various types of cores (oil, phenolic isocyanate, phenolic ester, furan hot box). Based on their data, the emission factor for total volatile and semivolatile organic emissions from PCS was 0.37 lb/ton, of which 0.32 lb/ton were HAPs. The single major HAP detected was benzene at 0.2 lb/ton. The organic emissions measured after the shakeout scrubber were about twice the emissions measured during the pouring and cooling steps.

Wingra Associates (1992) report emissions of organic HAPs from PCS at two foundries using green sand molds and various types of chemically bonded sand cores. Total organic HAP emission factors for PCS combined ranged from 0.42 to 1.6 lb/ton at the two foundries. Emission factors for the single major HAP (benzene at one plant and acrolein at another) ranged from 0.13 to 1.6 lb/ton.

The results obtained by Baldwin and by Euvrard and Jackson suggest that volatile organics are the primary component of the organic emissions from pouring and cooling and that semivolatiles (e.g., polycyclic aromatic hydrocarbons) are minor constituents. These higher boiling organic compounds may tend to condense on the sand as they migrate through the mold or core. However, as the mold is broken up in the shakeout process, the potential for semivolatile HAP emissions increases. Recent test data submitted with the survey responses indicated that emissions of methylnaphthalene (a semivolatile HAP) accounted for two-thirds of all HAP emissions from shakeout (EPA, 1998b).

The Casting Emission Reduction Program (CERP), a cooperative initiative involving several industry and government stakeholders to reduce air emissions and improve casting efficiency, performed testing in a "pre-production" foundry to measure emissions from PCS (CERP, 1999). The pre-production foundry is a general purpose manual foundry that has been adapted and instrumented to allow the measurement of emissions using EPA protocols. The report cautioned that the results are not suitable for use as general emission factors; however, the test results (summarized in Table 3-5) are consistent with those described earlier. The background baseline results with no known organics in the molds or cores show HAP emissions that are over an order of magnitude less than those when organics are present. The green sand baseline and core baseline both show about the same level of HAP emissions (0.32 lb/ton), even though there was over 20 times more mold sand than core sand. When organics are present in both the mold and core sand (green sand and core baseline), the results are roughly the sum of what was emitted during the green sand baseline and core baseline.

CERP also performed testing in a production foundry to measure emissions from PCS (CERP, 2000). Green sand molds with seacoal and phenolic urethane cold-box cores were used. The ratio of mold sand to metal was 8.3, and the ratio of core sand to metal was 0.36. Results are summarized in Table 3-6 and are consistent with other reported values.

TABLE 3-5. EMISSION TEST RESULTS FOR A PRE-PRODUCTION FOUNDRY

Parameter	Background baseline	Green sand baseline	Core baseline	Green sand and core baseline
Description	Molds and cores with no known organics	Green sand mold* and core with no known organics	Molds with no known organics and phenolic urethane cold-box core	Green sand mold* and phenolic urethane cold-box core
Mold sand-to-metal ratio	6.0	5.7	5.4	5.5
Core sand-to-metal ratio	0.27	0.27	0.24	0.26
Sum of HAPs (lb/ton of metal)	0.025	0.32	0.32	0.54
Benzene (lb/ton of metal)	0.006	0.12	0.14	0.22

* Contained seacoal.
Source: CERP, 1999.

TABLE 3-6. EMISSION TEST RESULTS FOR A PRODUCTION FOUNDRY

Analyte	PCS emissions, lb/ton of metal
Sum of HAP	0.49
Sum of POM*	0.06
Benzene	0.23
Toluene	0.072

* Polycyclic organic matter (primarily naphthalene, 1- and 2-methylnaphthalene).
Source: CERP, 2000.

3.6.1.3 Summary of Research Findings on Metal HAP Emissions from PCS. The available references provided little data on the composition of PM from PCS. Because of a large proportion of sand, emissions from shakeout are expected to contain a lower percentage of metal HAPs than the levels found in dust from melting furnaces. In one study, manganese was found at a level of 2.9 percent of the PM in one of two plants, but there was no indication whether the manganese resulted primarily from pouring or shakeout emissions (Wingra Associates, 1992).

Potas and Blair (1993) reported manganese as the major HAP in dust captured by a baghouse; their analysis of captured dust (probably largely sand) indicated that the metal HAP comprised only a fraction of a percent of the PM. Measurements reported at a gray iron foundry indicated that manganese was the major metal HAP from pouring and cooling (shakeout emissions were not analyzed), and that total metal HAPs were 3 percent of the PM (Euvrard, 1992).

Although limited, the above data indicate that metal HAPs comprise a few percent of the total PM from pouring and cooling and that the percentage is likely to be much less for shakeout emissions.

3.6.1.4 Factors Affecting HAP Emissions from PCS. Emissions from PCS are expected to be affected by factors such as the composition of molds and cores, mold size, sand-to-metal ratio, surface area of the sand/metal interface, metal temperature, pouring rate, and cooling rate. Benzene emissions, in particular, are a byproduct of the decomposition of seacoal and seacoal supplements in green sand molds; supplements include anthracite, gilsonite, causticized lignite, and ground coke. In one research study, the amount of benzene emitted during the pouring and subsequent cooling of molten metal into green sand molds was found to be directly proportional to the volatile matter content of the seacoal and seacoal supplements in the mold (LaFay and Neltner, 1998). This study also found that for a fixed casting weight, the quantity of benzene emitted due to decomposition of seacoal and seacoal supplements decreased as the sand-to-metal ratio increased. Considering the large number of factors that affect emissions, the available data on organic emissions from pouring, cooling, and shakeout are very limited.

3.6.2 Centrifugal and Permanent Mold Casting

Centrifugal castings are cylindrically symmetric shapes such as pipe that are made by pouring metal into a mold that is spun about its axis to hold the metal against its walls by centrifugal force. Permanent molds are completely filled with metal so that no motion is necessary; the metal is kept in place by gravity and pressure. Both types of molds are typically water cooled.

Upon solidifying, the metal shrinks slightly, facilitating separation of the casting from the mold. Little mechanical finishing is required for these types of castings because they can be produced with the desired surface finish and with minimal or no separation of sprues, runners, and risers required.

Emissions from centrifugal casting have not been measured, but they are assumed to consist of metal fumes and some organic compounds that arise from the sand cores normally used. The amount of sand used in these types of casting is much less than that used in sand casting. For centrifugal and permanent mold casting, the sand-to-metal ratio by weight is 0.05 or less (EPA, 1998b; Ductile Iron Pipe Research Association, 2000). By contrast, the ratio is typically 4 to 5 for sand casting (EPA, 1998b). However, the sand used in centrifugal and permanent mold casting is primarily for cores with chemical binders, whereas most sand casting uses green sand molds.

As shown in Table 3-5, cores with chemical binders can emit as much HAP as green sand molds, even when the amount of mold sand is 20 times the amount of core sand. The lower sand usage (sand-to-metal ratio of 0.05) for centrifugal and permanent molds suggests that HAP emissions may be somewhat lower than those from sand casting. However, at present no HAP emission measurements have been performed and there are no metal or organic HAP emission factors specific to centrifugal or permanent mold casting operations.

3.6.3 Investment Casting

Investment casting consists of simply pouring metal into the molds previously described. After the metal has solidified, the mold is broken away from the tree and individual castings are cut off the tree. Sometimes the shell does not separate cleanly from the tree and must be removed by leaching in molten salt (e.g., the Kolene® process).

Although no emission data are available for investment casting, no substantial HAP emissions seem possible because of the nature of the processes and materials involved, nor have significant emissions been observed during these operations.

3.6.4 Expendable Pattern Casting

Expendable pattern castings are made by pouring metal into a sprue that leads to the bottom of the polystyrene pattern and allowing the metal to simultaneously volatilize the pattern and replace it, forming a casting of the same shape as the pattern. Vapors generated in the process escape through the sand that surrounds first the pattern and then the casting. Castings are removed from the loose sand and then finished in much the same manner as those made by sand casting.

Emissions consist of metal fumes and pyrolysis products from the vaporized polystyrene. A discussion of organic emissions is presented by Twarog (1991). The consensus of available data suggests that emissions contain predominately styrene, along with benzene, ethyl benzene, and toluene. The presence of polycyclic aromatic hydrocarbons is indicated in some but not all studies.

3.7 SAND HANDLING

Shakeout operations generate a substantial volume of sand. Many foundries reuse a large portion of this sand and only remove a small portion as waste, which is primarily fine grains that result from abrasion of sand. Most foundries have a large multistep sand-handling operation for reclaiming the reusable sand. Large foundries often have conveyor sand-handling systems working continuously. Smaller, less mechanized foundries often use heavy equipment (e.g., front-end loaders) in a batch process (EPA, 1992).

Sand-handling operations receive sand directly from the shakeout step or from an intermediate sand storage area. A typical first step in sand handling is lump knockout. Sand lumps occur when the binders used in sand cores only partially degrade after exposure to the heat of molten metal. The lumps, or core butts, may be crushed and recycled into molding sand during this step. They can also be disposed of as waste material. A magnetic separation operation is often used to remove pieces of metal. Other steps involve screening to remove fines and cooling by aeration. In addition, some foundries thermally treat chemically bonded mold and core sand to incinerate binders and organic impurities (EPA, 1992). Emissions from sand handling include PM such as sand, metal particles, condensed organics, and residual binder. If a thermal treatment is used to reclaim chemically bonded sand, organic HAPs may be emitted.

In the 1998 survey, a total of 284 foundries reported sand reclamation processes, 35 of which used thermal reclamation. The sand-processing capacities of thermal and nonthermal reclamation processes were 260 and 8,600 tons/hr, respectively (EPA, 1998b). The majority of sand reclamation processes (both thermal and nonthermal) were controlled by filters; one thermal reclamation process was controlled by an incinerator.

Limited data are available on the analysis of waste sand destined for disposal. In 1978, Calspan Corporation reported that HAPs detected in the sand in trace quantities included lead (54 ppm), manganese (53 ppm), nickel (28 ppm), chromium (4.8 ppm), and phenol (1.1 ppm).

Considering the above information, emissions of HAPs from sand-handling operations do not appear to be significant. Some of the factors affecting HAP emissions from sand handling include:

- Type of sand processed (chemically bonded sand versus clay-bonded sand);
- Type of metal cast;
- Type of sand-handling operation (e.g., thermal treatment); and
- Workplace practices.

3.8 MECHANICAL FINISHING

All castings typically undergo some type of mechanical finishing. Finishing operations begin once the casting is removed from the mold and cooled. Hammers, band saws, abrasive cutting wheels, flame cut-off devices, and air-carbon arc devices may be used to remove the risers, runners, and sprues of the metal transfer system. Metal fins at the parting lines (lines on a casting corresponding to the interface between the cope and drag of a mold) are removed with chipping hammers and grinders. Residual refractory material and oxides are typically removed by sand blasting or steel shot blasting, which can also be used to give the casting a uniform and more attractive surface appearance (EPA, 1992).

Finishing operations generate PM, which may contain metal HAPs. From their tests at a gray iron foundry, Potas and Blair (1993) reported manganese as the major metal HAP from finishing, with smaller quantities of chromium and relatively insignificant levels of lead and cadmium also present. Uncontrolled manganese emission factors for the six emission points sampled ranged from 0.045 to 0.21 lb/ton (average of 0.1 lb/ton) compared to emission factors for chromium that ranged from 0.0036 to 0.032 lb/ton (average of 0.02 lb/ton). Uncontrolled emissions of manganese totaled 15 lb/hr for all six points associated with the finishing operation compared to chromium emission rates of 2.9 lb/hr for all six points. Manganese comprised 1.1 to 1.2 percent of the PM from the blast/grind and spotblast/reblast operations and ranged from 0.3 to 0.4 percent of the PM for the other emission points. Total HAPs were on the order of 1.4 to 1.6 percent from the blast/grind and shotblast/reblast operations and ranged from 0.3 to 0.5 percent of the PM for the other points (Potas and Blair, 1993).

Data presented by Euvrard and Jackson (1992) showed total metal HAPs from grinding to be 0.8 percent of the PM, compared to 1.1 percent for PM from shotblasting. These results appear to be consistent with typical manganese content of cast iron and steel, which generally ranges from 0.25 to 1.0 percent (Gschwandtner and Fairchild, 1992).

The PM produced by mechanical finishing is anticipated to be mainly coarse material that would not remain airborne. That is, uncontrolled PM produced by mechanical finishing would not generally escape the foundry building or be transported outside the facility boundaries.

3.9 CLEANING AND COATING

The cleaning of castings precedes any coating operations to ensure that the coating will adhere to the metal. Scale, rust, oxides, oil, grease, and dirt can be chemically removed from the surface of a casting using organic solvents (typically chlorinated solvents, although naphtha, methanol, and toluene are also used), emulsifiers, pressurized water, abrasives, alkaline agents (caustic soda, soda ash, alkaline silicates, and phosphates), or acid pickling. The pickling process involves the cleaning of the metal surface with inorganic acids such as hydrochloric, sulfuric, or nitric acid. Castings generally pass from the pickling bath through a series of rinses. Molten salt baths are also used to clean complex interior passages in castings (EPA, 1992).

Castings are often given a coating to inhibit oxidation, resist deterioration, or improve appearance. Common coating operations include painting, electroplating, electroless nickel plating, hard facing, hot dipping, thermal spraying, diffusion, conversion, porcelain enameling, and organic or fused dry-resin coating (EPA, 1992). Table 3-7 compares coating capacities (in tons/hr of castings coated) to melt capacities (tons/hr of metal poured) at foundries responding to the 1998 questionnaire (EPA, 1998b).

TABLE 3-7. MELTING AND COATING CAPACITIES

All foundries [1]	Foundries with coating operations [2]	
Total metal poured, tons/hr	Total castings coated, tons/hr	Total metal poured, tons/hr
8,944	1,344	2,373

[1] A total of 590 foundries reported melt capacities.
[2] A total of 128 foundries reported coating operations; however, only 78 of these foundries reported information on coatings and melt capacities.
Source: EPA, 1998b.

Cleaning and coating operations may generate organic HAPs from painting; coating and solvent cleaning and acid and metal ion mists from anodizing; plating; polishing; hot-dip coating, etching; and chemical conversion coating. HAP emissions from cleaning and coating were not assessed under this study because this assessment is being made under the development of a national emission standard for metal parts coating operations.

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4.0 CONTROL TECHNOLOGY AND PERFORMANCE OF CONTROLS

This chapter describes emission control technologies currently in use at iron and steel foundries and the performance of these controls. Unless otherwise noted, compilations of type and frequency of use of specific emissions capture and control technologies and performance data for those technologies are based on industry responses to the 1998 EPA survey questionnaire (EPA, 1998).

Emissions capture and control technologies are discussed for the following operations:

- Mold and core making,
- Scrap preparation,
- Metal melting, and
- Pouring, cooling, and shakeout.

These operations, discussed in Chapter 3, may produce substantial HAP emissions and, therefore, will be further assessed in this document.

The primary purpose of this document is to compile information for use in developing NESHAP for two of the source categories, namely "Iron Foundries" and "Steel Foundries," listed by the EPA as required by section 112(c) of the CAA. As discussed in Chapter 3, the EPA conducted a survey in 1998 of all known ferrous (i.e., iron and steel) foundries to collect information to assist in the development of regulations for these source categories. Of the 595 foundries reporting information in the 1998 industry survey, 339 foundries poured iron only, 165 poured steel only, and 91 poured both types of metal. To illustrate the similarities and differences between iron and steel foundries, process and emission control data are presented separately for iron foundries and steel foundries. The 91 foundries pouring both iron and steel were categorized as either iron foundries or steel foundries, for presentation in this document, depending on the relative amounts of iron and steel poured. If a foundry poured 50 percent or more of its iron and steel combined as steel, it was categorized in this document as a steel foundry. Thirty-six of the 91 foundries were placed in the iron foundry category and 55 in the steel foundry category, for totals of 375 iron foundries and 220 steel foundries contributing information to EPA's data base. The decision to categorize the foundries as described is somewhat arbitrary, but the distinction is clear for most of the 91 foundries in question because of the relative amounts of each type of metal poured by the foundry.

4.1 MOLD AND CORE MAKING

Most equipment for mold and core making does not include well-defined stacks. Exceptions are baking ovens and cold-box machines that use catalyst gases. For emissions that are not emitted through well-defined stacks, emissions control systems must include a hood or an engineered exhaust system to capture the exhaust stream. These capture mechanisms are then connected by ductwork to an air pollution control device (APCD).

Capture systems for mold- and core-making emissions were not specified in the survey responses, but many of the capture systems described for electric furnaces (i.e., canopy hoods, enclosures, building evacuation, etc.) were likely to be the systems used, if any, for these operations. Except for cold-box operations, mold- and core-making operations were mostly uncontrolled or controlled by filters, cyclones, and PM scrubbers. These PM controls reduce dust (i.e., sand) emissions that arise from the sand mullers. They are not effective in reducing emissions of organic vapors that arise from the chemical binder system. However, when considering the potential for HAP emissions, it is emissions of organic vapors, not PM (or metal HAPs), that are of concern from mold- and core-making operations. Meaningful HAP emission controls for mold- and core-making operations were almost entirely controls on cold-box lines aimed at reducing emissions of triethylamine (TEA).

TEA is a gaseous HAP that is frequently used as a catalyst to initiate the polymerization reaction for cold-box mold- and core-making lines. Table 4-1 shows the use of controls for cold-box mold- and core-making lines in which the catalyst gas was TEA. Most cold-box operations that used TEA were controlled by packed-bed scrubbers that used a sulfuric acid solution to absorb and react with the TEA gas. Packed-bed scrubbers operate on the principle of absorption, in which one or more components of a gas mixture are selectively transferred into a relatively nonvolatile liquid. Absorption of a gaseous component by a liquid occurs when the liquid contains less than the equilibrium concentration of the component. The difference between the actual concentration in solution and the equilibrium concentration provides the driving force for

TABLE 4-1. USE OF CONTROLS FOR TEA EMISSIONS FROM COLD-BOX MOLD- AND CORE-MAKING LINES [1, 2]

Iron foundries			Steel foundries		
Type of control	**Number of lines using control**	**Number of foundries using control [3]**	**Type of control**	**Number of lines using control**	**Number of foundries using control**
Wet scrubbing with acid solution	380	79	Wet scrubbing with acid solution	15	10
Incineration	7	3			
Condensation	3	2	Condensation	2	2
No control	49	25	No control	13	7

[1] A few of these lines may use dimethylethylamine (DMEA) for the catalyst; some questionnaire responses did not distinguish between TEA and DMEA.
[2] The use of controls for PM is not considered control for TEA.
[3] Three iron foundries operated a combination of controlled and uncontrolled lines.

absorption. The absorption rate depends on the physical properties of the gas/liquid system (e.g., diffusivity, viscosity, and density) and the absorber operating conditions (e.g., temperature and flow rates of the gas and liquid streams). Absorption is enhanced by lower temperatures, greater contacting surface, higher liquid-to-gas ratios, and higher concentrations in the gas stream (EPA, 1991).

Sulfuric acid wet scrubbers are very effective for TEA emissions control because the sulfuric acid reacts with the TEA, virtually eliminating dissolved TEA in the scrubbing solution. Therefore, the driving force for absorption is not limited by the amount of TEA removed, provided there is an adequate supply of unreacted sulfuric acid in the scrubbing media. Table 4-2 gives a summary of the available source test data for TEA emission controls.

TEA emissions (or concentrations) were generally too low to be quantified in the outlet gas streams from the acid wet scrubbers, for which source test data were available. As such, precise removal efficiencies could not be determined, though most of these scrubbers achieved a TEA removal efficiency of 99 percent or higher. The only other information on TEA control consists of control efficiency information reported without supporting test data in the responses

TABLE 4-2. SOURCE TEST DATA FOR TEA ACID WET SCRUBBERS

				TEA measured at scrubber inlet		TEA measured at scrubber outlet	
Foundry ID	**Test date(s)**	**Test method / Conditions of Test**	**Run No.**	**Mass rate, lb/hr**	**Conc., ppmv[1]**	**Mass rate, lb/hr**	**Conc., ppmv[1]**
GA-1	10/21/96 through 11/1/96	Method not reported /	1	7.55	55.8[2]	< 0.20	< 1.5[2]
		pH= 0.32 ΔP = 1.75" H_2O	2	5.99	44.6[2]	< 0.18	< 1.4[2]
		Q_{air} = 8,500 acfm Q_{sw} = 105.6 gpm	3	2.58	18.9[2]	< 0.18	< 1.4[2]
MI-33		Method not reported /	1	15.6	209	0.022	0.29
		Q_{air} = 4,520 dscfm	2	16.3	230	0.031	0.43
			3	17.5	255	0.023	0.34
NC-5	6/13/96	NIOSH Method 2010[3]	1-1	0.796	9.9[4]	< 0.00250	< 0.03[4]
		Q_{air} = 4,886 acfm T = 73°F	2-1	0.527	6.9[4]	< 0.00253	< 0.03[4]
			3-1	0.710	8.9[4]	< 0.00256	< 0.03[4]
			1-2	0.521	6.5[4]	< 0.00252	< 0.03[4]
			2-2	0.604	7.6[4]	< 0.00256	< 0.03[4]
			3-2	0.110	1.4[4]	< 0.00257	< 0.03[4]
VA-8	3/16/95 through 3/17/95	EPA Methods 2, 3, 4, and 18	1	33.89	133.48	< 0.02	< 0.07
		NIOSH Method 221	2	27.23	105.34	< 0.02	< 0.07
		Q_{air} = 16,500 acfm	3	21.71	85.00	< 0.02	< 0.07
WI-01	11/18/96	EPA Method 18	1			< 0.256	< 0.90[4]
		pH < 1.0 Q_{air} = 18,000 acfm	2			< 0.215	< 0.76[4]
		5.18 tons cores/hr	3			< 0.210	< 0.74[4]
WI-42	2/7/95	Method not reported	1	12.26[5]	24.0[4]	< 0.14	< 0.3[2]
		pH ~ 2.0	2	12.26[5]	24.0[4]	< 0.14	< 0.3[2]
		Q_{air} = 32,000 acfm	3	12.26[5]	24.0[4]	< 0.14	< 0.3[2]

[1] Parts per million by volume.
[2] Concentration in ppmv was calculated from the test value as reported in milligrams per cubic meter (mg/m^3).
[3] Concentration was calculated from reported TEA mass flow rate and air flow rate.
[4] NIOSH = National Institute of Occupational Safety and Health.
[5] Mass flow rate was calculated from TEA usage rate and estimated control system capture efficiency.

to the 1998 industry survey. Reported control efficiencies for wet scrubbers were 99.9 percent for two lines controlled by two scrubbers at one foundry; 99 percent for 42 lines controlled by 13 scrubbers at six foundries; and 98 percent or lower for 54 lines controlled by 13 scrubbers at four foundries. Efficiencies were not reported for 61 lines controlled by 11 scrubbers at five other foundries. The basis for the values was usually given as design efficiency. Scrubber design was described as a vertical packed bed for 10 of the 15 scrubbers with design collection efficiencies of 99 percent or higher. In most cases, the scrubber descriptions included the fact that acid solution was used as the collection medium.

Controls other than wet scrubbing used to control TEA emissions from cold-box mold- and core-making lines are thermal oxidation, which was reported as being used on seven cold-box lines, and condensation, which was used on three lines. Thermal oxidation would control emissions of organic HAPs other than TEA more effectively than scrubbing, but no information is available to indicate that either thermal oxidation or condensation was more effective for TEA than acid scrubbing.

For binder systems other than the TEA-catalyzed cold-box system, there are no emission control devices that effectively reduce HAP emissions from mold- and core-making lines. However, pollution prevention methods are possible for certain binder chemical systems. Referring to the data summarized in Appendix B, several systems produce relatively high emissions compared with others. HAPs emitted by these systems include cumene, dimethyl phthalate, methanol, methyl ethyl ketone, and phenol. The HAP content of each of the systems can be varied, but the HAPs cannot always be eliminated or reduced below certain thresholds, which depend on the conditions under which the systems are used (e.g., temperature or the strength requirements of the molds or cores). Discussions with industry suppliers indicate that methanol can be eliminated from the furan warm-box system, but HAP reductions in the other high-emitting systems cannot be prescribed. The furan warm-box system was used in 55 mold- and core-making lines in iron foundries and in 3 lines in steel foundries. At least 23 lines in iron foundries used formulations that did not contain methanol. Complete information on formulations is not available because the formulations were not reported in the 1998 survey. A sample of larger foundries, however, was contacted after the survey to obtain this information. Results of the sampling effort indicate that use of the furan warm-box system without methanol is easily achievable.

Two relatively low-emitting systems in common use, for which reductions are possible, are the phenolic urethane cold-box and phenolic urethane no-bake systems. Both systems use petroleum distillate solvents that contain naphthalene and lesser amounts of cumene and xylene. These solvents commonly contain about 10 percent naphthalene, but products are also available that contain 3 percent or less naphthalene. Naphthalene-depleted solvents can be identified in Material Safety Data Sheets (MSDS) through their Chemical Abstract Service (CAS) numbers, which are 70693-06-0 for a lower boiling point product (about 150 °C) and 68477-31-6 for a higher boiling product (about 200 °C); the latter of these two products is used in binder chemical formulations. The solvent with higher naphthalene content is CAS number 64742-94-5. Use of naphthalene-depleted solvents may result in substantial reductions of naphthalene emissions; 705 mold- and core-making lines in iron foundries and 205 lines in steel foundries used phenolic urethane cold-box or no-bake systems. The use of naphthalene-depleted solvent in these lines is not known completely because this information was not reported in the 1998 survey. Several larger foundries contacted after the survey supplied MSDS for the binder chemicals they used. The use of these solvents varied considerably; some foundries used chemicals containing depleted solvents in some lines but not in others. The use of these solvents seems to be constantly increasing; however, industry sources suggested that the availability of the naphthalene-depleted solvent may be limited (Brown, 2000; Stone, 2000).

Except for the furan warm-box and phenolic urethane systems, no HAP substitution opportunities that can be prescribed have been found. However, other binder systems, such as the furan no-bake, phenolic no-bake, and the Shell (Novolak flake) systems, can be formulated without methanol. According to an industry representative, methanol replacement in these binder systems cannot be prescribed because the substitute binder formulations may not be compatible for a specific foundry's operations (i.e., the substitute binder formulation may lack an essential characteristic of the methanol-containing formulation for a given application). However, use of different (low-HAP-emitting) binder formulations appears to be a potential means to reduce HAP emissions from mold- and core-making operations.

4.2 MOLD AND CORE COATING

For mold- and core-coating operations, in which HAPs may be present in the coating material as liquid constituents that evaporate, one form of control that is often used is the light-off procedure, in which the coating is ignited after application to dry it. This procedure can be used only if the coating material is flammable and if the adhesive properties of the binder chemicals are not degraded by the heat generated by the procedure. No information is available on emissions where the light-off process is used for coatings containing HAPs, but one such study was made for a coating containing a solvent based on isopropyl alcohol (Castings Development Centre, 1997). This study concluded that 70 percent or more of the solvent was destroyed when the drying period was minimized and that the major combustion product was carbon dioxide. One HAP for which emissions can be reduced by this procedure is methanol. The efficiency of reducing methanol emissions by this process is not known because the only emissions data available for a light-off process are for a coating with isopropanol as a constituent. Based on this study, a methanol destruction efficiency of roughly 70 percent can be expected.

In addition to the light-off process, pollution prevention methods can be used to reduce HAP emissions from mold- and core-coating operations. The primary pollution prevention method available is the substitution of a HAP-containing coating material (such as a methanol-based coating) with a non-HAP-containing coating material (isopropanol for example). Of 861 mold- and core-coating lines at iron foundries, 12 used a coating containing methanol and 339 used a coating containing isopropanol. Of 474 mold- and core-coating lines at steel foundries, 17 used a coating containing methanol and 226 used a coating containing isopropanol. Discussions with industry sources indicate that methanol can be replaced by isopropanol in coating formulations without forcing process changes. Coating formulations based on water instead of alcohol were also commonly used (by 382 coating lines at iron foundries and 191 lines at steel foundries).

4.3 SCRAP PREPARATION

Scrap metal typically undergoes some type of preparation before melting, which may include cutting or sizing, shot or sandblasting to remove coatings, cleaning with organic solvents to remove oils and grease, and preheating. Except for preheaters, the survey questionnaire did not ask about specific emissions capture or control technologies for scrap preparation, and no controls were reported for other phases of scrap preparation. Preheaters were used predominantly with EIFs, as noted in Chapter 3. Tables 4-3 and 4-4 summarize survey responses to APCDs used for loading, heating, and discharging scrap from preheaters.

TABLE 4-3. CONTROL CONFIGURATIONS FOR SCRAP PREHEATERS

Type of control used[1]			Number of foundries with control configuration		Number of preheaters with control configuration[2]	
Loading	Heating	Discharging	Iron	Steel	Iron	Steel
No control	No control	No control	68	7	76	18
Filter	Filter	Filter	17		24	
No control	Filter	Filter	8	1	19	1
No control	No control	Filter	5		7	
Filter	Filter	No control	2		2	
Filter	No control	Filter	2		3	
Filter	Cyclone	Filter	1		2	
No control	Filter	No control	1		1	
No control	Afterburner (AB)	No control	2		6	
Cyclone	Cyclone/AB	No control	1		6	
Cyclone	Cyclone	Cyclone	2		2	
Cyclone	Cyclone	Filter	1		6	
Scrubber	Scrubber	Scrubber	1		1	
No control	Cyclone	No control	1		1	
No control	No control	Scrubber		1		1
No control	Scrubber	No control	1		1	
TOTALS			113	9	157	20

[1] Blank responses to type of control were classified as "no control."
[2] Blank responses to number of preheaters were assigned a value of "1."

As shown in Table 4-4, most preheaters were uncontrolled. Preheaters that did use controls used mostly fabric filters, which controlled HAP metals contained in PM. Because the fabric filters were also commonly used to control the EIFs served by the preheaters, these devices will be discussed in the section on EIF controls.

Three foundries used afterburners, which constituted control for organic HAPs. Another form of organic HAP control was direct gas-fired preheating, which was the mode used by most foundries. Specifically, 171 of the 177 preheaters were direct gas-fired preheaters. Discussions with a sample of operators revealed that preheater gas burners operated at various temperature

TABLE 4-4. SPECIFIC CONTROL DEVICES ON SCRAP PREHEATERS

Controls and use	Loading		Heating		Discharging	
	Iron	Steel	Iron	Steel	Iron	Steel
Preheaters with no control[1, 2]	111	20	86	19	93	18
Facilities with no control	86	9	75	8	76	7
Preheaters with filter	31		46	1	61	1
Facilities with filter	22		28	1	34	1
Preheaters with afterburner (AB)			6			
Facilities with AB			2			
Preheaters with cyclone and AB			6			
Facilities with cyclone and AB			1			
Preheaters with cyclone	14		11		2	
Facilities with cyclone	4		5		2	
Preheaters with scrubber	1		2		1	1
Facilities with scrubber	1		2		1	1
Total number of preheaters	157	20	157	20	157	20
Total number of facilities	113	9	113	9	113	9

[1] Blank responses to type of control were classified as "no control."
[2] Blank responses to number of preheaters were assigned a value of "1."

ranges sfrom 800 to 1,300 °F. No emission tests have been conducted for organic species, so the relative efficiencies of afterburning versus direct gas firing cannot be determined.

In addition to the techniques described above, another form of scrap preparation that is commonly used is specification of quality. Of the 595 iron and steel foundries that provided survey responses, 360 (or 60 percent) of iron and steel foundries indicated that they used some type of scrap selection, cleaning, or inspection program to ensure the quality of scrap metal used by the foundry. The percentage of respondents that specified scrap selection as a work practice to reduce emissions was relatively consistent across foundries operating different furnace types: 45 percent of cupola foundries, 61 percent of EAF foundries, and 65 percent of EIF foundries.

The scrap selection, cleaning, or inspection programs included specifications on the types or grades of scrap used, limits or bans on oil, grease, and/or paint in the scrap, and restrictions on lead, galvanized metals (a source of cadmium), and certain alloys (a source of chromium, nickel, or high manganese). These scrap specifications could, in principle, result in reduced HAP emissions from preheating and melting, which is a pollution prevention procedure. No data, however, are available to quantify emission reductions that may result from eliminating or reducing organic contaminants and HAP metals in the scrap fed to preheaters and melting furnaces.

The size of foundries that used scrap specifications varied substantially, representing almost the entire range of foundry production. For example, annual production of foundries that had organic substance and/or HAP metal specifications for cupola, EIF, and preheater feed ranged from more than 100,000 to less than 1,000 tons per year in each case.

4.4 METAL MELTING

As noted in Chapter 3, the predominant types of furnaces at iron and steel foundries are cupolas (used only at iron foundries), EAF (used mainly at steel foundries), and EIF (commonly used at both iron and steel foundries). Emissions from these furnaces are predominately metal, but may include organic HAPs, especially in the case of cupolas. The following sections describe existing capture and control technologies for emissions from these three types of melting furnaces.

4.4.1 Cupola Controls

Emissions from cupolas arise from three operations: charging, melting, and tapping. Combustion air is blown through the base of the cupola and travels upward through the charge. Melting emissions are contained in this forced air flow, which is routed to an APCD. Cupolas have an opening (a charging door) in the shaft of the furnace above the charge level. The disposition of charging emissions depends on whether the exhaust gas takeoff to the melting APCD is above or below the charging door. When materials are not being charged to the furnace, the draft of the melting APCD creates sufficient negative gauge pressure inside the furnace to prevent release of emissions through the charging door. For cupolas with above-charge gas takeoff, the periodic addition of charge material (usually via a vibratory or belt feeder) momentarily alters the exhaust stream flow in the cupola shaft. If the flow alteration is significant, which could be caused by adding a large amount of charge material suddenly, a brief burst of emissions, or "puffing," may occur from the charging door. Puffing generally does not occur for cupolas with below charge gas takeoff because the exhaust is drawn from below the level of the charge, and the addition of charge material does not interrupt the exhaust stream flow within the cupola shaft. Charging and tapping emissions from cupolas are minimal compared with melting emissions and, hence, are typically uncontrolled (EPA, 1998).

For melting emissions, most cupolas have a wet scrubber or a fabric filter for PM control and also employ an afterburner, which is located upstream of the filter or scrubber, for control of organic substances. Table 4-5 summarizes the use of controls as reported in 1998. Wet scrubbers and fabric filters are briefly described in the following sections. The use of electrostatic precipitators is so infrequent in this industry that no discussion of this device is presented here, but the electrostatic precipitator is generally considered to be less effective than a fabric filter for fine PM control (Buonicore, 1992, p.114).

TABLE 4-5. CONTROLS FOR MELTING EMISSIONS FROM CUPOLAS

Controls	Number of foundries	Number of furnaces
Afterburner plus fabric filter	42	56
Afterburner plus wet scrubber*	36	49
Afterburner plus electrostatic precipitator	1	1
Wet scrubber*	17	22
Fabric filter	6	6
None	8	9
Totals	110	143

* Most wet scrubbers were venturi scrubbers.

4.4.1.1 <u>Wet Scrubbers</u>. Venturi scrubbers are the most common type of wet scrubber used to control PM emissions, and thus metal HAP emissions, from cupolas. The primary collection mechanisms inherent in a venturi scrubber are the impingement of particles on droplets and the condensation of liquid on the particles. Impingement is attained by accelerating the gas stream to velocities of 200 to 600 feet per second (ft/sec) in the venturi throat. When water is introduced into the high-velocity stream, it is atomized into tiny droplets. Because these droplets are at a relatively low velocity with respect to the gas stream, the particles are collected on these droplets through impaction. Particle collection through condensation also occurs when saturated streams are cooled in the venturi.

Pressure differential is a key factor affecting the efficiency of a scrubber in removing particulate matter and therefore metal HAPs. High-energy (i.e., high-pressure differential) scrubbers are capable of reducing particulate loadings from cupolas to about 0.05 grains per dry standard cubic foot (gr/dscf) (EPA, 1981, p. 73). As a rule of thumb, a high-efficiency scrubber is one with a pressure differential greater than 50 inches of water column. Table 4-6 summarizes pressure differentials for venturi scrubbers as reported in the survey. Of the 55 pressure differentials compiled in the table, 16 were equal to or greater than 50 inches of water. Scrubbers with pressure differentials in the range of 50 to 70 inches of water can reduce emissions from cupolas to 0.05 gr/dscf, and scrubbers with pressure differentials of 100 inches of water can reduce emissions to 0.03 gr/dscf (depending on the quality of the scrap) (EPA, 1981, p. 73). Scrubbers are generally designed to give constant removal efficiencies for a given pressure differential; thus, outlet grain loadings are expected to be dependent on inlet grain loadings.

Figure 4-1 shows the results of source tests for PM measured in exhaust gases from 19 wet scrubbers on cupolas. Average outlet PM concentrations for 15 of the 19 scrubbers ranged from 0.01 gr/dscf to 0.07 gr/dscf. As seen in Figure 4-1, the performance of the remaining four scrubbers is significantly inferior, ranging from 0.09 to 0.20 gr/dscf.

TABLE 4-6. PRESSURE DIFFERENTIALS OF VENTURI SCRUBBERS USED ON CUPOLAS

Pressure differential, inches of water column	Number of scrubbers
≤ 8	9
20 to 29	5
30 to 39	14
40 to 49	11
50 to 59	9
60 to 70	7

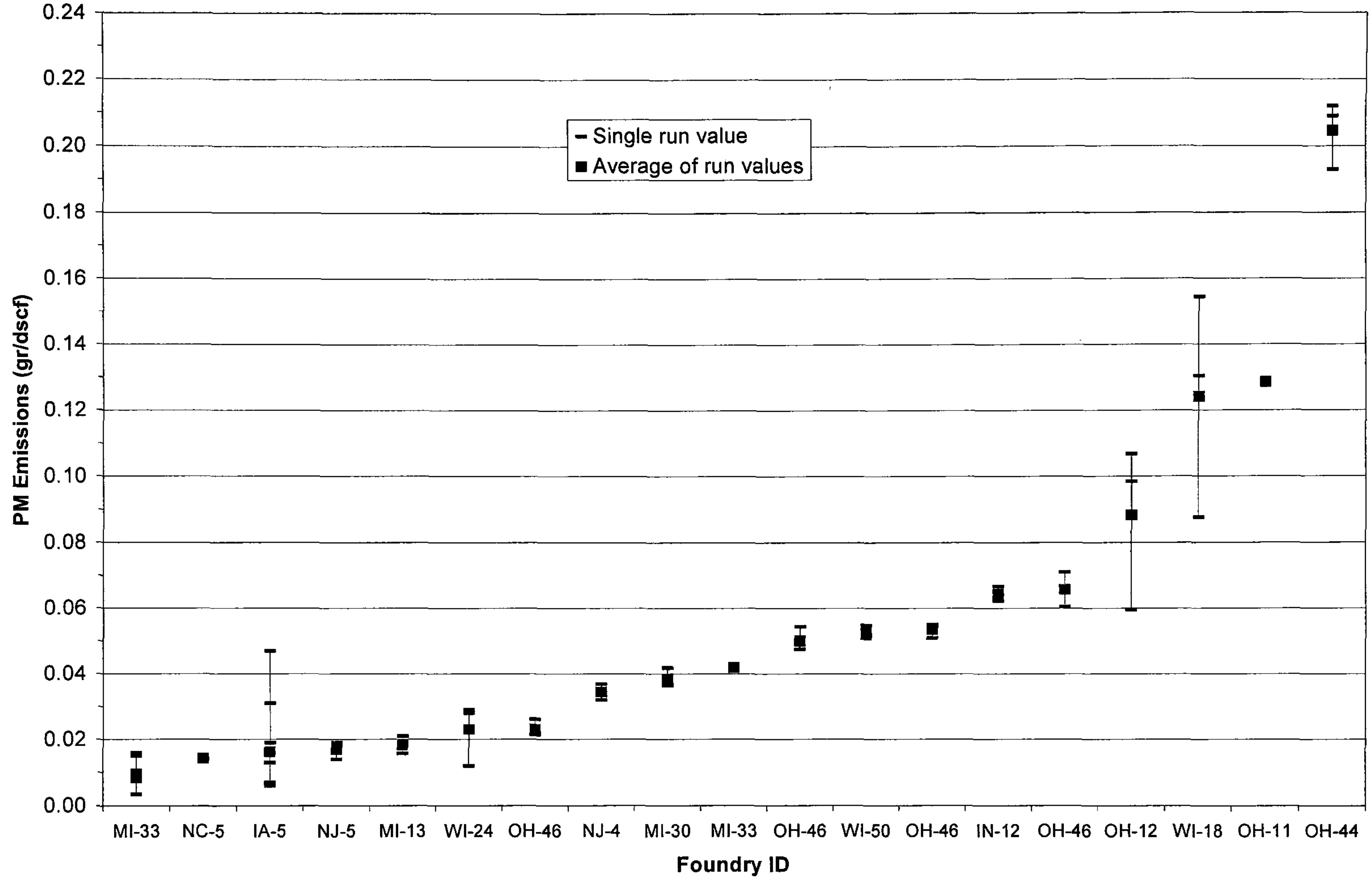


Figure 4-1. Filterable PM Emissions (gr/dscf) from Wet Scrubbers on Cupolas at Iron Foundries.

4.4.1.2 Fabric Filters. In a fabric filter, or baghouse, the particulate-laden gas stream passes unidirectionally though a woven or felt-type fabric, which screens out the PM. Particles greater than 1.4 micrometers (μm) in diameter are collected at nearly 100-percent efficiency via impaction, while particles 0.1 to 0.2 μm in diameter are collected by diffusion. The major design factor that affects the efficiency of a fabric filter is the air-to-cloth (A/C) ratio, which is the ratio of gas volume entering the filter (cubic feet per minute) to the total surface area of the filtering fabric (square feet) (EPA, 1981, p. 85), or, more simply, the velocity of the gas through the filter (feet per minute [ft/min]). The ratio chosen is generally dependent on the particle size of the emissions, with lower A/C ratios used for emissions streams with fine particulate. For woven fabrics, A/C ratios are typically 3.0 ft/min or less (Buonicore, 1992; p. 128). For felt-type materials, A/C ratios of 10 are common. Table 4-7 summarizes reported A/C ratios of fabric filters used on cupolas at ferrous foundries in 1998.

TABLE 4-7. A/C RATIOS FOR FABRIC FILTERS ON CUPOLAS

A/C ratio, ft/min	Number of filters
< 2	20
2 to 2.99	8
3 to 3.99	7
4 to 4.99	2
5 to 5.99	1

Figure 4-2 shows the results of source tests for PM measured in exhaust gases from twelve fabric filters on cupolas. Repetitive foundry listings (Figure 4-2) indicate that baghouses were tested multiple times. A summary of the test data referenced in this figure is given in Appendix D. Average PM concentrations ranged from less than 0.001 gr/dscf to 0.005 gr/dscf. These concentrations were lower than those achieved by wet scrubbers.

The two cupolas that achieved average outlet PM concentrations of less than 0.001 gr/dscf both employed a novel pulse-jet baghouse with horizontally supported bags rather than the traditionally designed vertically hanging bags. According to an operator of one of these novel baghouses, a lighter weight fabric can be used when the bags are horizontally supported.

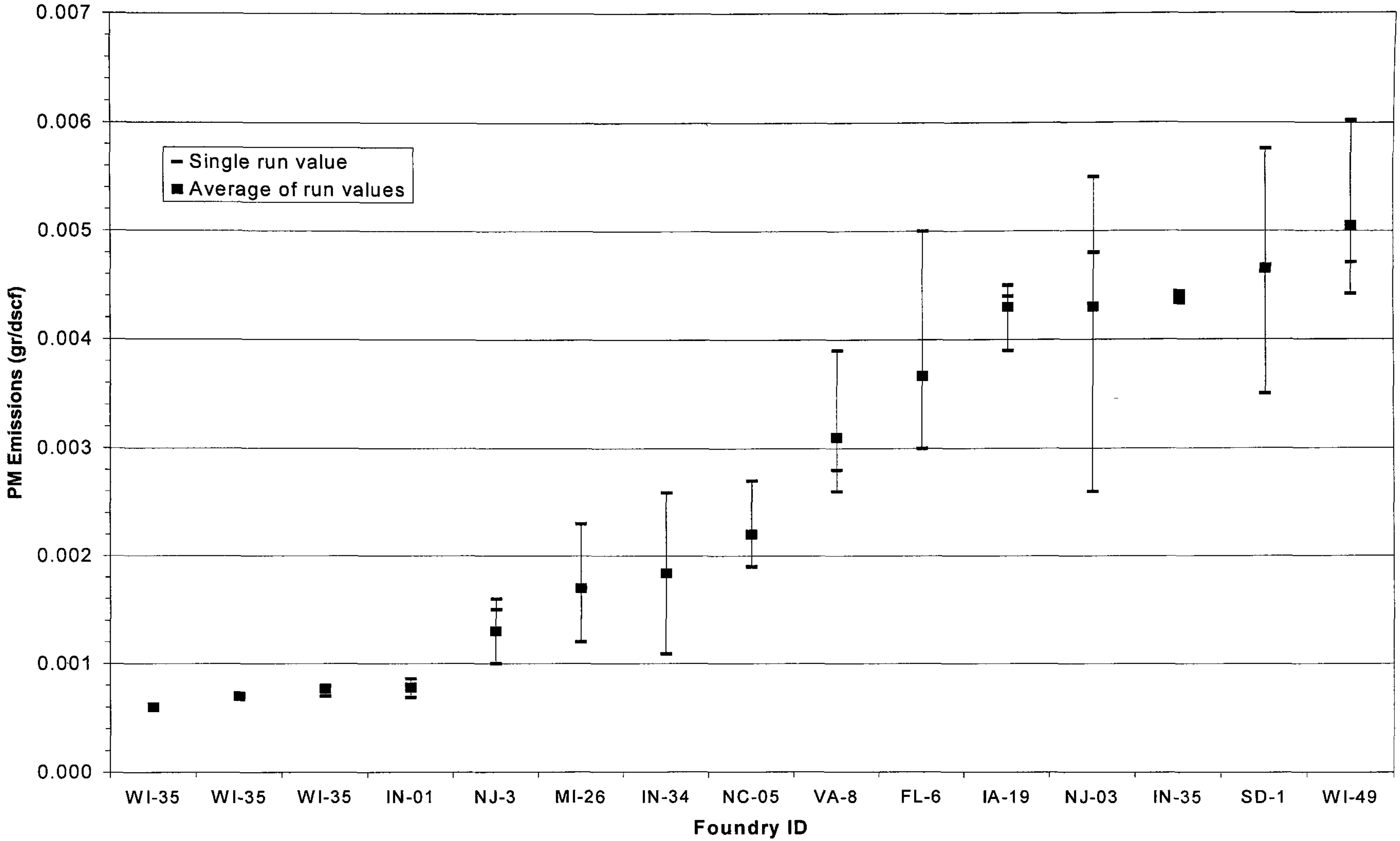


Figure 4-2. Filterable PM Emissions (gr/dscf) from Fabric Filters on Cupolas at Iron Foundries.

When bags hang vertically (as in traditional baghouses), the tops of the bags must be strong enough to hold up the weight of the entire bag (generally 2 or 3 ft long), and the entire filter cake on that bag. A light-weight bag would not be able to support the weight, and would tear. By having the bags supported horizontally, they are able to reduce the weight the bag material supports to only the small amount under the horizontal support (typical bags are 4 to 6 inches in diameter). The light-weight bag is easier to clean and is more permeable, which allows for a more even distribution of the air flow. Heavier weight bags tend to get more material caught in the bag material, and as a result need to be cleaned more frequently and more vigorously. The contact indicated that, "since 80% of emissions are associated with cleaning," by lowering the cleaning frequency, the baghouse emissions are lowered. The light-weight bag is also more permeable, so that pressure drop is reduced, and air flow is more evenly distributed. This, along with the low A/C ratio for these baghouses, allows more of the PM material to be collected on the bag surface, rather than becoming impregnated into the fabric, making it easier to clean the bags.

4.4.1.3 Afterburners. Afterburners are thermal incinerators that employ heat and oxygen to oxidize (combust) organic chemicals, converting them primarily to carbon dioxide and water. A typical cupola exhaust will contain CO at levels of 10 percent or higher. In applications associated with cupolas, afterburners are installed primarily to combust this CO, but they also act to incinerate any organic compounds present in the cupola exhaust. In general, combustion temperature and residence time are two important design parameters for afterburners. For a 98-percent destruction efficiency of nonhalogenated organics in an emissions stream, suggested values for combustion temperature and residence time are 1,600 °F and 0.75 seconds, respectively (EPA, 1991, p. 4-5). For a 99-percent destruction efficiency of a nonhalogenated emissions stream, suggested values for combustion temperature and residence time are 1,800 °F and 0.75 seconds, respectively (EPA, 1991, p. 4-5).

From the 1998 survey responses, most afterburners used to control cupola emissions reported design efficiency in terms of CO destruction. Table 4-8 presents the shows the relationship between PM outlet concentration and A/C ratio for the filters tested and also shows the filter materials used. The composition of the material is important in that it must be

TABLE 4-8. CUPOLA AFTERBURNER CO OUTLET CONCENTRATION AND EMISSIONS DATA

Foundry	CO outlet concentration (ppmv)				CO emission rate (lb/hr)
	Run 1	Run 2	Run 3	Average	
NJ-03	13	5.9	7	9	2.2
VA-08	17	16	13	15	3.3
IN-34				27*	4.2
NC-05	52	30	37	40	9.3
IA-19	51	72	119	81	16
AL-37	92	98	103	98	14.8
NJ-05	50	141	104	98	26
TX-18	75	293	18	129	36
MI-13	136	184		160	26
NJ-04	287	116	137	180	35
WI-42	155*	322*	334*	270*	22.7
WI-24				320	26.7
OH-13	1,800*	300*	380*	827*	66.5

*CO concentrations calculated from reported CO emissions and volumetric flow rates.

Table 4-9 offers a summary of combustion temperatures and residence times of afterburners used with cupolas. Note that discussions with foundry operators subsequent to questionnaire responses revealed that not all reported temperatures were for the same zone of the afterburner. This is because combustion of CO often continues in the exhaust stream from the afterburner, so that combustion temperatures and residence time in the afterburner combustion chamber itself may not represent the complete combustion characteristics. Some foundry operators considered only the afterburner combustion chamber in providing this information, while others considered the entire flue gas vent prior to heat recovery as the afterburner. As such, information collected from the 1998 industry survey with respect to temperature and residence time for cupolas is difficult to correlate with the afterburner destruction efficiency.

TABLE 4-9. OPERATING CONDITIONS FOR CUPOLA AFTERBURNERS*

Parameter and range	Number of recuperative hot-blast cupolas operating in this range	Number of nonrecuperative cupolas operating in this range
Temperature, °F		
> 1,000 to 1,300	7	17
> 1,300 to 1,600	25	21
> 1,600 to 1,800	3	3
> 1,800	0	2
Residence time, sec		
< 0.75	20	17
≥ 0.75	15	9

* Includes only those facilities that reported the requested information; data were not provided for all of the 143 cupolas.

compatible with the temperature of the gas and resistant to any conditions of wear, corrosion, and humidity that exist.

The EPA acquired speciated HAP data from the two tests for which PM and metal HAP data are summarized in Table 4-10. In these tests, the average cupola combustion zone temperatures were 1,670 and 1,560 °F. Three sampling runs were made in one test and four in the other. Test methods used were EPA Method 23, Determination of Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzofurans (PCDDs/PCDFs) From Stationary Sources, and SW-846 Methods 0010 (sampling) and 8270 (analysis), which are applicable to the determination of semivolatile principal organic hazardous compounds (POHCs) from incineration systems. Because the latter method measured 70 HAP compounds, and a cupola with an afterburner acts as an incineration device, we believe that this combination of methods is appropriate and that it analyzed a sufficient number of compounds to adequately assess organic HAP emissions from a cupola. The results of these source tests indicate that organic HAP emissions from cupola afterburners are very low. Most of the analytes were not present above the quantitation limits of the analytical methods. Those that were detected, were present at concentrations of less that 2 parts per billion by volume (ppbv).

TABLE 4-10. SOURCE TEST DATA FOR ORGANIC HAP EMISSIONS FROM CUPOLA AFTERBURNERS

Run No.	PCDD/PCDF concentration in offgas adjusted by the 2,3,7,8-TCDD TEF, ng/dscm		Semivolatile organic HAP concentration in offgas, ppbv	
	Total PCDD/PCDF	2,3,4,7,8-PeCDF	Acetophenone	Pyrene
Foundry IN-34 (combustion temperature: 1,650 °F)				
1	{1.82}*	1.01	1.79	ND†
2	3.65	1.93	0.65‡	ND
3	{5.47}	2.95	1.09	ND
Foundry MI-33 (combustion temperature: 1,550 °F)				
1	{0.85}	0.40	0.82‡	0.070
2	{0.54}	0.25	0.41‡	0.046
3	{0.18}	0.06	0.45	0.021
4	{0.17}	0.07	0.29‡	0.019

* Values in brackets indicate that at least some of the species contributing to the total value were detected in levels below the quantitative limit.
† ND - Not detected.
‡ Sample catch was less than five times the estimated laboratory blank value.

4.4.2 EIF Controls

Unlike cupolas, electric furnaces do not include well-defined stacks. Control systems for these furnaces must therefore include hoods or other types of capture mechanisms ducted to the control devices. Also, the charging, melting, and tapping phases of the melting cycle occur in sequence, whereas in a cupola these operations occur simultaneously. Charging emissions from these furnaces may be significant. Charging and melting emissions may be captured by different systems because the configuration of the furnace is different for the two operations (i.e., the furnace cover is removed for charging). The two exhaust streams may be ducted to separate control devices or to the same device. Depending on the capture systems used, tapping emissions may also be captured, usually incidentally because these emissions are relatively insignificant and no system dedicated to these emissions is normally used.

Tables 4-11 through 4-15 summarize the use of control devices reported in 1998 on EIFs. Most EIFs were not controlled. The vast majority of EIFs with controls used fabric filters or cartridge filters. As seen in Tables 4-11 and 4-13, although a great variety of combinations of controls exists, most of those combinations include only filters. Also, most preheaters (PHs) were used in conjunction with EIFs. As shown earlier in Table 4-4, 60 PHs were equipped with filters for at least one phase of the melting operation. Forty-eight of these were employed in conjunction with EIFs that also were equipped with filters. Of those 48 PHs, 30 were controlled by the same filters as their associated EIF.

Table 4-15 summarizes A/C ratio data for EIF filters. In general, baghouses used to control EIF emissions had higher A/C ratios than baghouses used to control cupola emissions.

Source test data for induction furnace and preheater PM emissions were available for 19 fabric filters (17 baghouses and 2 cartridge filters) used to control emissions from 57 EIFs and 16 scrap PHs, from 1 venturi scrubber on 2 electric induction furnaces, and from 1 cyclone on 2 EIFs. Figure 4-3 diagrams outlet gas PM concentration to illustrate the effectiveness of these control systems. Note, repetitive foundry listings for WI-47 in Figure 4-3 indicate separate fabric filter control systems; otherwise, repetitive foundry listings in Figure 4-3 indicate that the baghouses were tested multiple times. Detailed information on the source tests summarized in Figure 4-3 can be found in Appendix E.

TABLE 4-11. CONTROL CONFIGURATIONS FOR EIFs AT IRON FOUNDRIES[1]

Operation and type of control			Number of furnaces with configuration[2]	Number of foundries with configuration
Charging	Melting	Tapping		
No control	No control	No control	438	181
Filter[3]	Filter	Filter	210	69
Filter	Filter	No control	43	14
No control	Filter	No control	17	7
Filter	No control	No control	11	3
No control	Filter	Filter	8	2
No control	No control	Filter	6	2
No control	Wet scrubber	No control	5	1
Wet scrubber	Wet scrubber	No control	5	2
Wet scrubber	Wet scrubber	Wet scrubber	4	1
Filter	No control	Filter	2	1
No control	Cyclone	No control	2	1
No control	No control	Wet scrubber	2	1
Filter	Wet scrubber	Wet scrubber	1	1
Totals			754	286

[1] Blank responses were interpreted to mean no control and thus were classified as "no control."
[2] Information is ranked by the number of furnaces controlled with the given configuration.
[3] Filter = fabric filter or cartridge filter (the former make up the majority).

TABLE 4-12. SPECIFIC CONTROLS ON EIFs AT IRON FOUNDRIES[1]

Type of control	Number of operations controlled		
	Charging	Melting	Tapping
Furnaces with filter[2]	267	278	226
Foundries with filter	88	92	74
Furnaces with wet scrubber	9	15	7
Foundries with wet scrubber	3	5	3
Furnaces with cyclone		2	
Foundries with cyclone		1	
Total number of furnaces with control	276	295	233
Total number of foundries with control	91	98	77
Total number of furnaces with no control	478	459	521
Total number of foundries with no control	195	188	209
Total number of furnaces	754	754	754
Total number of foundries	286	286	286

[1] Blank responses were interpreted to mean no control and thus were classified as "no control."
[2] Filter = fabric filter or cartridge filter (the former make up the majority).

TABLE 4-13. CONTROL CONFIGURATIONS FOF EIF AT STEEL FOUNDRIES[1]

Operation and type of control			Number of furnaces with configuration[2]	Number of foundries with configuration
Charging	Melting	Tapping		
No control	No control	No control	509	144
Filter[3]	Filter	Filter	81	23
Filter	Filter	No control	14	3
No control	Filter	No control	11	5
Cyclone	Cyclone	Cyclone	6	2
No control	Filter	Filter	4	3
Wet scrubber	Wet scrubber	Wet scrubber	4	1
No control	Electrostatic oil collection	No control	4	1
Argon gas cover	Argon gas cover	No control	3	1
Filter	No control	No control	3	1
No control	No control	Filter	2	1
No control	Wet scrubber	No control	2	1
Totals			643	186

[1] Blank responses were interpreted to mean no control and thus were classified as "no control."
[2] Information is ranked by the number of furnaces controlled with the given configuration.
[3] Filter = fabric filter or cartridge filter (the former make up the majority).

TABLE 4-14. SPECIFIC CONTROLS ON EIFs AT STEEL FOUNDRIES[1]

Type of control	Number of operations controlled		
	Charging	Melting	Tapping
Furnaces with filter[2]	98	110	87
Foundries with filter	27	34	27
Furnaces with wet scrubber	4	6	4
Foundries with wet scrubber	1	2	1
Furnaces with other	9	13	6
Foundries with other	3	4	2
Total number of furnaces with control	111	132	98
Total number of foundries with control	31	43	31
Total number of furnaces with no control	532	514	546
Total number of foundries with no control	155	146	156
Total number of furnaces	643	643	643
Total number of foundries	186	186	186

[1] Blank responses were interpreted to mean no control and thus were classified as "no control."
[2] Filter = fabric filter or cartridge filter (the former make up the majority).

TABLE 4-15. A/C RATIOS FOR FILTERS ON EIFs

A/C ratio	Filters in iron foundries	Filters in steel foundries
< 2	3	1
2 to 2.99	12	6
3 to 3.99	17	1
4 to 4.99	8	4
5 to 5.99	6	5
≥ 6	17	3

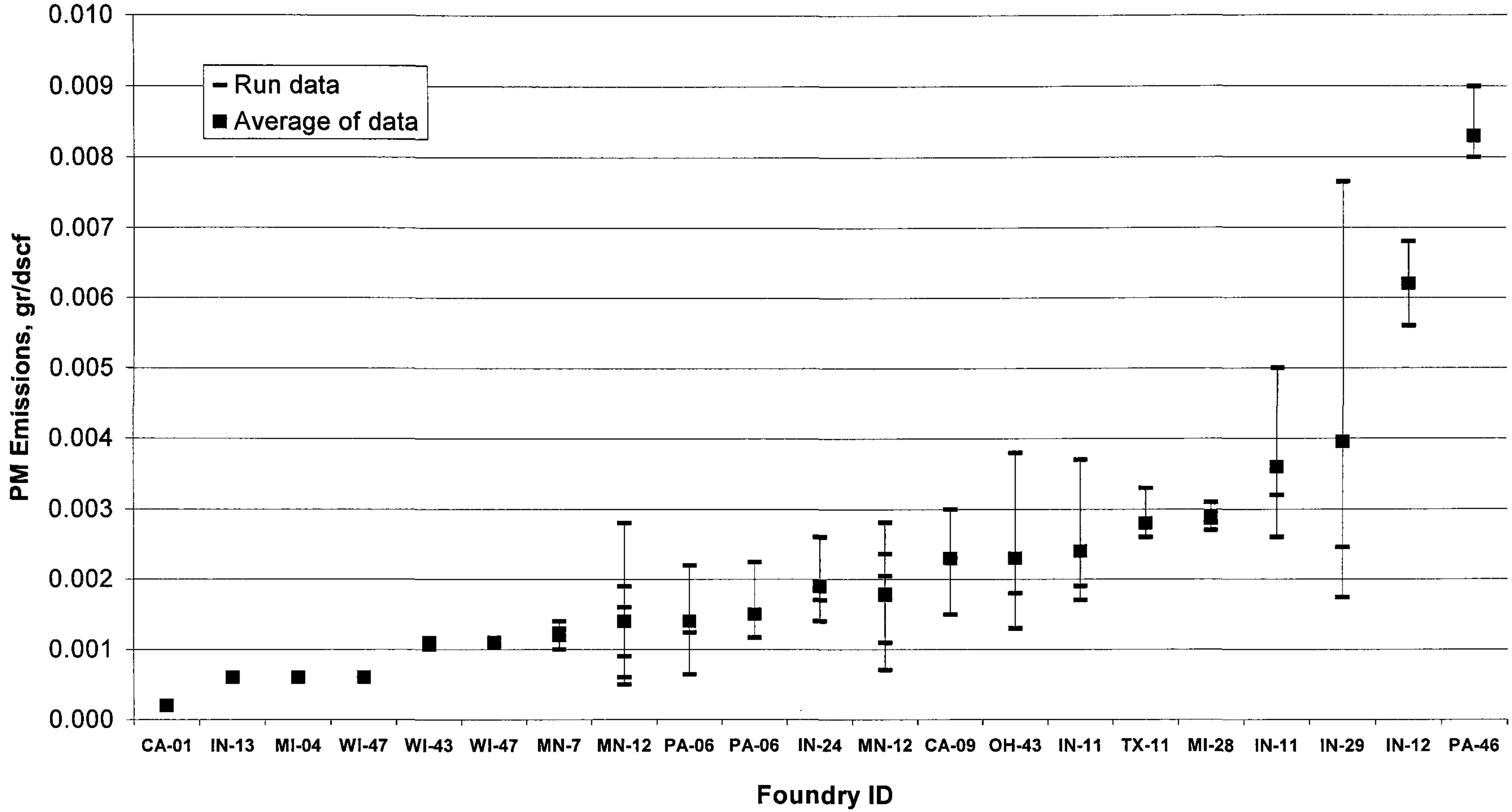


Figure 4-3. Filterable PM Emissions (gr/dscf) from Fabric Filters on EIFs at Iron and Steel Foundries

Other available data include measurements on actual HAP emissions. Data for HAP metals are available from one test on a wet scrubber and one test on a cyclone device, termed a skimmer, that serves a PH. The latter test was conducted in 1973, when the quality of scrap was not as closely controlled as it is today, and therefore emissions would not be characteristic of those expected in present operations. Emissions tested in either case are not representative of the best controlled EIF/PH emissions from current foundries. Organic HAP emission data are available for only two wet scrubbers controlling three EIFs at two foundries; one of these scrubbers also controls a pouring and cooling line. Collectively, these data are not sufficient to establish a basis for estimating HAP emissions.

4.4.3 EAF Controls

The use of controls for EAFs in iron and steel foundries for melting is similar to that for EIFs. The number of EAFs used in ferrous foundries is much smaller than the number of EIFs used. Arc furnaces are more common in steel than in iron foundries. Tables 4-16 through 4-20 summarize the use of controls on EAFs in 1998. Fabric filters were by far the most common devices used. Table 4-20 summarizes A/C ratio data for EAF baghouses.

TABLE 4-16. CONTROL CONFIGURATIONS FOR EAFs AT IRON FOUNDRIES[1]

Operation and type of control			Number of furnaces with configuration[2]	Number of foundries with configuration
Charging	Melting	Tapping		
No control	Filter[3]	No control	10	3
Filter	Filter	Filter	8	4
Filter	Filter	No control	6	2
No control	Filter	Filter	4	2
Totals			28	11

[1] Blank responses were interpreted to mean no control and thus were classified as "no control."
[2] Information is ranked by the number of furnaces controlled with the given configuration.
[3] Filter = fabric filter or cartridge filter (the former make up the majority).

TABLE 4-17. SPECIFIC CONTROLS ON EAFs AT IRON FOUNDRIES[1]

Type of control	Number of operations controlled		
	Charging	Melting	Tapping
Furnaces with filter[2]	14	28	12
Foundries with filter	6	11	6
Furnaces with no control	14	0	16
Foundries with no control	5	0	5
Total number of furnaces	28	28	28
Total number of foundries	11	11	11

[1] Blank responses were interpreted to mean no control and thus were classified as "no control."
[2] Filter = Fabric filter or cartridge filter (the former make up the majority).

TABLE 4-18. CONTROL CONFIGURATIONS FOR EAFs AT STEEL FOUNDRIES[1]

Operation and type of control			Number of furnaces with configuration[2]	Number of foundries with configuration
Charging	Melting	Tapping		
No control	Filter[3]	No control	48	23
Filter	Filter	No control	34	15
Filter	Filter	Filter	33	21
No control	Filter	Filter	17	9
No control	No control	No control	3	3
Totals			135	71

[1] Blank responses were interpreted to mean no control and thus were classified as "no control."
[2] Information is ranked by the number of furnaces controlled with the given configuration.
[3] Filter = fabric filter or cartridge filter (the former make up the majority).

TABLE 4-19. SPECIFIC CONTROLS ON EAFs AT STEEL FOUNDRIES[1]

Type of control	Number of operations controlled		
	Charging	Melting	Tapping
Furnaces with filter[2]	67	132	50
Foundries with filter	36	68	30
Furnaces with no control	68	3	85
Foundries with no control	35	3	41
Total number of furnaces	135	135	135
Total number of foundries	71	71	71

[1] Blank responses were interpreted to mean no control and thus were classified as "no control."
[2] Filter = fabric filter or cartridge filter (the former make up the majority).

TABLE 4-20. A/C RATIOS FOR FABRIC FILTERS ON EAFs

A/C ratio	Filters in iron foundries	Filters in steel foundries
< 2	0	5
2 to 2.99	9	39
3 to 3.99	1	10
4 to 4.99	1	0
5 to 5.99	0	2
≥ 6	0	2

Source test data for arc furnace PM emissions are available for 10 baghouses used to control the emissions from 23 EAFs operated by iron and steel foundries. Figure 4-4 is a chart of outlet gas PM concentration data; repetitive foundry listings in Figure 4-4 indicate a baghouse that was tested multiple times. Information on the source tests from which data in this figure are derived is summarized in Appendix F. Average outlet PM concentrations for the ten baghouses tested ranged from 0.0005 to 0.0044 gr/dscf, except for one baghouse that had a measured concentration of 0.0080 gr/dscf and another baghouse for which the result of one of two tests was 0.0066 gr/dscf.

4.4.4 EAF and EIF Capture Systems

Emissions from the different operations in the melting cycle (charging, melting, and tapping) require different capture techniques. For example, melting emissions can be captured by a close-fitting lid or hood equipped with a duct, which can be connected to a control device.

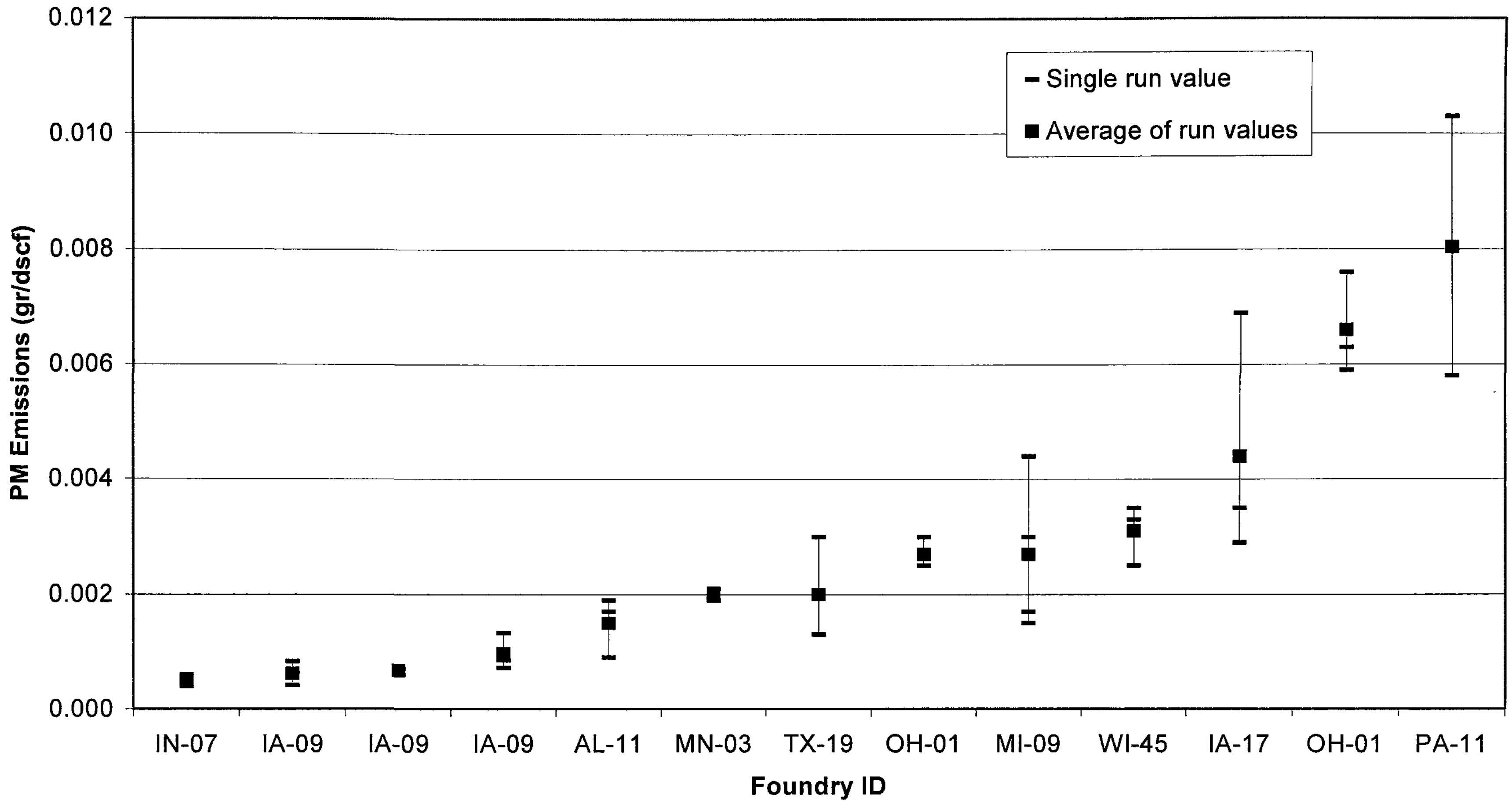


Figure 4-4. Filterable PM Emissions (gr/dscf) from Fabric Filters on EAFs at Iron and Steel Foundries.

This lid must be removed for charging when the top of the furnace is open and for tapping when the furnace is tilted to pour the molten metal. Capture systems consist of two general types: close capture and general capture. Close-capture systems, which are more effective, use techniques such as side draft hoods, direct evacuation systems, fume rings, and close-fitting hoods that capture emissions before they escape from the immediate vicinity of the furnace. These systems require only a small volume of air flow, which is drawn through attached ductwork to a control device that can be dedicated to specific operations. General-capture systems employ (1) canopy hoods or total enclosures, both of which can be used with dedicated control devices but require a higher volume of air flow than close-capture systems, or (2) building or bay evacuation systems, which also require large volumes of air and must serve the entire building or a large segment of it.

Information on the use of capture systems in 1998 is given in Tables 4-21 and 4-22. Most EIF emissions were not captured. Melting emissions from most EAFs were captured, mainly with close- capture systems, probably because arc furnaces produce more emissions. Comparing this information with the information on use of controls given previously, most emissions (from both types of furnace) that were captured were also controlled. The following sections describe some of the capture mechanisms identified above.

4.4.4.1 **Side Draft Hoods.** Side draft hoods are used on both EIFs and EAFs. For EIFs, the side draft hood is located to the side of the furnace (near the top), where it controls emissions from charging and melting operations and from the tapping spout (see Figures 4-5a and 4-5b). For EAFs, the side draft hood is mounted on the roof of the furnace to control melting emissions (see Figure 4-6). The capture system in Figure 4-6 requires a tight fit of the furnace roof so that emissions can escape only through the spaces between the electrodes and the hood. The roof hood is not effective when it is removed during charging and tapping. Particulate capture efficiency ranges between 90 and 100 percent for melting emissions, with a typical efficiency of 99 percent (EPA, 1981). Side draft hoods on EAFs may also be placed to the side of the furnace to control emissions from charging operations and from the tapping spout.

TABLE 4-21. USE OF CAPTURE SYSTEMS ON EIFs AT IRON AND STEEL FOUNDRIES

Capture system type	Melting furnace operation serviced		
	Charging	Melting	Tapping
Close capture[1]:			
Number of furnaces	211	261	160
Number of foundries	66	78	53
Other type[2]:			
Number of furnaces	185	200	169
Number of foundries	69	84	63
No capture[3]:			
Number of furnaces	1001	936	1068
Number of foundries	334	315	353
Total number of furnaces: 1,397 **Total number of foundries:** 445[4]			

[1] Close capture includes side draft hood, fume ring, close-fitting hood, and direct evacuation (melting).
[2] Other includes canopy hood, draft system or ventilation to a baghouse, area ducting, suction tube, and building evacuation to a baghouse.
[3] No capture includes not reported, roof vent, exhaust fan, lid or cover, or general ventilation.
[4] The number of foundries in the table totals over 445 because some foundries had multiple configurations.

TABLE 4-22. USE OF CAPTURE SYSTEMS ON EAFs AT IRON AND STEEL FOUNDRIES

Capture system type	Melting furnace operation serviced		
	Charging	Melting	Tapping
Close capture[1]:			
Number of furnaces	32	120	33
Number of foundries	20	62	19
Other type[2]:			
Number of furnaces	41	26	17
Number of foundries	18	9	11
No capture[3]:			
Number of furnaces	92	17	113
Number of foundries	46	10	52
Total number of furnaces: 168 **Total number of foundries:** 81[4]			

[1] Close capture includes side draft hood, fume ring, close-fitting hood, and direct evacuation.
[2] Other includes canopy hood, draft system or ventilation to a baghouse, area ducting, suction tube, and building evacuation to a baghouse.
[3] No capture includes not reported, roof vent, exhaust fan, lid or cover, or general ventilation.
[4] The number of foundries in the table totals over 81 because some foundries had multiple configurations.

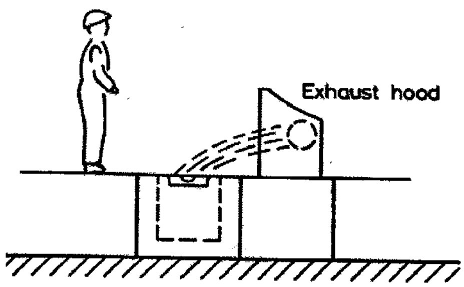


Figure 4-5a. Side Draft Hood on EIF (Shaw, 1982).

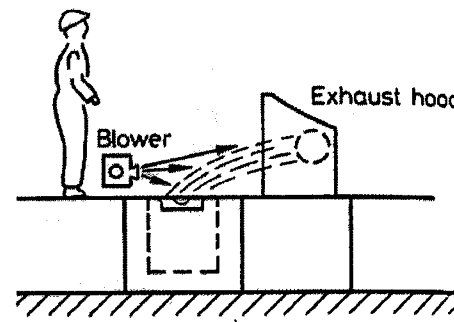


Figure 4-5b. Side Draft Hood with Blower on EIF (Shaw, 1982).

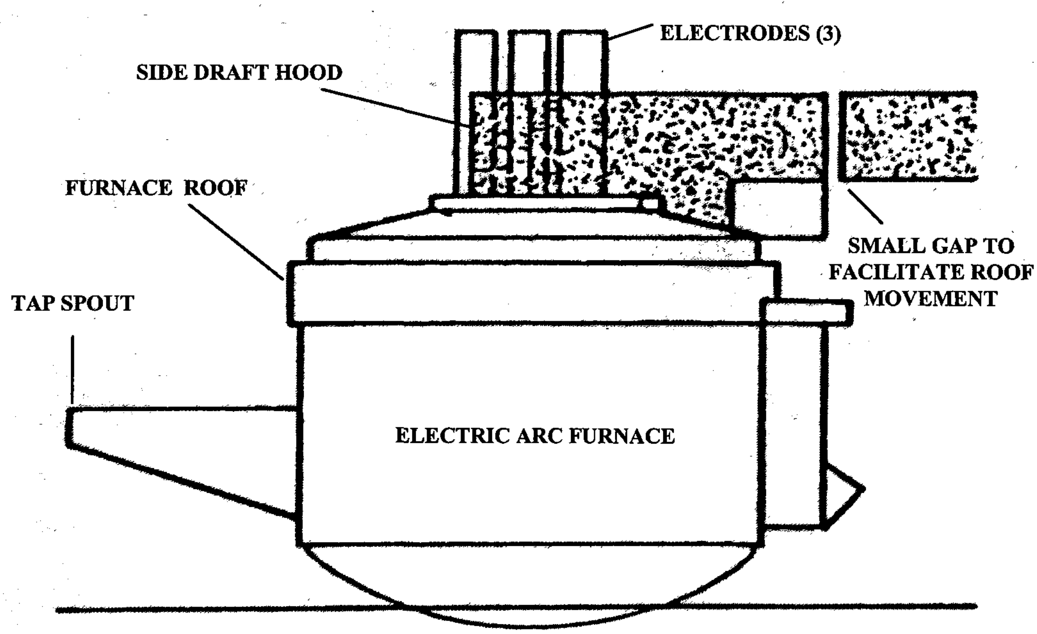


Figure 4-6. Side Draft Hood on an EAF (EPA, 1983).

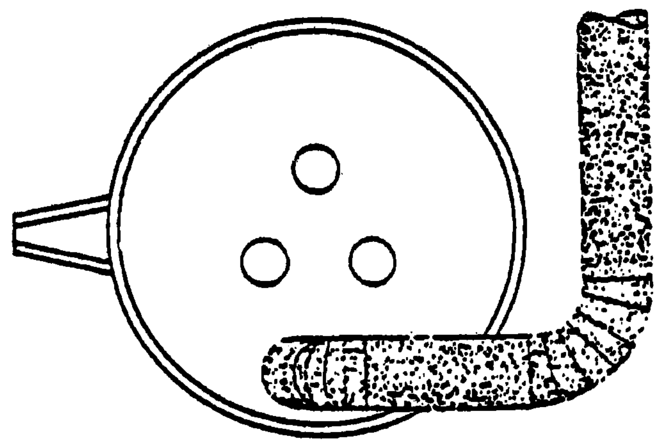
4.4.4.2 **Direct Evacuation Control (DEC) System.** The DEC system draws exhaust gases from beneath the roof of an electric furnace. The system consists of a water-cooled or refractory-lined duct that attaches to the furnace roof, and, when the roof is in place, joins a duct that is connected to an emission control device (see Figure 4-7 for an example of a DEC on an EAF). At the connecting point of the two ducts, there is a small gap that allows dilution air to enter the duct. The gap also allows room for the furnace roof to be elevated and rotated to the side for charging and for the furnace to be tilted for tapping. The DEC system is only effective when the furnace roof is in place.

The DEC system provides good emission control with a minimum of energy because the air volume withdrawn is the lowest of the process emission capture devices (EPA, 1983, p. 4-3). During melting, a slight negative pressure is maintained within the furnace to effectively withdraw the emissions through the DEC system. The DEC system withdraws between 90 and 100 percent of the melting emissions from the furnace. A typical particulate capture efficiency with a properly operated DEC system is estimated to be 99 percent (EPA, 1981).

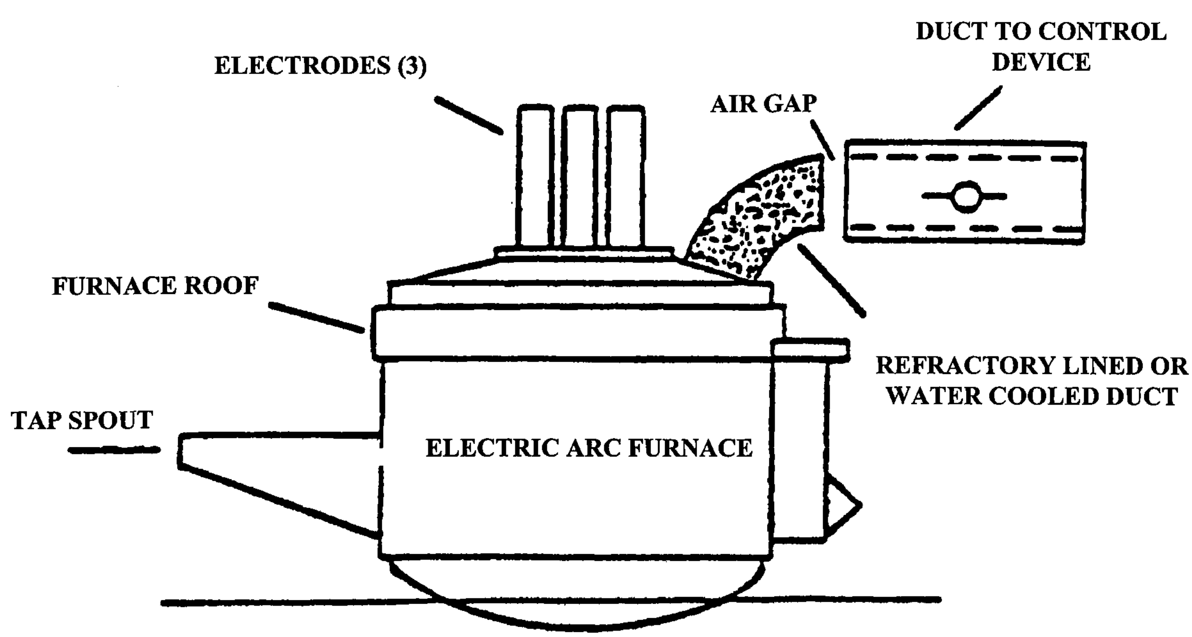
4.4.4.3 **Fume Rings.** As shown in Figure 4-8, a suction ring (also known as a fume ring or lip extraction ring) can be fixed to the top of an EIF to capture emissions during melting. A fume ring works well when the furnace lid is in place for melting and holding; however, when the lid is removed for charging, capture is poor. During pouring, capture may not be good even though the exhaust connection is still in use with the furnace tilted. Consequently, some facilities use the fume ring for melting emissions in combination with a canopy hood for emissions during charging and pouring (Shaw, 1982).

4.4.4.4 **Close-Fitting Hoods.** A close fitting hood is a broad term for capture mechanisms that are located closer to their emissions sources than canopy hoods, but that do not fall under the specific categories of side draft hoods and DEC systems. Figure 4-9 shows an example of two close- fitting hoods on an EAF. In this figure, a rectangular hood that completely surrounds the electrodes is used to evacuate melting and refining emissions using minimum exhaust volumes.

4.4.4.5 **Canopy Hoods.** Figure 4-10 provides an example of a canopy hood system. The hood is placed as close above the furnace as possible, but allowing clearance for a monorail or crane charging system and for the vertical electrodes of an EAF, including the upward



PLAN VIEW



ELEVATION

Figure 4-7. Direct Evacuation System on an EAF (EPA, 1983).

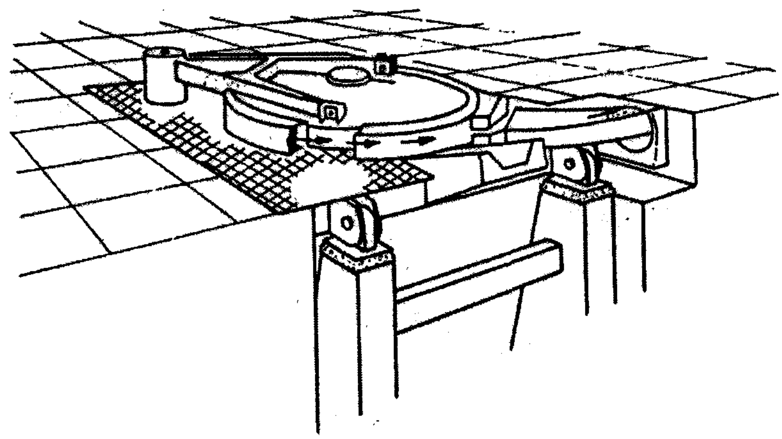


Figure 4-8. Fume Ring on an EIF (Shaw, 1982).

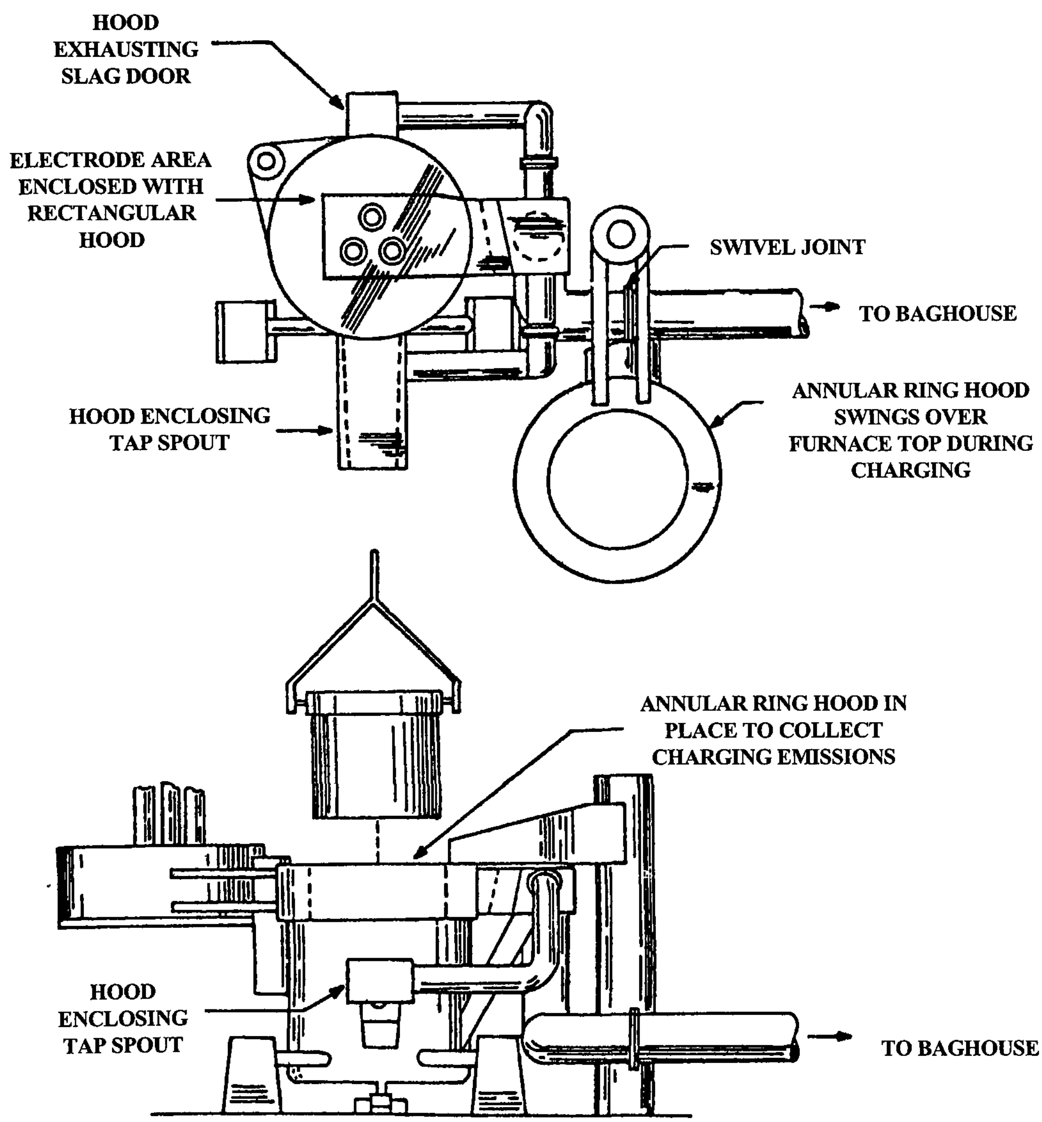


Figure 4-9. Close-Capture Hood System on an EAF (EPA, 1981).

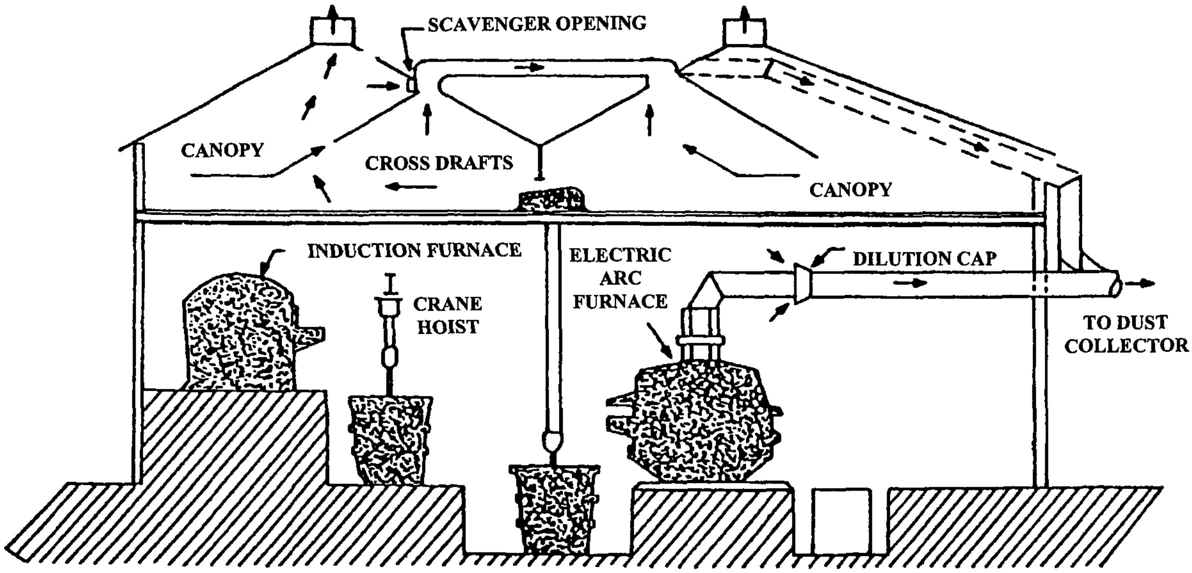


Figure 4-10. Canopy Hood System (EPA, 1981).

movement of the electrodes when the furnace roof is removed. The hood may run only during charging and tapping stages or may run through the complete melting cycle, and it must be physically large enough and draw through a large enough volume of air to ensure effective capture of emissions. Impingement on overhead equipment and cross drafts in the shop can lower the collection efficiency. Devices such as curtain walls and air curtains may be used to reduce cross drafts. The particulate capture efficiency of a canopy hood can be 80 to 90 percent, with the lower figure considered a more typical value when considering potential crossdrafts (EPA, 1981, p. 86).

4.4.4.6 <u>Total Furnace Enclosure</u>. A total furnace enclosure completely surrounds a furnace with a metal shell that acts to contain all the charging, melting and refining, and tapping emissions, as well as to reduce furnace noise and heat radiation outside the enclosure (see Figure 4-11). The enclosure is typically designed to capture all the process and fugitive emissions because the emissions are confined to a small area. Total furnace enclosures operate with a greatly reduced air flow compared with building evacuation or canopy hood systems. The volume of air that must be removed from the total furnace enclosure is estimated to be only 30 to 40 percent of that required for an efficient canopy hood system. Particulate capture efficiencies for total furnace enclosures are estimated to range from 90 to 100 percent (EPA, 1983, p. 4-2).

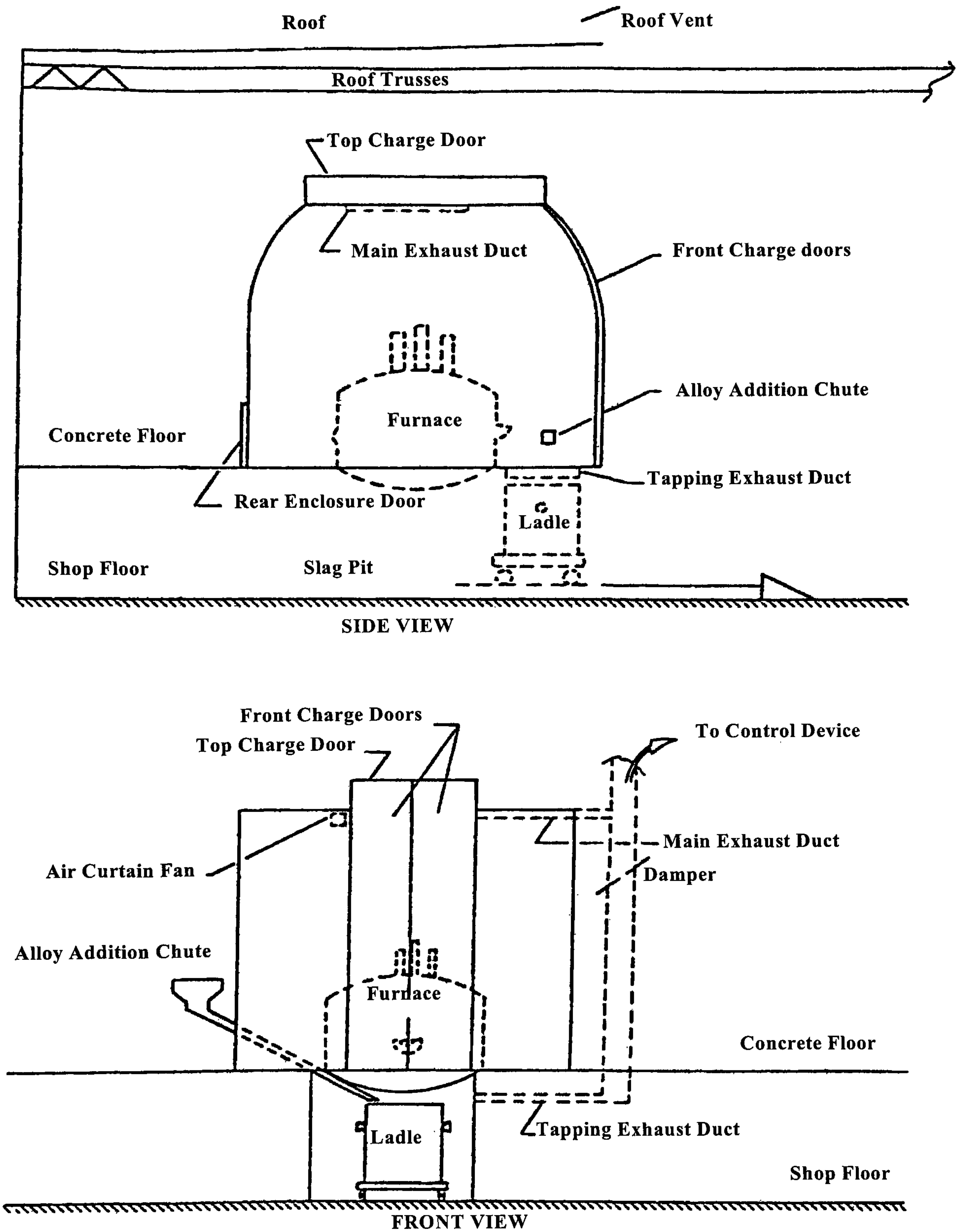


Figure 4-11. Schematic of a Total Furnace Enclosure (EPA, 1981).

4.4.4.7 **Building and Bay Evacuation.** A building or bay evacuation system involves a closed shop roof with ductwork at the peak of the roof to collect all emissions from the shop operations (see Figure 4-12). The system requires a large volume of air flow but has a particulate capture efficiency of 95 to 100 percent (the typical maximum particulate removal efficiency is 99 percent) (EPA, 1981, p. 86). Bay evacuation systems can produce an emission capture efficiency similar to building evacuation (EPA, 1981, p. 86). In bay evacuation systems (see Figure 4-13), each shop bay is separated from other bays by air locks and/or soundproof doors, and each bay is evacuated separately (EPA, 1981, p. 86).

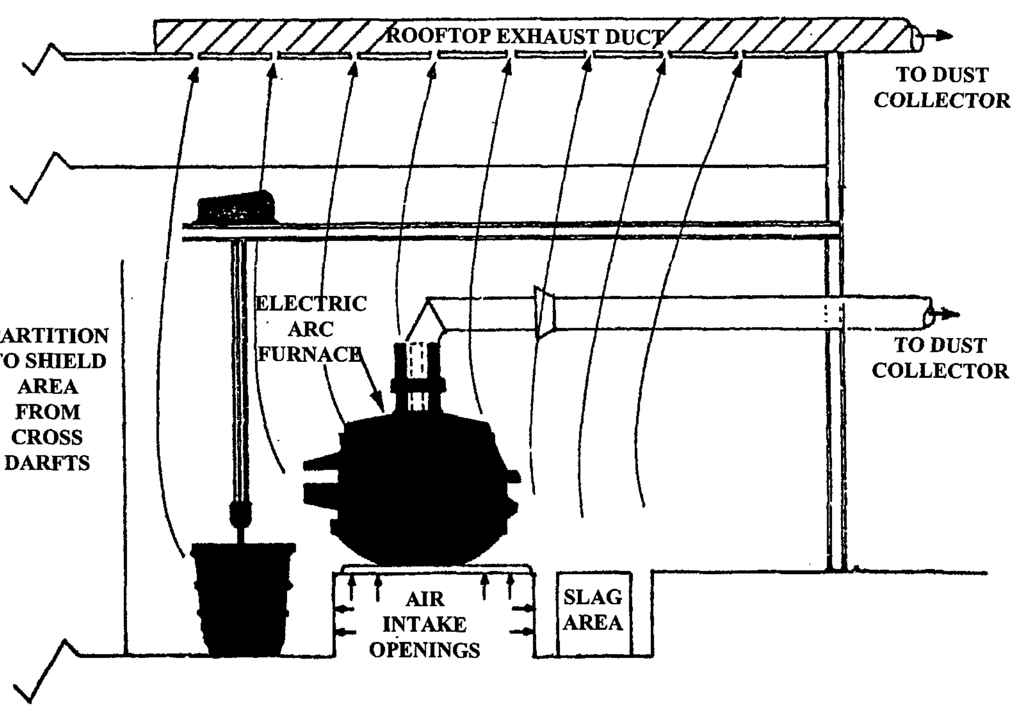


Figure 4-12. Building Evacuation System (EPA, 1991).

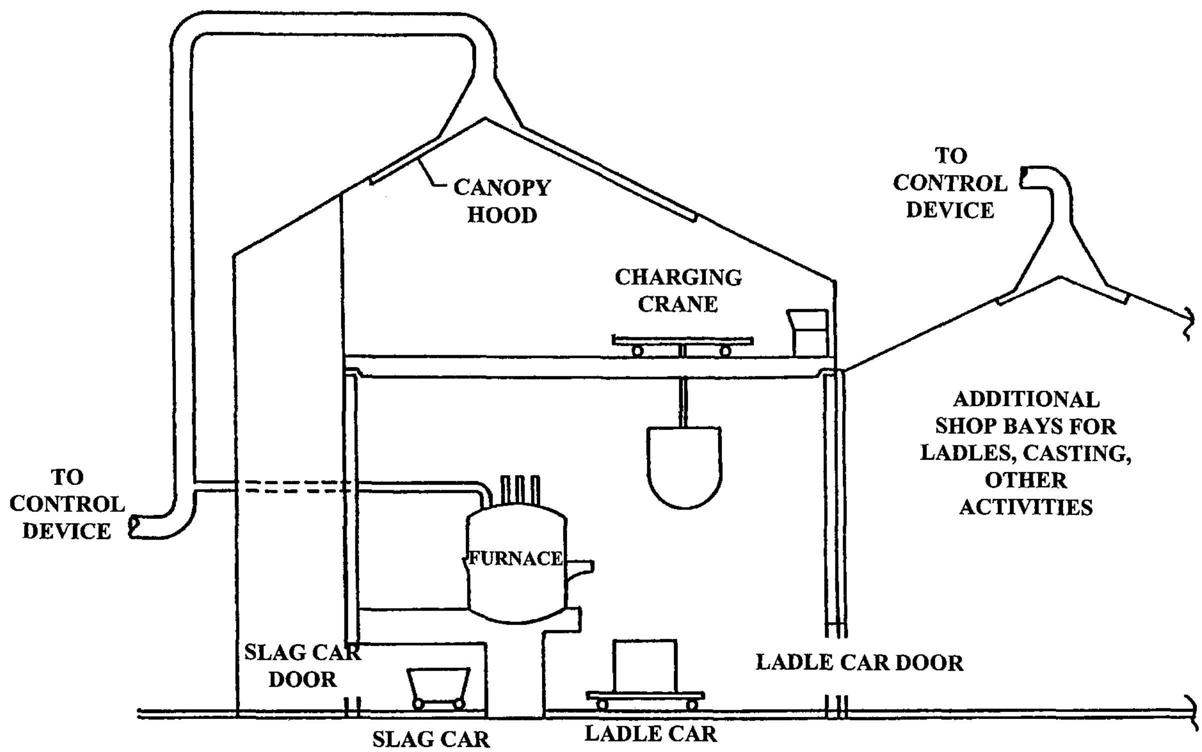


Figure 4-13. Schematic of a Bay Evacuation System (EPA, 1980).

4.5 POURING, COOLING, AND SHAKEOUT

Controls for organic compound emissions are rarely used. Most reductions for these compounds are achieved by ignition of the mold vents, which occurs spontaneously on automated lines and is commonly done by manual ignition in floor or pit pouring stations.

In 1998, one foundry employed a thermal oxidizer on one of its pouring/cooling lines. This line used exclusively sand molds that were chemically bonded by the phenolic urethane cold-box process. According to the foundry operator, fumes from this line were substantially greater than fumes from their green sand line. The oxidizer was operated at 1,500 °F. VOC emissions in the exhaust gases were reported to be 2.3 ppm. No measurements were taken for inlet gases. By comparison, emissions of benzene measured at various locations in a pouring/cooling line in an EPA test by a portable test unit that used a gas chromatography/mass spectrography analysis system were typically 3 ppm (EPA, 1999). Benzene was the primary HAP detected in this test. VOCs were not measured, so no direct comparisons in emissions are possible between the green sand lines for which mold vent ignition was used and the chemically bonded mold line in which thermal oxidation was used.

Additionally, two foundries employed a carbon adsorption system to control emissions from their pouring/cooling lines. One of these lines used chemically bonded sand molds; the other line used green sand molds with chemically bonded cores.

In contrast to organic emissions, controls for PM emissions are almost universal, especially in shakeout processes, where most of these emissions are produced. Shakeout PM emissions are mainly large particles that are mostly sand. These emissions are almost always controlled, usually by fabric filters, but often by wet scrubbers or other devices. Shakeout usually occurs in a partially enclosed area or in a device designed for sand/casting separation such as a rotating cylinder or vibrating conveyor in which the sand is screened from the castings.

Emissions of PM from pouring are quite different from shakeout emissions, consisting mainly of metal and metal oxide fumes. Emissions of PM from cooling are generally low and consist mainly of condensible byproducts (i.e., soot) generated by the incomplete combustion of organic material (seacoal, chemical binders, and other additives) contained in the mold and core sand. Pouring and cooling emissions are often captured (by such devices as canopy or side draft hoods), but they are not always controlled.

Control devices for PCS operations may be dedicated to one or more of these operations but also may serve a variety of emission sources. Their use varies greatly from one foundry to another. Emission data from control devices will therefore reflect the fact that many types of PM are present in inlet streams and also that inlet PM loadings will vary substantially depending on air flow requirements in serving the various emission sources.

As shown in Table 4-23, fabric filters and cartridge filters were the most common control devices used for shakeout and controlled approximately half of the stations. Table 4-24 provides the A/C ratios for these filters and shows that the ratios were generally higher than those for filters used on melting furnaces. Similarly, the pressure drops for wet scrubbers (Table 4-25) show levels much lower than those used on cupolas.

TABLE 4-23. CONTROL DEVICES USED ON SHAKEOUT STATIONS

Control device	Number of shakeout stations	Number of foundries
Fabric or cartridge filter	602	360
No control	384	225
Wet scrubber	161	79
Other[1]	9	7
Total	1,156	569[2]

[1] Other includes cyclone, rotoclone, and "wet system."
[2] Total number of foundries reporting shakeout stations. The sum for each type of control is greater than 569 because several foundries had multiple configurations.

TABLE 4-24. A/C RATIOS FOR FABRIC FILTERS ON SHAKEOUT STATIONS

A/C ratio, ft/min	Number of filters
< 2	38
2 to 2.99	37
3 to 3.99	34
4 to 4.99	23
5 to 5.99	61
6 to 6.99	57
≥ 7	91

TABLE 4-25. PRESSURE DROPS FOR WET SCRUBBERS ON SHAKEOUT STATIONS

Pressure drop, inches of water	Number of scrubbers
2 to 4.9	7
5 to 5.9	22
6 to 6.9	21
7 to 7.9	15
8 to 9.9	11
10 to 13.5	19

Data for PCS PM emissions consist of outlet concentration measurements on 33 fabric filters and 8 wet scrubbers at 21 foundries. The data for the respective devices are shown in Figures 4-14 and 4-15. The repetitive foundry listings in Figure 4-14 indicate separate fabric filter control systems, except for one fabric filter at WI-43 that was tested twice. Repetitive foundry listings in Figure 4-15 indicate separate wet scrubber control systems, except for one wet scrubber at TN-9 that was tested three times. A summary of the data is also given in Tables 4-26 and 4-27, which also identify other emission sources served by the devices.

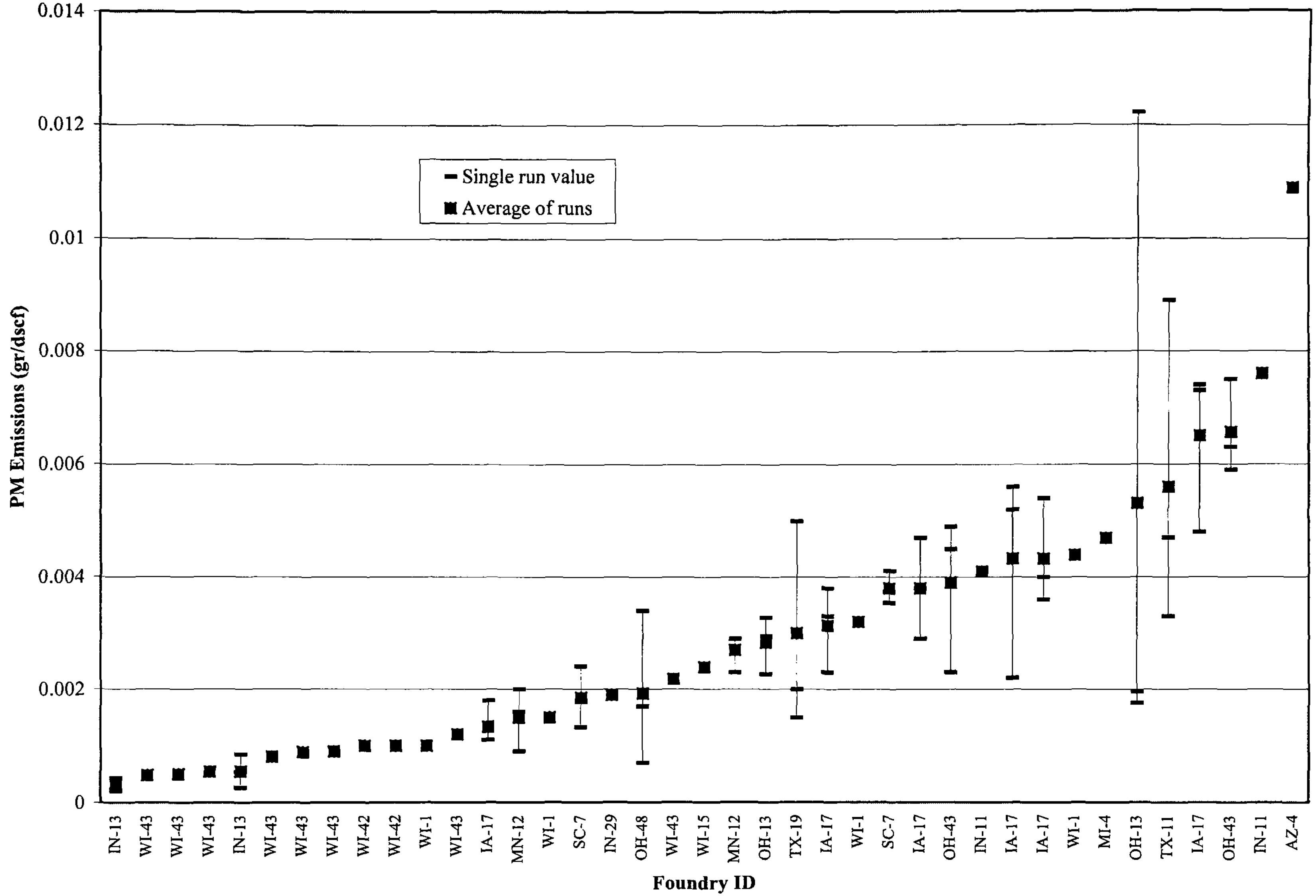


Figure 4-14. Filterable PM Emissions (gr/dscf) from Fabric Filters on PCS at Iron and Steel Foundries. (does not include OH-22 at 0.03 gr/dscf – see Appendix G for details)

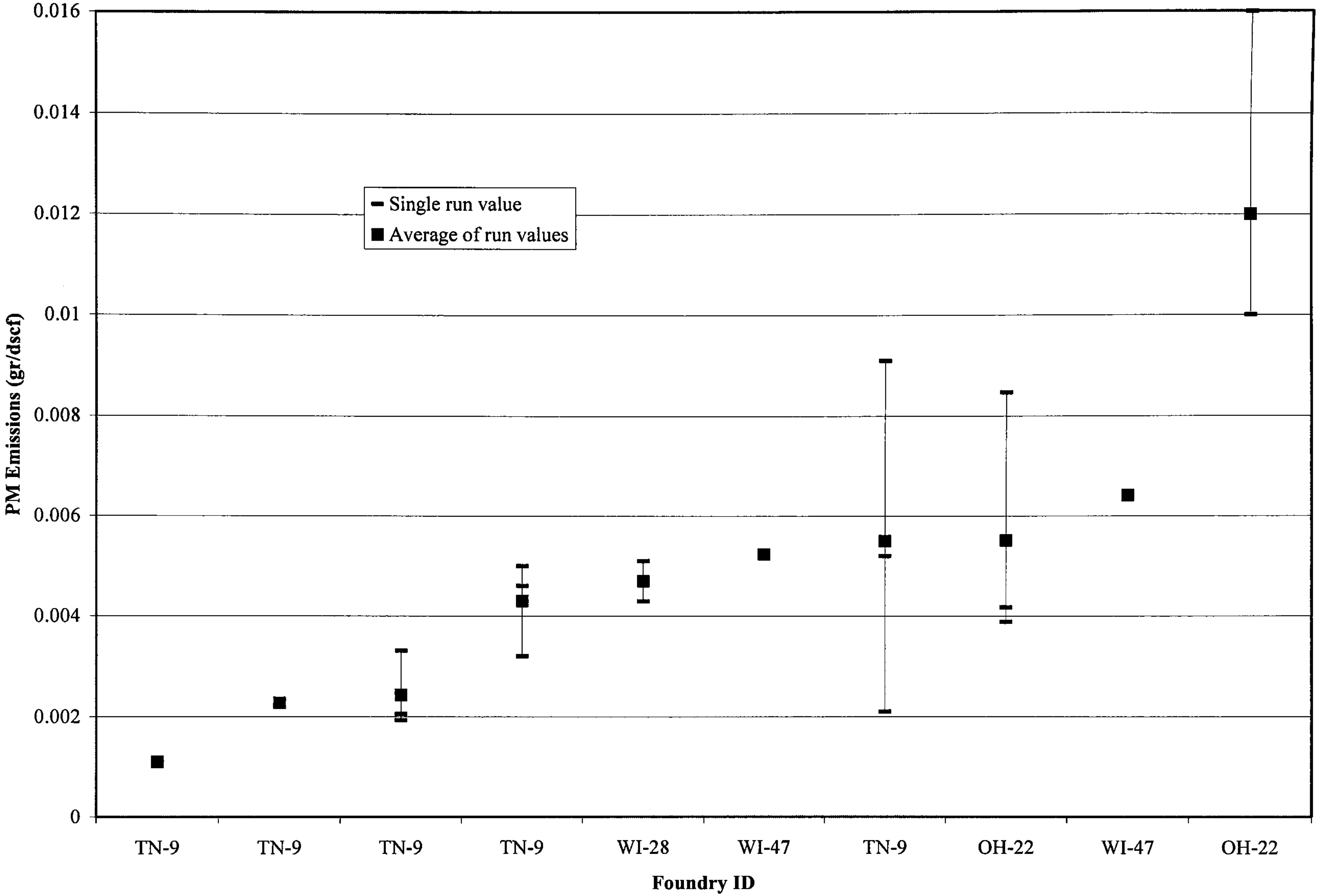


Figure 4-15. Filterable PM Emissions (gr/dscf) from Scrubbers on PCS at Iron and Steel Foundries

TABLE 4-26. PCS FABRIC FILTER OUTLET CONCENTRATION AND SERVICE DATA

Foundry ID	PM (gr/dscf)	Design information for fabric filters				Operations served
		acfm	A/C ratio, ft/min	Material	Cleaning type	
IN-13	0.00029	150,000	4.5	polyester	pulse jet	shakeout lines 1 & 2; return sand system
WI-43	0.0005	143,000	5.6	polyester felt	pulse jet	cooling and grinding
WI-43	0.0005	60,000	7.1	polyester felt	pulse jet	shakeout and grinding
WI-43	0.0005	101,000	7.1	polyester felt	pulse jet	cooling and sand handling
IN-13	0.00055	85,500	4.4	polyester	pulse jet	shakeout lines 3 & 4
WI-43	0.0008	60,000	7.1	polyester felt	pulse jet	cooling, shakeout, grinding
WI-43	0.0009	60,000	7.1	polyester felt	pulse jet	cooling, shakeout, grinding
WI-43	0.0009	60,000	7.1	polyester felt	pulse jet	cooling, shakeout, grinding - line 1
WI-42	0.001	150,000	6.6	polyester felt	pulse jet	2 pouring/cooling lines; 2 cast cooling lines
WI-42	0.001	150,000	6.5	polyester felt	pulse jet	shakeout
WI-1	0.001	198,000	NR	NR*	NR	5 shakeout/cast cooling lines
WI-43	0.0012	180,000	7.1	polyester felt	pulse jet	cooling, shakeout, grinding - line 6
IA-17	0.0013	50,000	1.4 (cartridge)	cellulose	pulse jet	shakeout and sand transfer with line 802
MN-12	0.0015	12,400	9.4	polyester	shaker	pouring
WI-1	0.0015	51,000	NR	NR	NR	pouring/cooling lines 1 & 5; sand mullor
SC-7	0.00185	60,000	NR (cartridge)	NR	pulse jet	pouring/cooling
IN-29	0.0019	51,000	5.5	polyester felt	pulse jet	shakeout
OH-48	0.0019	10,000	9.1	polyester	pulse jet	shakeout
WI-43	0.0022	96,000	8.9	polyester	pulse jet	cooling and shakeout
WI-15	0.0024	75,000	7.0	polyester	pulse jet	pouring, cooling, shakeout
MN-12	0.0027	10,000	5.8 (cartridge)	felt	pulse jet	cooling
OH-13	0.0028	65,000	6.5	polyester	pulse jet	pouring, cooling, shakeout, miscellaneous
TX-19	0.0030	30,000	6.5	polyester	pulse jet	shakeout

(continued)

Table 4-26. (continued)

Foundry ID	PM (gr/dscf)	Design information for fabric filters				Operations served
		acfm	A/C ratio, ft/min	Material	Cleaning type	
IA-17	0.0031	140,000	7.4	singed polyester	pulse jet	shakeout and sand transfer with Line 803
WI-1	0.0032	198,000	NR	NR	NR	pouring/cooling lines 2 & 4; sand handling
SC-7	0.0038	20,000	NR (cartridge)	NR	pulse jet	shakeout
IA-17	0.0038	375,000	5.0	polyester	pulse jet	shakeout and sand transfer with line 801
OH-43	0.0039	50,000	5.2	polyester	pulse jet	cooling; bond and sand storage
IN-11	0.0041	174,000	3.6	polyester	pulse jet	shakeout
IA-17	0.0043	110,000	5.9	polyester	pulse jet	shakeout and sand transfer with line 802
IA-17	0.0043	110,000	5.9	polyester	pulse jet	shakeout and sand transfer with line 802
WI-1	0.0044	101,000	NR	NR	NR	pouring/cooling Lines 2 & 4; sand handling
MI-4	0.0047	75,000	5.1	polyester	pulse jet	shakeout
OH-13	0.0053	65,000	6.5	polyester	pulse jet	pouring, cooling, shakeout; miscellaneous
TX-11	0.0056	170,300	2.0	polyester	shaker	pouring, cooling, shakeout
IA-17	0.0065	35,600	7.4	singed polyester	pulse jet	shakeout and sand transfer with line 803
OH-43	0.0066	50,000	5.2	polyester	pulse jet	shakeout and sand cooling
IN-11	0.0076	180,000	7.4	polyester	pulse jet	shakeout
AZ-04	0.0109	45,000	6.1	polyester	pulse jet	shakeout
OH-22	0.0294	80,000	6.4	polypropylene	pulse jet	shakeout

* NR = Not reported.

TABLE 4-27. PCS WET SCRUBBER OUTLET CONCENTRATION AND SERVICE DATA

Foundry ID	PM, gr/dscf	Design information for wet scrubbers				Operations served
		acfm	Type	Δp, inches water column	Liquid-to-gas ratio, gal/1,000 acf	
TN-9	0.0011	75,000	cyclonic	13.5	8	shakeout
TN-9	0.0023	75,000	cyclonic	13.5	8	shakeout
TN-9	0.0024	45,000	centrifugal	6.0	2.5	shakeout
TN-9	0.0043	54,000	centrifugal	5.8	2.5	pouring and cooling
WI-28	0.0047	60,000	venturi	6.0	5	cooling, shakeout
WI-47	0.0052	73,500	venturi	13	2	induction furnace, pouring, cooling
TN-9	0.0055	75,000	cyclonic	13.5	8	shakeout
OH-22	0.0055	99,000	venturi	3.5	not reported	shakeout
WI-47	0.0064	32,000	venturi	13	2	shakeout
OH-22	0.012	104,000	venturi	3.2	not reported	shakeout

4.6 SUMMARY OF FEDERAL AND STATE REGULATIONS

The Federal government has not established NSPS or other air standards specific to the metal- casting industry. Depending on the wastes produced or managed at the foundry, foundries may be subject to the hazardous waste rules under the Resource Conservation and Recovery Act.

Applicable State regulations were reviewed for the six states with the highest foundry metal melting rates. These State regulations are summarized below.

4.6.1 PM Emission Limits

Michigan has PM standards specific to foundry melting furnaces and sand handling. Existing "production" (captive) cupolas have a PM concentration limit ranging from 0.40 lb PM/1,000 lb gas (approximately 0.2 gr/dscf) for cupolas with melting capacities less than 10 tons/hr to 0.15 lb PM/ 1,000 lb gas (approximately 0.08 gr/dscf) for cupolas with melting capacities greater than 20 tons/hr. Existing "jobbing" cupolas have a PM concentration limit of 0.40 lb PM/1,000 lb gas (approximately 0.2 gr/dscf). New cupolas have an emission factor PM limit ranging from 1.8 to 0.7-lb PM/ton metal charged, with the 0.7 lb/ton factor applying to all cupolas with melting capacities over 15 tons/hr. EAF melting and sand handling both have a concentration PM limit of 0.10 lb PM/1,000 lb gas (approximately 0.05 gr/dscf).

Wisconsin also has PM standards specific to foundry melting furnaces. Cupolas have a PM concentration limit of 0.45 lb PM/1,000 lb gas (approximately 0.24 gr/dscf). Both EAFs and EIFs have a PM concentration limit of 0.10 lb PM/1,000 lb gas (approximately 0.05 gr/dscf).

Indiana has PM standards specific to foundry operations. Cupolas are provided a PM concentration limit of 0.15 gr/dscf. All other foundry operations cannot discharge into the atmosphere any gases with PM concentrations exceeding 0.07 gr/dscf.

Ohio has mass PM emission limits based on the process weight rate capacity of a generic PM emission source. These PM emission limits can be converted into emission factor limits based on the melting capacity of the furnace. The emission factors vary widely based on the furnace melting capacity: a 1-ton/hr melting furnace would have an effective PM emission factor limit of approximately 4 lb/ton, a 10-ton/hr melting furnace would have an effective PM emission factor limit of approximately 2 lb/ton, and a 100-ton/hr melting furnace would have an effective PM emission factor limit of approximately 0.5 lb/ton.

Illinois has similar generic PM emission limits based on process weight rates. These PM emission limits can be converted into emission factor limits based on furnace melting capacities. The emission factors are identical to the Ohio State PM limits for sources constructed prior to 1972. For sources constructed or modified since 1972, examples of the PM emission factor limits follow: A 1-ton/hr melting furnace would have an effective PM emission factor limit of approximately 2.6 lb/ton, a 10-ton/hr melting furnace would have an effective PM emission factor limit of approximately 0.87 lb/ton, and a 100-ton/hr melting furnace would have an effective PM emission factor limit of approximately 0.3 lb/ton.

Alabama also has PM limits based on process weights. Examples include a limit of approximately 4.7 lb/ton for a 1-ton/hr melting furnace, 2.5 lb/ton for a 10-ton/hr melting furnace, and 0.4 to 0.5 lb/ton for a 100-ton/hr melting furnace (depending on the county).

4.6.2 Opacity Emission Limits

Opacity emission limits were found for five states (Alabama, Wisconsin, Michigan, Indiana, and Ohio). These limits generally apply to general roof vents that may contain fugitive emissions from various sources throughout the foundry. Four of the states (Alabama, Wisconsin, Michigan, and Ohio) have 20-percent opacity limits. Indiana has a 30-percent or 40-percent opacity limit, depending on the location of the source (by county). Most of these limits allow one 6-minute average per hour to be above the specified limit, but must be below a secondary opacity limit (60 percent for most states except 40 percent for Alabama).

4.6.3 CO Emission Limits

Four states (Alabama, Michigan, Wisconsin, and Indiana) have CO limits that specifically address cupola emissions. Michigan requires cupolas with a melting capacity of 20 tons/hr or more to be equipped with an afterburner control system that reduces CO emissions from the cupola by 90 percent. Alabama and Wisconsin require that cupola emissions be incinerated at 1,300 °F for 0.3 seconds. Indiana requires gas streams from cupolas with a melting capacity of 10 tons/hr or more to be burned using either a direct-flame afterburner, a boiler, or equivalent control system.

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5.0 BASELINE EMISSIONS AND CONTROL OPTIONS

This chapter describes the methodology used to develop nationwide HAP emission estimates for iron and steel foundries.

5.1 GENERAL APPROACH FOR ESTIMATING HAP EMISSIONS

Facility-specific data were available for both iron and steel foundries as a result of the detailed information collection request (ICR) conducted by the EPA (EPA, 1998a). With the availability of these data, which covered a large number of different foundry operations and a large number of processes for each operation, model plants were not used. Instead, HAP emissions were estimated for each foundry based on its unique configuration (melting furnace type, type of metal melted, mold type, etc.). Average HAP emissions factors (emissions normalized by metal melting rate, which is also assumed to be the pouring rate) were developed for the different types of processes used by the foundries. This modeling approach accounts for differences in the emissions based on the type of metal melted, the type of processes used (e.g., type of melting furnace, use of scrap preheating or metal treatment, use of cores, etc.), and the type (or absence) of APCD for each process.

By applying average emission factors to facility-specific data (production rates and process sequences), a direct correspondence (or weighting) of emissions to process types is achieved. A given foundry may have actual emissions that vary significantly (e.g., by a factor of 2 or more) from the emissions predicted using the average emission factors. There are many factors that can influence the process-specific emissions, such as size and configuration of castings, that are not accounted for in the emission estimation methodology described in this chapter. These factors can contribute to inaccuracies in the emissions estimated for a specific plant. However, when summing all individual foundry emission estimates to calculate the nationwide emission estimates, the inaccuracies at the foundry level (high and low facility emission estimates) tend to cancel out. Thus, the methodology described in this chapter is anticipated to provide the most accurate and technically defensible estimate of nationwide emissions from the foundry industry. This method also provides a reasonable estimate of the HAP emissions at the foundry level, although the foundry level emission estimates are likely to have a greater uncertainty than the nationwide emission estimates.

5.2 SUMMARY OF EMISSION FACTORS FOR PRIMARY FOUNDRY OPERATIONS

The following sections provide a summary of the emission factors used for each of the primary foundry processes. Appendix B contains more detailed documentation of the development of emission factors for mold- and core-making operations. Appendix C contains more detailed documentation of the development of emissions factors for melting and pouring, cooling, and shake-out operations from source test data or published literature.

5.2.1 Emission Factors for Mold and Core Making and Coating

The primary sources of HAPs in the mold- and core-making operations are the chemical binders used to help "set" the molds and cores and coatings applied to the molds and cores to improve surface finish of the cast and to aid in the separation of the cast part from the mold. Therefore, mold- and core-making emissions are estimated only for foundries that use coatings or binders that contain HAPs in their mold- and core-making processes. Green sand systems that do not use cores are expected to have minimal HAP emissions during the mold-making process.

Emission factors for mold and core making were developed based on the chemical make-up of the different binder systems and estimates of the percentage of those chemicals that are emitted during the mold- or core-curing process. Few direct emission measurement data were available to estimate emissions from mold and core making; the percentage of chemicals emitted during the mold- or core-curing process was estimated primarily based on guidance provided by the AFS and the Casting Industry Suppliers Association (CISA) (AFS and CISA, 1998). The emission factors are most directly related to the amount of each HAP added to the mold or core. Where available, actual chemical usage rates reported by a foundry and submitted on the MSDS (which contained HAP concentration information) were used to determine the amount of each HAP used at the foundry. Generally, this detailed information was not available, and emission estimates had to be made based on typical binder system characteristics (e.g., the typical binder-to-sand ratio for a given binder system and its typical HAP contents). Chemical usage rates were generally estimated based on the reported sand usage rates for a given mold or core line and the average binder chemical-to-sand ratio for the binder system used with that mold or core-making line. Emission factors were also developed based on the typical HAP content for a given binder system. More detail regarding the development of these emission factors are provided in Appendix B. The average chemical-to-sand ratio and the default emission factors for each binder system are provided in Table 5-1.

The solvents used for mold and sand coatings are assumed to be 100 percent emitted. For some flammable organic solvent coatings, the solvent is ignited and allowed to burn off (through the light-off process). This process should effect some reduction in coating solvent emissions, but few data are available to quantify the emission reduction it achieves. Consequently, for the purposes of estimating baseline emissions, 100 percent of the HAP in the liquid portion of the coating solvent is assumed to be emitted during the coating process.

5.2.2 Emission Factors for Melting Operations

Metal HAP emissions from melting operations (which include scrap preheating, melting furnaces, and inoculation) are estimated from PM emission data along with estimates of metal composition. PM test data reported in the literature, EPA source test data, and test data reported by the industry in response to EPA's detailed ICR were compiled, and emission factors, based on tons of metal melted (or tons of metal poured), were calculated (see Appendix C). A summary of the PM emission factor data for melting operations is provided in Table 5-2. A summary of the HAP content of the various PM emission sources appears in Table 5-3. Values used from these tables to estimate baseline emissions are presented in bold.

Organic HAP emission data for cupolas that use afterburners indicate negligible organic HAP emissions, with most HAPs present below analytical detection limits (see EPA source test data in Appendix C). Consequently, no organic HAP emissions are estimated for cupolas that employ afterburning for the purposes of the baseline emission estimate.

There are no data for organic HAP emissions from cupolas that do not use afterburning. However, it is anticipated that coke combustion with inadequate oxygen (as indicated by percent levels of CO in the exhaust gas of cupolas prior to afterburning) will generate benzene and other organic HAP emissions. Certain fluid catalytic cracking units (FCCUs) in the petroleum refinery industry employ "partial" combustion of coke as they regenerate the FCCU catalyst. These regenerators burn coke under similar oxygen-deficient conditions and temperatures, resulting in similar percent levels of CO in the exhaust gas as found in cupolas that do not use afterburning. The estimated organic HAP emission factor reported for FCCU incomplete combustion

TABLE 5-1. AVERAGE CHEMICAL-TO-SAND RATIOS AND EMISSION FACTORS USED IN MOLD- AND CORE-MAKING EMISSION ESTIMATES

Binder system	Chemical-to-sand ratio, lb chemical/ ton sand	Emission estimates, lb chemical emitted/100 lb binder[1] chemicals									
		Phenol	Formal-dehyde	Naphtha-lene	Cumene	Xylene	Methanol	Glycol ethers	Dimethyl phthalate	Methyl ethyl ketone	TEA
Acrylic/epoxy/SO_2	34.				5.0						
Furan hot box	40.		0.15								
Furan no-bake	24.	0.	0.0014				10.2				
Furan/SO_2	30.		0.022				1.1		20.2	0.9	
Furan warm box	32.		0.02				10.				
Phenolic baking	30.[2]	0.4	0.05								
Phenolic ester nobake	33.	0.08	0.01								
Phenolic ester cold box	32.	0.08	0.01				0.	0.			
Phenolic hot box	30.[2]	0.25	0.1								
Phenolic no-bake	27.	0.164	0.0068				10.7				
Phenolic-Novolac flake	50.	3.6	0.				0.				
Phenolic urethane no-bake	25.	0.066	0.0011	0.16	0.051	0.016					

(continued)

Table 5-1. (continued)

Binder system	Chemical-to-sand ratio, lb chemical/ ton sand	Emission estimates, lb chemical emitted/100 lb binder[1] chemicals									
		Phenol	Formal-dehyde	Naphtha-lene	Cumene	Xylene	Methanol	Glycol ethers	Dimethyl phthalate	Methyl ethyl ketone	TEA
Phenolic urethane cold box - resin plus coreactant	30.	0.066	0.0011	0.09	0.029	0.009					
Phenolic urethane cold box - gas	3.										100.
Urea formaldehyde	30.[2]		0.02								

[1] Based on typical chemical composition data and fraction emitted estimates as described in Appendix B.
[2] Values are based on nominal values for other systems; not enough information is available for these systems to establish values.
Source: EPA, 1998a.

TABLE 5-2. SUMMARY OF PM EMISSION FACTORS FOR MELTING FURNACE OPERATIONS*

Emission category/ source of data	Basis of reported values	Range of emissions factors, lb/ton	Median emissions factor, lb/ton	Average emissions factor, lb/ton
Cupolas controlled with wet scrubbers				
GM - Saginaw (EPA, 1999b)	4 Run EPA source test	0.038 - 0.21	0.110	0.117
ICR PM Tests	11 Source tests	0.090 - 1.46	0.56	**0.580**
AP-42 (EPA, 1995)	4 Values for different scrubber types	0.08 - 5.0		3.0
Cupolas controlled with fabric filters				
Waupaca - Tell City (EPA, 1999a)	2 of 3 Run EPA source test	.010 - 0.017		0.014
ICR PM Tests	3 Source tests	0.030 - 0.082	0.077	**0.063**
AP-42 (EPA, 1995)	As reported	0.70		0.70
Cupolas uncontrolled (or prior to controls)				
Waupaca - Tell City (EPA, 1999a)	3 Run EPA source test	3.45 - 9.7	7.7	7.0
GM -Saginaw (EPA, 1999b)	4 Run EPA source test	3.6 - 4.9	4.1	4.3
ICR - Baghouse catch	Data for 17 cupola	8.14 - 64.1	24.0	**26.1**
Kearney (1971)	Data for 24 cupola	7.5 - 66.3	21.9	30.2
EAF melting controlled with fabric filters				
ICR PM Tests	4 Source tests	0.037 - 0.56	0.15	0.22
EAF - BID (EPA, 1980)	Data for 11 EAF	0.052 - 0.69	0.15	**0.23**
EAF melting uncontrolled				
ICR PM Tests	1 Source test (3 runs)	20.2 - 25.9	23.9	25.7
ICR - Baghouse catch	Data for 13 EAF	3.3 - 29.5	8.4	**11.0**
Kearney (1971)	Data for 19 EAF	4.0 - 40.0	12.7	13.8
EAF charging & tapping uncontrolled				
EAF - BID (EPA, 1980)	As reported	1.4 iron, 1.6 steel	1.4	1.6
EAF steel - BID (EPA, 1983)	As reported	1.6 - 2.0		**1.8**
Induction furnace with PM control				
ICR PM Tests	5 Source tests	0.080 - 0.67	0.13	**0.30**
AP-42 (EPA, 1995)	As reported	0.20		0.20
Induction furnaces uncontrolled				
ICR PM Tests	2 Source tests	0.44 - 8.94		4.7
ICR - Baghouse catch	Data for 8 furnaces	0.33 - 4.0	1.75	**2.0**
BCIRA (Shaw, 1982)	Data for 14 furnace tests	0.26 - 3.3	0.62	0.9

* Emissions factors selected for estimating baseline emissions are presented in bold.

TABLE 5-3. IRON FOUNDRY HAP METAL CONTENT OF PM[1]

Source	Reference	Mn, %	Pb, %	HAP[2] metals, %
Cupola Melting Furnace				
Uncontrolled	EPA source test at GM (EPA, 1999b)	4.7	0.8	5.5
Uncontrolled	EPA source test at Waupaca (EPA, 1999a)	2.1	1.9	4.1
Wet scrubber	EPA source test at GM (EPA, 1999b)	7.3	1.1	8.5
Wet scrubber	Euvrard (EPA methods) - source test (Euvrard, 1992)			6.5[2]
Wet scrubber	Auburn Foundry (#31) - ICR	**3.3**	**0.9**	**5.9**
Wet scrubber	CMI Cast Parts (#77) - ICR	2.2	0.3	2.5
Wet scrubber	Blanchester (#140) - ICR		2.2	
Baghouse	EPA source test at Waupaca (EPA, 1999a)	0.9	1.1	5.1
EAF Melting Furnace				
Dust analysis	1980 EPA EAF proposal BID (ref. 48)	**2.0**	0.5-2	2.5-4.1 [**3.3**]
Induction Melting Furnace				
Uncontrolled	CERP source test report (CERP, 1998)	**1.3**	**0.5**	**2.0**
Uncontrolled	Auburn Foundry (#31) - ICR	0.7	0.3	1.0
Uncontrolled	British study - source test (Shaw, 1982)	0.5		1.1-1.3
Dust analysis	EPA Air Emissions Species Manual (1990)	1.7	0.5	2.4
Dust analysis	Brillion Iron Works (#201) - ICR	0.4	0.8	1.2
Scrap Preheater				
Uncontrolled	Brillion Iron Works (#201) - ICR	0.91	0.38	1.4
Cyclone	Brillion Iron Works (#201) - ICR	1.3	0.69	2.7
Inoculation/Metal Treatment				
Uncontrolled	Baldwin and Westbrook (1983)	**0.06**	>0.1	>0.17

[1] HAP contents used to develop baseline emission estimates are presented in bold.
[2] Vast majority was manganese.

regeneration is 0.0020 lb HAP/lb coke burned (EPA, 1998b). Based on the similarities in these coke combustion units, the 0.0020 lb HAP/lb coke burned emission factor was used to estimate the organic HAP emission rate for cupolas not controlled by afterburning. The coke combustion rate for a typical cupola was estimated from process data collected during an EPA source test (EPA, 1999a) and is 140 lb coke/ton of metal melted. Consequently, the organic HAP emission factor for cupolas that do not use afterburning is 0.28 lb HAP/ton metal melted (0.0020×140). This emission factor (0.28 lb/ton metal) was used to estimate the total organic HAP emission rate from cupolas without afterburning. Because benzene emissions are a potential concern from mold PCS operations, a benzene emission factor was also estimated for cupolas without afterburners. The benzene content of the total organic HAP emissions for partial combustion

FCCU catalyst regeneration was always less than 10 percent, so an emission factor of 0.028 lb/ton was used, a relative high-end estimate for benzene emissions from cupolas without afterburning.

5.2.3 Emission Factors for PCS

Emissions data reported in the literature (primarily Scott, Bates, and James, [1976]; EPA, 1998a; EPA, 1998c; and CERP, 1998) were compiled to develop emission factors for PCS in terms of tons of metal poured. When emissions were reported separately for pouring, for cooling, and for shakeout, the emissions were summed to develop an emission factor for PCS as a system; however, some of the data compiled may represent emissions from a single component of the PCS system. Table 5-4 provides a summary of the organic HAP emission factors for PCS. The CERP emission factors were selected for use in estimating nationwide emissions because the CERP data appeared to provide generally median HAP emission estimates for individual and total HAP.

The organic HAP emission factors presented in Table 5-4 are based on data from automated PCS lines. Automated PCS lines are the most prevalent, accounting for over 95 percent of the production capacity of the anticipated major source iron foundries. The mold vents in automated PCS lines generally ignite spontaneously (auto-ignite). Floor and pit molding is generally used at foundries that produce very large cast parts. The vent gases from these large molds do not always auto-ignite. It is typical industry practice to ignite the mold vents that do not auto-ignite. This mold vent "flame" is anticipated to destroy organic HAPs in the vent gases, but the destruction efficiency is unknown. Consequently, the organic emissions factors presented in Table 5-4 from pouring and cooling are considered to be representative of emissions from operations where the mold vents either spontaneously ignite or are manually ignited.

Additionally, the emission factors for PCS systems presented in Table 5-4 were developed from data of sand mold systems and may be overly conservative for certain casting operations that do not use much sand, e.g., permanent mold casters, centrifugal casters, and investment casters. The organic HAP emissions from PCS lines at permanent and centrifugal casting operations are expected to be less than the organic HAP emissions from sand mold systems because of the lower sand-use rates for permanent and centrifugal casting operations. However, no data are available to develop emission factors that may be more relevant to these systems. Additionally, the sand that is used in permanent and centrifugal

TABLE 5-4. SUMMARY OF ORGANIC HAP EMISSION SOURCE TEST RESULTS FOR PCS

Source/HAP	Emission factor, lb/ton metal poured				
	CERP (CERP, 1998)	GM - Saginaw[1] (EPA, 1998c)	WI study green sand (RMT, 1995)	WI study no-bake (RMT, 1995)	Scott, Bates, & James
Pouring					
Benzene	**0.00219**	0.0054	0.0057	0.011	
Toluene	**0.00105**	0.0011			
Formaldehyde	**0.000138**	0.000354	0.0032	0.0059	
Total organic HAPs	**0.0050**	0.0082			
Cooling					
Benzene	**0.0349**	0.14	0.045	0.032	0.093[2]
Toluene	**0.0189**	0.033			0.027[2]
Formaldehyde	**0.00173**	0.0035	0.0014	0.0031	0.0015[2]
Total organic HAPs	**0.078**	0.22			0.152[2]
Shake-out					
Benzene	**0.0268**	0.022	0.0083	0.0053	
Toluene	**0.0221**	0.012			
Formaldehyde	**0.0257**	0.0026	0.0039	0.0008	
Total organic HAPs	**0.20**	0.065			
PC&S Combined					
Benzene	**0.0639**	0.167	0.059	0.048	0.093[2]
Toluene	**0.0421**	0.046			0.027[2]
Formaldehyde	**0.0276**	0.064	0.0085	0.0098	0.0015[2]
Total organic HAPs	**0.283**	0.294			0.152[2]

[1] Values reported by General Motors using their gas chromatography method.
[2] Median values from Scott, Bates, and James (1976). Includes pouring/cooling emissions only.

casting operations is typically chemically bonded (the sand is used for cores). Even with the low sand-use rates, there is adequate organic material in the sand, due to the chemical binders, to generate emissions of the magnitude measured for sand mold systems. Therefore, the emission factors presented in Table 5-4 were applied to all sand mold systems except expendable pattern casting (EPC, or the lost-foam process).

Limited test data are available to characterize organic HAP emissions from PCS lines associated with EPC operations (Twarog, 1991). These data suggest that the organic HAP emissions from EPC operations may be significantly higher than from other casting operations. The emission factors developed for PCS lines associated with EPC operations from these limited data are summarized below in Table 5-5.

TABLE 5-5. EMISSION FACTORS DEVELOPED FOR PCS LINES ASSOCIATED WITH EPC OPERATIONS

HAP	Emission factor, lb/ton
Benzene	0.33
Styrene	0.58
All other HAPs	0.11

Particulate matter (PM) and metal HAP emission estimates were developed for PCS lines by evaluating emissions data for captured vent streams that were dedicated to only one of the three components of the PCS line (i.e., pouring only, cooling only, or shake-out only). Many systems combine two or more of the PCS component emissions to a single exhaust vent or control device and combine PCS component emissions with other foundry operation emissions (e.g., sand-handling, shot-blasting, or grinding operations). The PM emission factors developed for the individual components provided PM emission estimates that compared reasonably well with the PM emissions measured from combined PCS component vent streams. The primary reason for limiting the PM emission data to individual PCS components for estimating baseline emissions is that the metal HAP content of the different component emissions vary widely. The metal HAP content of the emissions from each PCS component was determined from measured HAP emissions or captured baghouse dust analysis from control devices dedicated to a single PCS component. The metal HAP content was assumed to be representative of both controlled and uncontrolled HAP emissions (as a percentage of PM). The PM emission factors are provided in Table 5-6. The metal HAP content is shown in Table 5-7. Note: These data are for automated PCS lines. We have no data specific for floor or pit molding emissions. To provide baseline emissions estimates, the emissions factors and HAP content values presented in Tables 5-5 and 5-6 (for automated lines) are also used to estimate emissions from floor and pit molding operations.

TABLE 5-6. PM EMISSION FACTORS FOR PCS LINES

PCS Component	Uncontrolled component PM emission factor, lb/ton metal melted	Controlled component PM emission factor, lb/ton metal melted
Pouring	0.0873	0.026
Cooling	0.29	0.038
Shakeout	79.3	0.30

TABLE 5-7. HAP CONTENT OF PM FROM PCS COMPONENTS

PCS Component	Manganese Content, percentage of PM	Total Metal HAP Content, percentage of PM
Pouring	3.20 %	5.08 %
Cooling	0.11 %	0.22 %
Shakeout	0.021 %	0.024 %

Because the PM concentration of pouring and cooling emissions vent stream are very low (due to low PM emissions and large volume of air used to capture the emissions and to effect cooling of the molds), PM reduction efficiencies for pouring and cooling emission control devices are limited. Conversely, due to the high PM loading and generally coarse nature of the PM from shakeout operations (primarily sand), PM controls for shakeout generally effect greater than 99-percent removal of the PM in the vent stream.

5.3 BASELINE EMISSIONS

Baseline emission estimates for iron and steel foundries were estimated using the facility- and process-specific information developed from the detailed industry survey responses (EPA, 1998a) and best estimates of HAP emission factors (see Section 5.2). The survey provided a snapshot of the amount of metal melted in 1997. To account for fluctuations in production, the production capacity of each foundry was estimated from the annual production rates reported in the survey responses combined with reported capacity utilization rates. Capacity utilization rates reported for the iron foundry industry for the 4 years between 1997 and 2000 ranged from 80 to 88 percent (Kirgen, 1997, 1998, and 1999). The 80-percent capacity utilization value was selected for the purposes of estimating each foundry's capacity. Therefore, the production rates reported in the survey were scaled by a factor of 1.25, and preliminary emission estimates were made using the emission factors presented in Section 5.2 to identify foundries with the potential to emit more than 10 tons/yr of a single HAP or more than 25 tons/yr total of all HAPs (i.e., "major sources" of HAP emissions).

Using this information, HAP emission estimates were developed for all 595 foundries that responded to the survey. This preliminary analysis indicates that essentially all (over 99.9 percent) of foundry HAP emissions originated from three "primary" operations:

- Mold and core making and coating
- Melting, and
- Pouring, cooling, and shakeout.

In addition to making preliminary emission estimates, we contacted State and Regional environmental regulators to identify additional foundries that reported to be major sources of HAP emissions. This effort was conducted to identify foundries that either have higher emissions than projected using the average emission factors, or that have a potential to emit that is much greater than expected based on the foundry production capacity estimates (e.g., a foundry that operates 2,000 hr/yr could have a capacity 4 times greater than the capacity projected for the foundry based on potential operating hours in a year).

Based on the emission modeling and additional data gathering efforts, 96 facilities that responded to the detailed industry survey were projected to be major sources of HAP emissions. Two of these facilities operate two adjacent foundries that each responded to the industry survey, so that 98 of the 595 respondents to the EPA survey are actually included in the pool of major sources. However, based on the definition of a facility in the CAA, these adjacent foundries are considered one facility and the emissions from these adjacent foundries are summed to determine if the facility's emissions exceed the major source emission threshold levels. The major source foundries are generally large production sand casters with production capacities of 100,000 tons/yr or higher. Several foundries appear to be major sources based on use of chemical binders in their mold- and core-making processes; these foundries typically have much lower production rates.

Baseline emission estimates provided in this section include only the emission estimates for those iron and steel foundries projected to be major sources of HAP emissions. As described previously, the emission factors employed are average values, and some foundries may have higher or lower emissions than are estimated using these emission factors. Consequently, some foundries projected to be just above the major source emission threshold may not, in fact, be a major source of HAP emissions. Conversely, some foundries that are projected to be just below the major source emission threshold may actually be a major source of HAP emissions. Thus, the precise list of major source foundries may differ slightly from the foundries used in assessing the baseline emissions for the major source foundries. Therefore, rather than presenting facility-specific emission estimates, we present the baseline emissions for each of the three primary sources of HAP emissions separately using general classes of operations.

5.3.1 Baseline Emissions for Mold and Core Making and Coating

Table 5-8 presents the baseline emission estimates for mold- and core-making operations based on the binder system type and total chemical usage rates for the mold lines. The number of mold lines per type of binder system within the anticipated major source foundries is also provided.

Nearly all mold and core coatings used at iron foundries are either water based or isopropanol based. These coating solvents do not contain HAP and do not produce HAP emissions. Using reported coating solvent hourly use rates, and assuming (1) 100 percent solvent emissions during the coating drying process and (2) the coating process operates 8,000 hours per year, the following HAP emissions are estimated for mold- and core-coating operations from the major source foundries:

- Methanol-Based Coatings (used at eight mold or core lines)
  - 223 tons/yr of methanol used
  - 223 tons/yr of methanol emitted

TABLE 5-8. EMISSIONS FROM MOLD- AND CORE-MAKING LINES AT MAJOR SOURCE IRON FOUNDRIES[1]

Chemical sand binder system[2]	No. of core lines	Chemicals used, tons/yr	No. of mold lines	Chemicals used, tons/yr	Estimated emissions, tons/yr						
					Phenol	Formal-dehyde	Naph-thalene	Cumene	Xylene	Methanol	TEA
Phenolic urethane cold box: TEA is controlled[3]	214	10,480[4]			6.9	0.12	9.4	3.0	0.94		10.5
			5	4,390[4]	2.9	0.05	3.9	1.3	0.39		4.4
Phenolic urethane cold box: TEA is not controlled	57	2,130[4]	0		1.4	0.02	1.9	0.62	0.19		213
Shell (phenolic Novolac flake): Foundry coats sand	111[5]	3,750[5]			135					0.	
			32[6]	4,200[6]	151					0.	
Shell (phenolic Novolac liquid): Foundry coats sand	111[5]	3,750[5]			49	0.94				188	
			32[6]	4,200[6]	55	1.05				210	
Shell (phenolic Novolac): Foundry uses precoated sand	221[5]	7,500[5]	7[6]	930[6]							
Furan hot box	70[7]	4,350[7]	0			6.53					
Phenolic hot box	69[7]	4,350[7]	0		10.8	4.35					
Phenolic urethane no-bake	109	5,530			3.65	0.06	8.85	2.82	0.89		
			18	14,620	9.65	0.16	23.4	7.46	2.34		

(continued)

TABLE 5-8. (CONTINUED)

Chemical sand binder system[2]	No. of core lines	Chemicals used, tons/yr	No. of mold lines	Chemicals used, tons/yr	Estimated emissions, tons/yr						
					Phenol	Formal-dehyde	Naph-thalene	Cumene	Xylene	Methanol	TEA
Furan no-bake	5	180				0.003				18.6	
			5	13,590		0.19				1,386	
Furan warm box	24[8]	1,360[8]				0.27				136	
			1	130		0.03				13	
Phenolic baking (warm box)	24[8]	1,360[8]	0		10.9	4.35					
Phenolic no-bake	7	330			0.53	0.02				35	
			12	8,120	13.3	0.55				869	
Acrylic/epoxy/SO_2	2	400	0					19.9			
Phenolic ester no-bake	5	360			0.29	0.04					
			3	3,310	2.65	0.33					
Phenolic ester cold box	4	480	0		0.38	0.05					
Other systems, mostly CO_2-catalyzed systems	20	2,810	4	940							
Core oil	23	1,630	0								
Alkyd urethane	3	1,480	0								

(continued)

TABLE 5-8. (CONTINUED)

Chemical sand binder system[2]	No. of core lines	Chemicals used, tons/yr	No. of mold lines	Chemicals used, tons/yr	Estimated emissions, tons/yr						
					Phenol	Formal-dehyde	Naph-thalene	Cumene	Xylene	Methanol	TEA
Free radical/SO_2	9	480	0								
TOTALS (556.1 tons/yr for all HAPS)					448.	15.6	47.5	35.1	4.8	2,170.	228

[1] No emission estimates were made for the shell system using precoated sand or for the core oil, alkyd urethane, free radical/SO_2, or CO_2-catalyzed systems because no data for these emissions exist. Amounts of chemicals were not determined for the latter four systems because their use is very limited.

[2] Systems are listed in order of chemical usage, where known, and by the number of lines using the system otherwise.

[3] TEA control is assumed to be 99 percent.

[4] Amounts given are for the liquid (resin) components only. Weight of catalyst gas used is approximately 10 percent of the weight of the resin.

[5] Assumes shell core systems are 25% flake, 25% liquid, and 50% precoated.

[6] Assumes shell mold systems are 45% flake, 45% liquid, and 10% precoated.

[7] Survey requested data for hot-box systems in general: assumes 50% furan hot box and 50% phenolic hot box.

[8] Survey requested data for warm-box systems in general: assumes 50% furan warm box and 50% phenolic baking.

- Naphtha- or Aliphatic-Petroleum-Distillates-Based Coatings (used at five mold or core lines)
  - 622 tons/yr of naphtha used
  - 62 tons/yr of HAPs emitted (assumes naphtha contains 10 percent HAPs)
  - HAPs emitted may include benzene, toluene, xylene, and naphthalene
- Water-Based with 1 percent #2 Fuel Oil (used at one core line)
  - 2,716 tons/yr phenol resin used
  - 2.7 tons/yr HAPs emitted (assumes #2 fuel oil contains 10 percent HAPs)
- Phenol Resin (used at one mold line)
  - 1.8 tons/yr phenol resin used
  - 1.8 tons/yr phenol emitted (this is actually a dry-coating material, phenol content of the resin is not known; estimate is a worst-case assumption)

5.3.2 Baseline Emissions for Melting

Table 5-9 presents the baseline metal HAP emissions for the melting processes by furnace type. Roughly 70 percent of the baseline metal HAP emissions from melting processes are metal HAPs emitted from cupolas that are controlled with a wet scrubber. In addition to the metal HAP emissions presented in Table 5-9, two foundries have cupolas that do not use afterburning. Organic HAP emissions from these cupolas are estimated to be 4.4 tons/year, but these estimates have large uncertainty due to the lack of emissions data available for cupolas that do not operate with afterburning.

5.3.3 Baseline Emissions for PCS

The baseline emissions for PCS lines are presented in Table 5-10. Based on the capacity of the PCS lines, the fraction of each PCS component that was controlled was determined for anticipated major source iron foundries. These fractions were applied to the annual production rate for the major source foundries to establish production rates attributed to controlled and uncontrolled processes. The majority of pouring and cooling lines are not controlled for PM, whether they are automated pouring and cooling lines or are stationary floor or pit molds. All automated shakeout lines for the anticipated major source foundries are controlled. Most floor mold shakeout operations are uncontrolled. One of the areas of uncertainty in the PCS emissions is the fact that the emission factors were developed only using data from automated PCS lines.

TABLE 5-9. ASSIGNED ANNUAL PRODUCTION AND METAL HAP EMISSIONS FOR MODEL MELTING FURNACE

Type of melting furnace & control device[1]	Number of furnaces	Production, tons/yr			PM emission factor, lb/ton	Annual emissions, tons/yr	
		Iron	Steel	Total production		Manganese[2]	Total metal HAPs[2]
Cupolas							
Cupola w/ WS	35	4,337,000		4,337,000	0.60	42.9	76.8
Cupola w/ BH	28	3,355,000		3,355,000	0.06	3.3	5.9
Total for cupolas	63	7,692,000		7,692,000		46.3	82.7
Electric Arc							
Total for EAFs (w/ BH)[3]	50	534,000	751,000	1,285,000	0.23	3.0	4.9
Electric Induction							
EIF w/ BH or CF	122	2,395,000	8,000	2,403,000	0.30	4.7	7.2
EIF w/ WS	12	357,000	2,000	359,000	0.30	0.7	1.1
EIF w/ no APCD	88	910,000	43,000	953,000	2.00	12.4	19.1
Total for EIFs	222	3,662,000	53,000	3,715,000		17.8	27.3
TOTAL	335	11,888,000	804,000	12,692,000		67.0	114.9

[1] WS = Wet scrubber; BH = Baghouse; CF = Cartridge filter; APCD = air pollution control device.
[2] Assumptions: Cupola PM: Mn = 3.3%, total = 5.9%; EAF PM: Mn = 2.0%, total = 3.3%; EIF PM: Mn = 1.3%, total = 2.0%.
[3] All major source foundries that use EAF melting furnaces control PM emissions using baghouses.

TABLE 5-10. EMISSION ESTIMATES FOR MODEL PCS LINES

Model line	Metal poured, tons/yr	Emissions, tons/yr				
		Benzene	Total organic HAPs	PM	Mn	Total metal HAPs
Emissions from pouring controlled for PM	5,660,000	6.2	14.2	74	2.35	3.74
Emissions from pouring uncontrolled for PM	7,072,000	7.7	17.7	309	9.88	15.68
Emissions from cooling controlled for PM	7,889,000	137.7	307.7	150	0.16	0.33
Emissions from cooling uncontrolled for PM	4,843,000	84.5	188.9	702	0.77	1.54
Emissions from shakeout controlled for PM	12,598,000	168.8	1,259.8	1,890	0.40	0.45
Emissions from shakeout uncontrolled for PM	134,000	1.8	13.4	5,313	1.12	1.28
Totals for all PCS lines	12,732,000	406.7	1,801.6	8,437	14.68	23.02

However, because 95 percent of production at the anticipated major source iron foundries is processed in automated lines, the uncertainty in PCS emissions for floor and pit molding operations lines is not expected to significantly affect the estimated baseline emissions.

As discussed previously, automated PCS lines are generally auto-ignite, and the organic HAP emission factors are considered to be applicable to these "controlled" units. For floor and pit molds that do not auto- ignite, it is typical industry practice to ignite these vents. Consequently, it is assumed, for the purposes of estimating baseline emissions, that all mold vents either auto-ignite or are manually ignited. Additionally, one pouring and cooling line at one foundry uses a thermal oxidizer to control odor (and presumably effects some organic HAP emissions). This line represents 0.1 percent of the major source foundry production rate. With no "additionally controlled" emission factors available, and this line representing such a small fraction of the overall production, little error is introduced in the baseline emissions estimate in applying only the "controlled" organic HAP emission factors to this line.

5.4 CONTROL OPTIONS

Various control options were considered for each of the primary sources of HAP emissions. Table 5-11 summarizes the environmental impacts of the control options identified. Additional discussion of the control options is provided in the following sections.

5.4.1 Control Options for Mold and Core Making and Coating

The primary add-on control device used in conjunction with mold and core making is an acid wet scrubber used to control TEA emissions from phenolic urethane cold-box systems. No other effective add-on control options were identified to reduce the emissions from mold and core making. However, there appear to be substitute binder formulations that can be used to achieve HAP emission reductions for certain binder formulations. The control options evaluated for mold and core making are:

- Acid wet scrubber to reduce TEA emissions;
- Binder reformulations to reduce methanol content and emissions;
- Solvent substitution to reduce naphthalene content and emissions; and
- Coating formulations that do not contain HAP.

5.4.1.1 TEA Scrubber. Acid wet scrubbers are used to control TEA emissions from all but four phenolic urethane cold-box mold- and core-making lines at the anticipated major sources. The four uncontrolled lines have emissions of 146 tons/yr; emission reductions of over 99 percent are anticipated. The addition of a TEA scrubber requires pumps and fans that consume energy and produce a spent-acid waste water stream that requires treatment and disposal.

5.4.1.2 Methanol Replacement in Binder Systems. Methanol is used as a carrier solvent for certain binder formulations. Alternative binder formulations are currently available that use a non-HAP carrier solvent for furan warm-box systems. These alternative furan warm-box binder formulations are already replacing the methanol-containing systems at many foundries and are available at no additional cost to the foundry. Other binder systems, such as the furan no-bake, phenolic no-bake, and the Shell (Novolak flake) systems, can be formulated without methanol. Methanol replacement in binder formulations is estimated to effect a HAP emission reduction of between 150 and 2,860 tons/yr, depending on the current use of non-methanol-containing systems and the compatibility of the non-methanol-containing systems for a specific foundry's operations.

TABLE 5-11. SUMMARY OF ENVIRONMENTAL IMPACTS

Control Option	HAP emission reduction, ton/yr	VOC emission reduction, ton/yr	PM emission reduction, ton/yr	Energy consumption rate, MW-hy/yr	Natural gas consumption rate, MMcf/yr	Water consumption rate, MMgal/yr	Solid waste disposal, tons/yr
Acid (TEA) scrubber	146	146	0	510	0	4	0
Non-methanol binder formulations	340 [1]	340 [1]	0	0	0	0	0
Use of naphthalene-depleted solvents	32	32	0	0	0	0	0
Non-HAP coatings	303	Up to 303	0	0	0	0	0
Replace cupola wet scrubber and fabric filter	64	0	1,085	(129,463)	0	(14,633)	0
Afterburner for cupola	4	43	0	300	27	0	0
Fabric filter for EIF	31	0	1,293	17,658	0	0	1,293
Mold vent light-off	?	?	0	0	0	0	0
Fabric filter for automated pouring lines	22	0	386	7,387	0	0	386
Fabric filter for automated cooling lines	1	0	822	60,447	0	0	822
Fabric filter for automated shakeout lines	0	0	0	0	0	0	0
Fabric filter for floor and pit shakeout	2	0	6,536		0	0	6,536

[1] Best estimate; actual emission reduction dependent on the current use of non-methanol containing systems and compatibility issues.

5.4.1.3 Reduction of Naphthalene Content in Binder System Formulations. Naphthalene-containing solvents are used primarily in phenolic urethane binder systems, either the phenolic urethane no-bake system or the phenolic urethane cold-box system. Except for the shell system, these are the most commonly used binder systems, especially by the higher production rate foundries. Phenolic urethane binder systems typically use a solvent that contains approximately 10 percent naphthalene. The naphthalene content of these systems can be reduced by using a naphthalene-depleted solvent that contains 3 percent or less naphthalene, effectively reducing the air emissions of naphthalene from these mold- and core-making lines by approximately 70 percent. Based on the baseline emissions of naphthalene for both the phenolic urethane no-bake and the phenolic urethane cold-box systems, this control option is estimated to achieve an emission reduction of 32 tons/yr of naphthalene.

5.4.1.4 Mold- and Core-Coating Replacements. Methanol, naptha, and other HAP-containing solvents are used as carrier solvents for some mold- and core-coating operations. Alternative coating systems are currently available that use non-HAP carrier solvents. These non-HAP alternative systems already dominate the foundry market, representing over 90 percent of mold- and core-coating lines. Therefore, HAP emissions can be eliminated from foundries by replacing HAPs containing coating solvents with non-HAP solvents (e.g., water or isopropanol). The total organic HAP emission reductions are estimated to be 303 tons/yr. Depending on the replacement coating system used, these HAP emission reductions may or may not indicate a reduction in VOC emissions.

5.4.2 Control Options for Melting

Control options considered for melting furnaces include:

- Replacement of existing venturi scrubbers on cupolas with fabric filters; and
- Addition of fabric filters to control captured, but uncontrolled emissions from induction furnaces.

5.4.2.1 Replacement of Cupola Wet Scrubbers with Fabric Filters. The replacement of cupola wet scrubbers is estimated to yield a 64-ton/year reduction in metal HAP emissions and a 1,085 ton/year reduction in particulate matter (PM). Additionally, the baghouses operate at lower pressure drops, and realize a savings in both energy usage and water consumption. Although more mass of particulates is expected to be collected by the baghouse, the dust is collected dry. The particulates collected by the wet scrubber retain some water, therefore the mass of solids requiring disposal is greater for the wet scrubber than for the baghouse, given a common mass of dry particulate collected. It is assumed that the higher mass of particles collected by the baghouse is approximately equal to the wet mass of particles currently requiring disposal from the wet scrubbers.

5.4.2.2 Afterburners for Cupolas without Afterburning. Two cupolas at the major source foundries do not use afterburning. Afterburning is estimated to effect a 98-percent emission reduction of organic HAPs, based on general design characteristics of afterburners. Table 5-11 summarizes the emission reductions and secondary impacts anticipated from installing afterburners on these cupolas.

5.4.2.3 Fabric Filters for Uncontrolled EIF. PM control options are available for EIFs. Table 5-11 summarizes the emission reductions anticipated if all currently uncontrolled EIFs added capture and fabric filter controls.

5.4.3 Control Options for PCS

Control options considered for PCS lines include:

- Requiring light-off of mold vents that do not spontaneously ignite; and
- Adding fabric filters to control captured PCS emissions from automated PCS lines.

5.4.3.1 Mold Vent Light-off. Automated PCS lines are the most prevalent, and they account for over 95 percent of the production capacity of the anticipated major source iron foundries. These mold vents generally ignite spontaneously. Floor and pit molding is generally used at foundries that produce very large cast parts. The vent gases from these large molds do not always spontaneously ignite. It is typical industry practice to ignite these vents. All current organic HAP emission estimates from pouring and cooling lines were made at automated lines where the mold vents spontaneously ignite. This "vent flame" is anticipated to destroy organic HAPs in the vent gases, but the destruction efficiency is unknown. Because all organic emissions estimates are based on data from pouring and cooling lines that have this vent flame, and because the light-off process is generally used for floor and pit molding, no additional emission reduction is attributed to this control option.

One foundry has a thermal oxidizer on one pouring and cooling line, and two foundries have carbon adsorption systems on their pouring and cooling line to eliminate odors and VOC (and presumably organic HAP). These pouring and cooling lines are expected to have higher organic emissions than typical sand casting pouring and cooling lines based on the amount of chemically bonded sand used at these foundries. For typical mold pouring and cooling lines, the organic HAP content in the ventilation gas stream is very low, so that incineration, carbon adsorption, and other known control technologies are inefficient and lead to significant adverse secondary impacts.

5.4.3.2 Fabric Filters for Uncontrolled Automated PCS Lines. PM control options are available for PCS lines. All automated shakeout at the anticipated major source iron foundries is controlled. Floor and pit mold PCS emissions are generally uncontrolled due to the difficulties associated with capturing emissions from these large area sources. Table 5-11 summarizes the maximum emissions reductions anticipated if all currently uncontrolled PCS lines added capture and fabric filter controls.

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6.0 CONTROL COSTS

This chapter describes the methodology used to develop nationwide control costs associated with the installation and operation of HAP emission control equipment for iron and steel foundries.

6.1 GENERAL APPROACH FOR ESTIMATING CONTROL COSTS

EPA conducted a detailed survey of the iron and steel industries in 1998 to gather information regarding the types of processes and control devices used by each foundry. This survey information was used to identify the specific processes within each foundry that would need to be upgraded or to have new control equipment added. The control costs were estimated using the cost algorithms described in the *OAQPS Control Cost Manual* (EPA, 1996) and the *Handbook: Control Technologies for Hazardous Air Pollutants* (EPA, 1991). The control costs were estimated in fourth-quarter 1998 dollars.[1] Costs of the control systems were driven primarily by the flow rate of the exhaust gas requiring treatment. Typical vent stream characteristics (e.g., flow rates per unit capacity or throughput, temperature) were developed from data reported in response to the detailed questionnaires. Costs also were included for monitoring devices, such as CO monitors for cupola afterburners, VOC monitors for scrap preheaters, and bag leak detection systems for fabric filters (baghouses). Finally, costs were included for recordkeeping and reporting requirements. More details regarding the control costs estimated for specific processes are provided in the following sections.

6.2 CUPOLA MELTING FURNACE CONTROL SYSTEMS

One control option available for cupolas is to require all cupolas to operate using a baghouse. To estimate the costs of replacing venturi scrubbers with baghouses, essentially two cost estimates were made. First, the capital investment costs and the annual operating and

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[1] Cost estimates were calculated in 1998 dollars because the detailed industry survey provided a snapshot of the industry in 1998.

maintenance costs (AOCs) of a new baghouse system were estimated. Second, the AOCs of a venturi wet scrubber system were estimated (because these costs were already being incurred by the foundries and offset the operating cost of the baghouse). Additionally, the proposed MACT establishes CO emission limits (as a surrogate for organic HAPs) for cupolas. Therefore, costs were also developed for installing an afterburner to cupola furnace exhaust streams that currently do not use afterburning.

6.2.1 Baghouse Control Costs for Cupola Melting Furnaces

Baghouse or fabric filter control costs were estimated using the CostAir program (EPA, 1996). The fabric filters were designed as pulse-jet modular systems with an A/C ratio of 3.0 ft/min using Nomex bags. Auxiliary equipment included a new fan, a motor, two dampers, 300 feet of ductwork, and a new stack. The cost of the additional damper and ductwork (300 ft versus a typical value of 100 ft) and an additional system pressure drop of 4 inches of water were included in the cost analyses to roughly simulate the added capital and operating costs associated with cooling the cupola exhaust stream prior to the baghouse by using the hot exhaust gases to preheat the cupola blast air. These costs would be incurred because a baghouse control system cannot operate at as high an inlet gas temperature as a venturi scrubber control system. A retrofit cost factor of 2 was applied to the total capital investment cost estimate to capture the costs of removing existing control equipment and of dealing with other difficulties anticipated with a system retrofit of this nature. All cost values were calculated in fourth-quarter 1998 dollars (Vatavuk Air Pollution Control Cost Index = 110.9).

Control costs for six different sizes of baghouses were calculated based on the anticipated range of vent stream flow rates. The baghouse flow rates considered ranged from 20,000 to 280,000 actual cubic feet per minute (acfm), which covers an approximate range of cupola melting furnace capacities of 10 to 140 tons/hr. The total capital investment and the AOCs for these model baghouse systems are summarized in Table 6-1. The calculated control costs for these systems were essentially linear over the flow rates investigated; a linear regression analysis of the capital and the operating and maintenance control costs had R^2 values of 0.999 and 0.993, respectively. Consequently, a simple linear expression was derived to estimate the total capital investment (TCI) and the AOC based on the system exhaust flow rate as follows:

$$TCI_{BH} = 463{,}700 + 25.03\ Q_{BH} \quad (6.1)$$

$$AOC_{BH} = 93{,}970 + 3.312\ Q_{BH} \quad (6.2)$$

where

TCI_{BH} = total capital investment for a baghouse ($ fourth-quarter 1998);

AOC_{BH} = AOC for a baghouse (1998 $/yr); and

Q_{BH} = design exhaust vent flow rate based on cupola-baghouse (acfm).

TABLE 6-1. SUMMARY OF CONTROL COSTS FOR BAGHOUSES AND WET SCRUBBERS: 1998 $

Flow rate through control device—baghouse (wet scrubber), acfm	Baghouse total capital, $\$10^3$	Baghouse annual capital, $\$10^3$*	Baghouse annual operating, $\$10^3$/yr	Baghouse total annual, $\$10^3$/yr	Wet scrubber annual operating, $\$10^3$/yr
20,000 (15,400)	$870	$80	$137	$217	$199
40,000 (30,800)	$1,454	$133	$202	$335	$308
80,000 (61,500)	$2,527	$231	$395	$626	$527
120,000 (92,300)	$3,544	$323	$518	$841	$745
200,000 (154,000)	$5,503	$499	$761	$1,260	$1,181
280,000 (215,000)	$7,406	$671	$1,001	$1,672	$1,617

* Reflects capital recovery based on a 20-year life and a 7-percent interest rate.

The TCI and AOC for each cupola baghouse were calculated using these equations and the maximum anticipated flow rate based on the cupola melt capacity and the cupola exhaust system design (above or below gas takeoff). Table 6-2 provides the flow rate factors used to estimate the exhaust stream flow rate based on the cupola melting capacity and exhaust system design.

TABLE 6-2. ESTIMATING EXHAUST AIR FLOW RATES FOR CONTROL COSTS ESTIMATES

Cupola charge position and type of air pollution control device	Flow rate factor, acfm/tons/hr*
Above-charge takeoff /fabric filter	3,000
Above-charge takeoff /wet scrubber	2,200
Below-charge takeoff /fabric filter	1,500
Below-charge takeoff /wet scrubber	1,200

* Adjusted for typical operating temperatures of approximately 500 °F.

A capital recovery factor (CRF) of 0.0944 was used for baghouses to annualize the capital investment on the basis of a 20-year equipment life and an annual interest rate of 7 percent. The total annualized cost (TAC) was calculated as the sum of the annualized capital investment cost and the annual operating and maintenance cost (e.g., TCI × CRF + AOC).

6.2.2 Venturi Scrubber Control Costs for Cupola Melting Furnaces

The costs of operating a venturi scrubber with a pressure drop of 40 inches of water were estimated using the cost algorithms described in the *Handbook: Control Technologies for* Hazardous Air Pollutants (EPA, 1991). The cost of waste water disposal was assumed to be the same as the water consumption cost, an assumption that likely understates the operating cost of the venturi scrubber. The control costs were converted from 1989 to 1998 dollars using the Chemical Engineering Plant Cost Index (from 355 for base year to 389.5). As with baghouses, the operating costs for venturi scrubbers were calculated for six different exhaust vent flow rates, and a linear regression analysis was performed. Because the operating and maintenance costs for venturi scrubbers are driven by (1) the fan electrical usage, (2) the water consumption, and (3) the waste water treatment costs, the AOC for venturi scrubbers is linear with exhaust stream flow rate ($R^2 = 0.99999$). The resulting AOC equation for venturi scrubbers is

$$AOC_{VS} = 90{,}250 + 7.090\ Q_{VS} \qquad (6.3)$$

where

AOC_{VS} = AOC for a venturi scrubber (1998 \$/yr), and

Q_{VS} = design exhaust vent flow rate based on cupola venturi scrubber (acfm).

As shown in Table 6-2, the average flow rate per furnace capacity is approximately 30 percent higher when baghouse systems are employed than when venturi scrubbers are used. This is thought to be caused primarily by additional air sucked into the exhaust system (the vent is at a negative pressure with respect to the atmosphere) when the exhaust stream is cooled prior to the baghouse. Consequently, the AOC for venturi scrubbers are provided in Table 6-1 for flow rates ranging from 15,400 to 215,000 acfm, because these costs are more comparable to the baghouse costs reported in Table 6-1 on the basis of cupola melting capacity.

6.2.3 Net Metal HAP Control Cost for Cupola Melting Furnaces

The net control costs for replacing a venturi scrubber with a baghouse control system were calculated using the following equations:

$$TCI_{VS\text{-}BH} = TCI_{BH} \quad (6.4)$$

$$AOC_{VS\text{-}BH} = AOC_{BH} - AOC_{VS} \quad (6.5)$$

$$TAC_{VS\text{-}BH} = CRF \times TCI_{VS\text{-}BH} + AOC_{VS\text{-}BH} \quad (6.6)$$

where

$TCI_{VS\text{-}BH}$ = TCI for replacing a venturi scrubber with a baghouse, (1998 $);

$AOC_{VS\text{-}BH}$ = net AOC for replacing a venturi scrubber with a baghouse (1998 $/yr);

$TAC_{VS\text{-}BH}$ = total annualized cost for replacing a venturi scrubber with a baghouse (1998 $/yr); and

CRF = capital recovery factor = 0.0944 (20 years; 7 percent interest).

6.2.4 Sample Calculation of Metal HAP Control Cost for Cupola Melting Furnaces

The AOC of an existing venturi scrubber system was first calculated based on the melting capacity of the furnace. For example, given an above-charge takeoff cupola with a melting capacity of 50 tons/hr, the design vent stream flow rate for a cupola-venturi scrubber system was calculated to be Q_{VS} = 50 tons/hr × 2,200 acfm/tons/hr (flow rate factor from Table 6-2) = 110,000 acfm. The AOC of the existing venturi scrubber system was then calculated using Eq. (6.3) to yield an AOC_{VS} = $870,000/yr.

The design exhaust flow rate of the new fabric filter system was then calculated as Q_{BH} = 50 tons/hr × 3,000 acfm/tons/hr (factor from Table 6-2) = 150,000 acfm. The control costs for the new fabric filter system were then calculated using this revised design exhaust flow rate as shown in Eqs. (6.1) and (6.2), yielding TCI_{BH} = $4,220,000 and AOC_{BH} = $591,000/yr.

The net control costs were then calculated using Eqs. (6.4) through (6.6) to yield $TCI_{VS\text{-}BH}$ = $4,220,000; $AOC_{VS\text{-}BH}$ = ($279,000/yr); and $TAC_{VS\text{-}BH}$ = $118,000/yr.

6.2.5 Afterburning Control Cost for Cupola Melting Furnaces

Afterburning control costs were estimated using the CostAir program for incinerator systems (EPA, 1996). The incinerators were designed to operate at a minimum of 1,300 °F. From data collected during EPA source tests, it was assumed that the temperature of the cupola exhaust stream entering the incinerator/afterburner was 500 °F. This inlet gas stream was assumed to contain adequate oxygen, coming from air entering the cupola exhaust stream through the charge door opening. The CO concentration after dilution with the charge door ventilation air was assumed to be 5 percent. The incinerator/ afterburner was assumed to operate without heat recovery, and a retrofit cost factor of 1.2 was applied to the TCI cost estimate.

Control costs for 10 different sizes of incinerators were calculated based on the anticipated range of vent stream flow rates because of a shift in the cost curves identified for gas flows less than 40,000 acfm. The shift in the cost curve function can be seen in Figure 6-1. Subsequently, two control cost equations were developed for each cost parameter (TCI and AOC): one for systems of less than 40,000 acfm and one for systems of 40,000 acfm or more. A log-log correlation was used for the TCI cost curves. The calculated control cost equations are:

For systems $Q_{AB} < 40{,}000$ acfm

$$TCI_{AB} = 1{,}000 \times \exp[2.997 + 0.2355 \ln(Q_{AB})] \tag{6.7}$$

$$AOC_{AB} = 36{,}360 + 2.113\ Q_{AB} \tag{6.8}$$

For systems $Q_{AB} \geq 40{,}000$ acfm

$$TCI_{AB} = 1{,}000 \times \exp[3.339 + 0.2355 \ln(Q_{AB})] \tag{6.8}$$

$$AOC_{AB} = 60{,}430 + 2.040\ Q_{AB} \tag{6.9}$$

where

TCI_{AB} = TCI for an afterburner, ($ fourth quarter 1998);

AOC_{AB} = AOC for an afterburner (1998 $/yr); and

Q_{AB} = design exhaust vent flow rate at afterburner inlet (acfm).

A linear regression analysis of these control cost equations had R^2 values of 0.9999 or greater.

The cupola inlet gas flow rate was estimated using the flow rate factors presented in Table 6-2. These flow rate factors were developed from systems that had afterburners, but the flow rate measurements were made downstream of the cupola afterburner. Thus, use of the flow rate factors in Table 6-2 is expected to yield cost estimates that are biased high. Nonetheless, because cupola afterburners generally operate with a minimum of auxiliary fuel (CO in the exhaust stream being the primary fuel), applying the flow rate factors in Table 6-2 should result in a reasonable estimate of the flow rate at the inlet to the afterburner.

A capital recovery factor of 0.1424 was used for baghouses to annualize the capital investment on the basis of a 10-year equipment life and an annual interest rate of 7 percent. The total annualized cost was calculated as the sum of the annualized capital investment cost and the annual operating and maintenance cost (e.g., TCI × CRF + AOC).

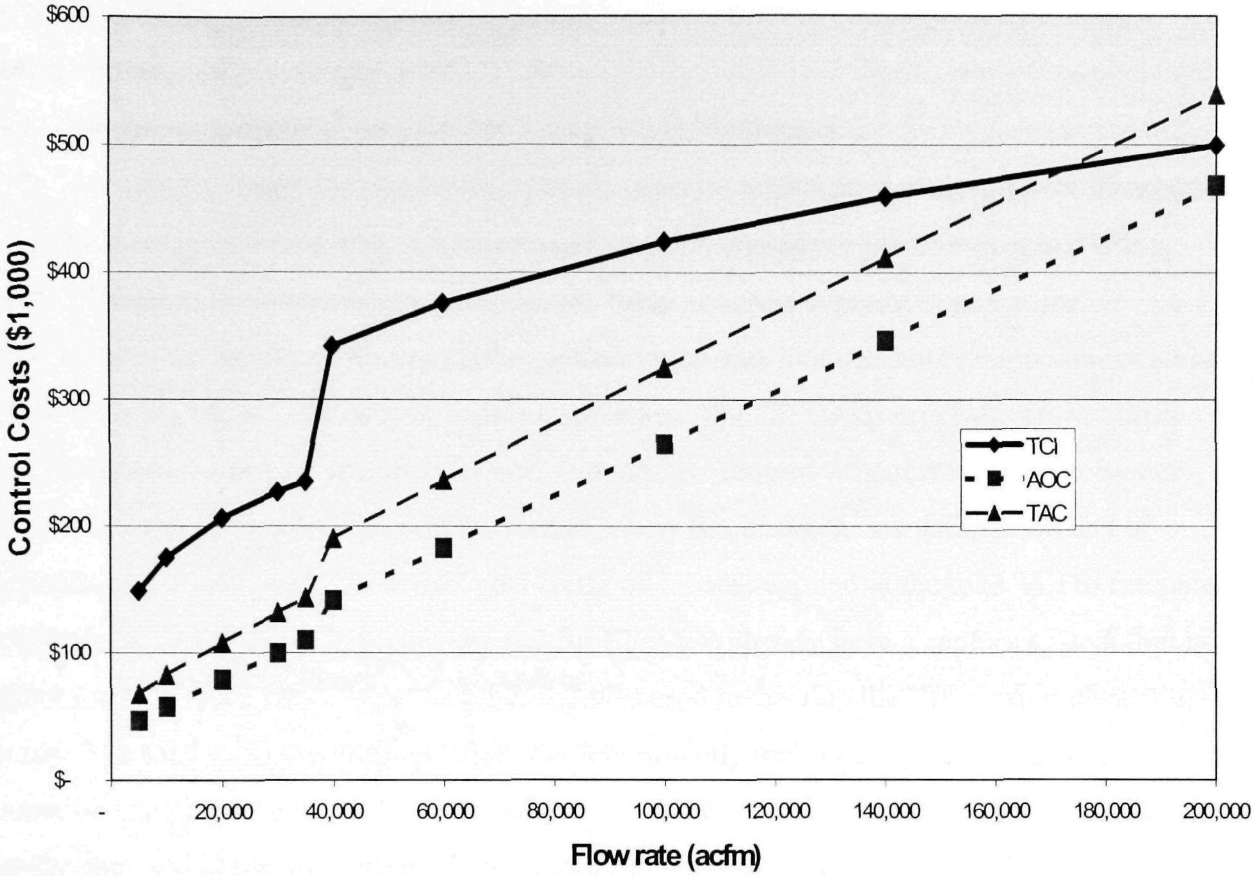

Figure 6-1. Control Cost Curves for Cupola Afterburners.

6.2.6 Sample Calculation of Organic HAP Control Cost for Cupola Melting Furnaces

Continuing the example of an above-charge takeoff cupola with a melting capacity of 50 tons/hr, the design exhaust flow rate was estimated as Q_{AB} = 50 tons/hr × 3,000 acfm/tons/hr (factor from Table 6-2) = 150,000 acfm. The control costs for the new afterburner system were then calculated using Eqs. (6.8) and (6.9), yielding TCI_{AB} = $467,000 and AOC_{BH} = $366,000/yr. Using the capital recovery factor of 0.1424, TAC_{AB} = $433,000/yr.

6.3 ELECTRIC INDUCTION, SCRAP PREHEATER, AND POURING STATION CONTROL SYSTEMS

Control options for EIFs, scrap preheaters, and pouring stations generally entail the installation of a new emission control system rather than replacing an existing control system as in the cupola metal HAP control option. All EAFs at the 96 foundries expected to be major sources of HAP emissions were controlled using baghouses, so no additional control costs are estimated for EAFs. Some EIFs, scrap preheaters, and pouring stations, however, are not controlled for PM (metal HAPs). Costs were estimated for adding new PM control systems (assumed to be baghouses for costing purposes) for those sources currently not operating a control system.

6.3.1 Baghouse Control Costs for EIFs and Scrap Preheaters

As with the baghouse costs developed for cupolas, baghouse control costs for the control of EIFs and scrap preheater PM emissions were estimated using the CostAir program (EPA, 1996). However, the fabric filters in service for these emission sources, based on the information in the detailed industry survey, generally operate at much lower temperatures and at significantly higher A/C ratios than cupola baghouses. The EIF/scrap preheater fabric filters were designed as pulse-jet modular systems with an A/C ratio of 7.6 acfm/ft^2 using polyester bags. Auxiliary equipment included the cost of a new fan, a motor, one damper, 40 feet of ductwork, and a new stack. A retrofit cost factor of 1.2 was applied to the total TCI to estimate the retrofit costs for all scrap preheaters and for EIFs that already have a capture system (but no control device). This retrofit cost factor of 1.2 was used to develop the EIF/scrap preheater cost curves. The total capital investment cost was subsequently multiplied by 1.1 if no capture system was reported for the EIF. Essentially, this equates to a retrofit factor of 1.32 for EIF systems that do not already capture their emissions. As before, all cost values were calculated in fourth-quarter 1998 dollars (Vatavuk Air Pollution Control Cost Index = 110.9).

Control costs for 10 different sizes of baghouses were calculated based on the anticipated range of vent stream flow rates. There is a noticeable shift in the operating cost curve for gas flows between 40,000 and 50,000 acfm (see Figure 6-2). Subsequently, two control cost equations were developed for each cost parameter (TCI and AOC): one for systems of less than 50,000 acfm and one for systems of 50,000 acfm or more. Overall, the baghouse flow rates considered ranged from 5,000 to 180,000 acfm. A linear regression analysis of the capital and the operating and maintenance control costs resulted in R^2 values exceeding 0.999 for each size range for each cost parameter.

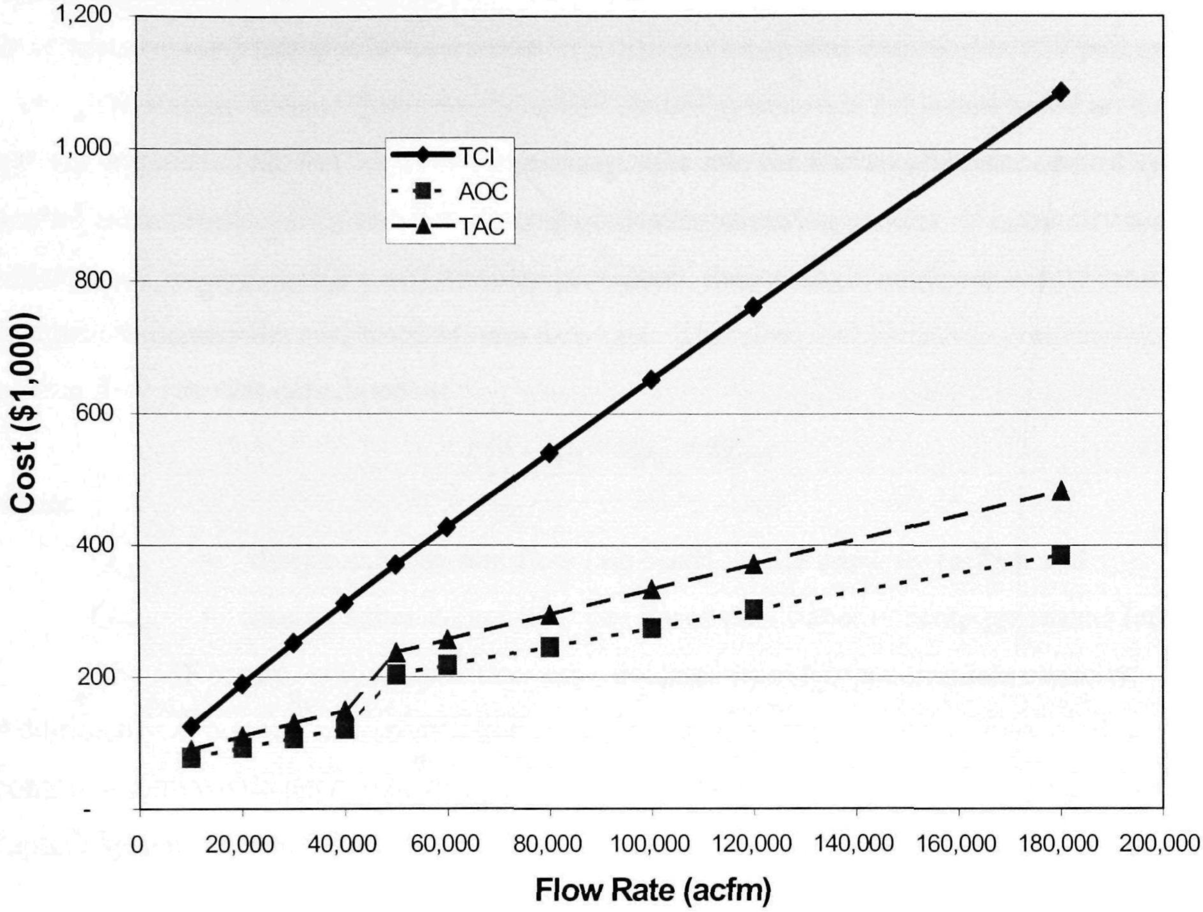

Figure 6-2. Control Cost Curves for EIF/Scrap Preheater Baghouses.

From the linear regression analysis, the following control cost equations were developed:

<u>For systems $Q_{EIF/SPH} \leq 50{,}000$ acfm</u>

$$TCI_{EIF/SPH} = 63{,}840 + 6.221\ Q_{EIF/SPH} \tag{6.10}$$

$$AOC_{EIF/SPH} = 63{,}870 + 1.427\ Q_{EIF/SPH} \tag{6.11}$$

<u>For systems $Q_{EIF/SPH} \geq 50{,}000$ acfm</u>

$$TCI_{EIF/SPH} = 99{,}090 + 5.492\ Q_{EIF/SPH} \tag{6.12}$$

$$AOC_{EIF/SPH} = 133{,}900 + 1.398\ Q_{EIF/SPH} \tag{6.13}$$

where

$TCI_{EIF/SPH}$	=	TCI for an EIF/scrap preheater baghouse (1998 \$);
$AOC_{EIF/SPH}$	=	AOC for an EIF/scrap preheater baghouse (1998 \$/yr); and
$Q_{EIF/SPH}$	=	design exhaust vent flow rate based on EIF/scrap preheater (acfm).

Again, a capital recovery factor of 0.0944 was used for baghouses to annualize the capital investment on the basis of a 20-year equipment life and an annual interest rate of 7 percent.

The design exhaust flow rate of the EIF control system was estimated based on the melting capacity of the EIF. The design exhaust flow rate for a scrap preheater control system was estimated based on the number of scrap preheaters requiring control. If a foundry needed to add controls for both its EIFs and its scrap preheaters, then a single baghouse would need to be designed to control the combined system flow rate. Therefore, the EIF/scrap preheater control system flow rate was calculated as:

$$Q_{EIF/SPH} = Q_{EIF} + Q_{SPH} \tag{6.14}$$

where

Q_{EIF} = design exhaust vent flow rate based on EIF capacity (acfm); and

Q_{SPH} = design exhaust vent flow rate based on number of scrap preheaters (acfm).

The EIF control system flow rate was calculated from EIF melting rate capacity. Additionally, if pouring station emission controls were also required at the foundry, then the EIF control system would need to be designed to include the flow rate from the pouring station capture system, as well. Specifically, the EIF exhaust flow rate was estimated as:

$$Q_{EIF} = 5{,}000 \times (MeltCap_{EIF})^{0.667} + Q_{PourSt} \tag{6.15}$$

where

$MeltCap_{EIF}$ = melting rate capacity of the EIF (tons/hr); and

Q_{PourSt} = design exhaust vent flow rate based on number of pouring stations (acfm) (see Section 6.3.2).

The factor of 5,000 was assigned based on a 5-ft × 5-ft canopy hood with an entrance design velocity of 200 ft/min for a 1-ton/hr EIF. The capture system exhaust flow rate from other EIF melting furnaces was assumed to be proportional to the cross-sectional area of the furnace (or to the 2/3 power of the capacity of the furnace). If pouring stations also required control at the foundry, the exhaust from the pouring station capture systems was assumed to be added to the EIF exhaust stream prior to the control device.

The flow rate of a scrap preheater control system was calculated as a simple function of the number of scrap preheaters requiring PM controls, as follows:

Number of Scrap Preheaters Requiring Control:	Exhaust Flow Rate:
1	Q_{SPH} = 20,000 acfm
2, 3, or 4	Q_{SPH} = 60,000 acfm
5 or more	Q_{SPH} = 100,000 acfm

These scrap preheater exhaust flow rates were used directly as the control system flow rates in Eqs. (6-10) through (6-13) if the EIFs at a given foundry did not need control. That is, pouring-station exhaust flows were only combined with EIF/scrap preheater control systems when the EIFs required control. Otherwise, costs for separate control systems were developed when a foundry required control of a scrap preheater and a pouring station, but not an EIF.

6.3.2 Baghouse Control Costs for Pouring Stations

Baghouse control costs for the control of PM emissions from pouring stations were again estimated using the CostAir program (EPA, 1996). The design used for pouring-station control systems was based on baghouses used to control PM emissions from PCS lines. As such, the cost curves presented in this section can be used to estimate baghouse costs for controlling pouring, cooling, or shakeout PM emissions. However, these equations were employed only for pouring-station emission control, and then only when no additional EIF emission control was required at the foundry. The pouring-station baghouses were designed as pulse-jet modular systems with an A/C ratio of 10 acfm/ft^2. Auxiliary equipment included the cost of a new fan, a motor, one damper, 40 feet of ductwork, and a new stack. A retrofit cost factor of 1.2 was applied to the total capital investment cost estimate. Again, all cost values were calculated in fourth-quarter 1998 dollars (Vatavuk Air Pollution Control Cost Index = 110.9).

Control costs for nine different sizes of baghouses were calculated based on the anticipated range of vent stream flow rates. As with the EIF/scrap preheater operating cost curve, there is a noticeable shift in the operating cost curve for gas flows between 40,000 and 50,000 acfm (see Figure 6-3). Subsequently, two control cost equations were developed for each cost parameter (TCI and AOC): one for systems less than 50,000 acfm and one for systems of 50,000 acfm or more. Overall, the baghouse flow rates for which direct cost estimates were developed ranged from 5,000 to 180,000 acfm. A linear regression analysis of the capital and the operating and maintenance control costs resulted in R^2 values exceeding 0.999 for both size ranges and for each cost parameter evaluated. The resulting control cost equations follow:

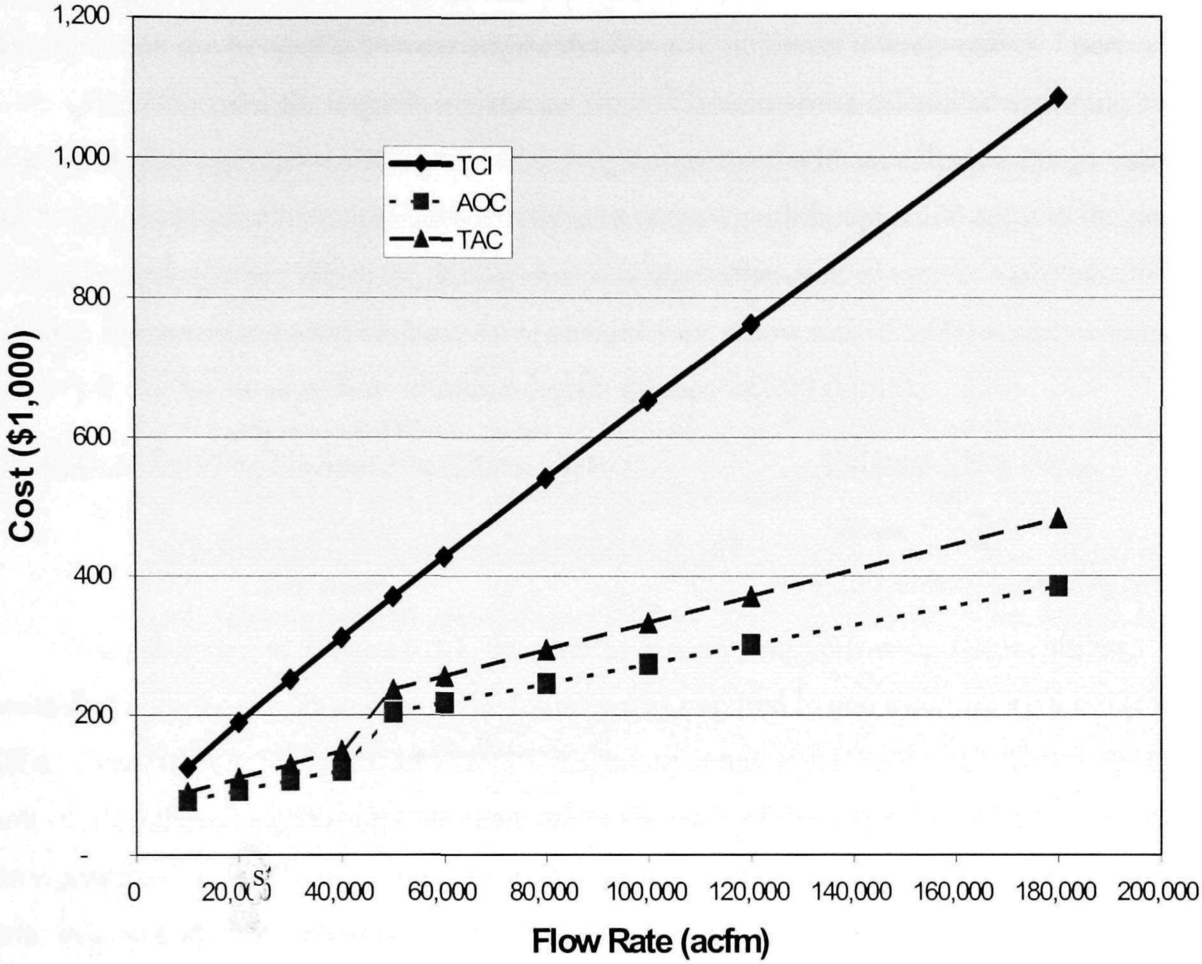

Figure 6-3. Control Cost Curves for Pouring Station Baghouses.

For systems $Q_{PourSt} < 50,000$ acfm

$$TCI_{PourSt} = 63,830 + 5.481\ Q_{PourSt} \quad (6.16)$$

$$AOC_{PourSt} = 63,860 + 1.513\ Q_{PourSt} \quad (6.17)$$

For systems $Q_{EIF/SPH} \geq 50,000$ acfm

$$TCI_{PourSt} = 99,100 + 4.752\ Q_{PourSt} \quad (6.18)$$

$$AOC_{PourSt} = 133,900 + 1.484\ Q_{PourSt} \quad (6.19)$$

where

TCI_{PourSt} = TCI for pouring-station baghouse (1998 $);

AOC_{PourSt} = AOC for pouring-station baghouse (1998 $/yr); and

Q_{PourSt} = design exhaust vent flow rate based on number of pouring stations requiring additional control (acfm).

Again, a capital recovery factor of 0.0944 was used for baghouses to annualize the capital investment on the basis of a 20-year equipment life and an annual interest rate of 7 percent.

The flow rates for the pouring-station control systems were calculated assuming each pouring-station capture system was a 4-ft × 4-ft canopy hood with an entrance design velocity of 200 ft/min, so that each pouring station requiring control contributed 3,200 acfm to the pouring-station control system. However, if only one pouring-station control system required control at a foundry, the pouring station baghouse was designed for a flow rate of 5,000 acfm (essentially a 5-ft × 5-ft canopy hood with an entrance design velocity of 200 ft/min).

Number of Pouring Stations Requiring Control:	Exhaust Flow Rate:
1	Q_{PourSt} = 5,000 acfm
2 or more	Q_{PourSt} = 3,200 acfm × # Pouring Stations

As discussed in Section 6.3.1, the pouring station emissions were assumed to be combined with the EIF emissions if the foundry was required to add a control system for the EIFs. Even though the cost of an EIF/SPH baghouse at any given flow rate is higher than the cost of a similar-sized pouring station baghouse (because of the different A/C ratios assumed for these systems), it is still more cost-effective to install a single control system at the lower A/C ratio than to install two separate control systems. It is also likely that foundries that have to control both scrap preheater and pouring-station emissions will install a single control system for both of these emission sources to save on costs. However, based on the logic used in the control cost model, separate control systems were designed for these emission sources if no additional control was required for the EIFs.

6.4 MOLD- AND CORE-MAKING CONTROL SYSTEMS

Two emission reduction measures for mold- and core-making lines were considered. For binder systems that employ a TEA gas catalyst, the emission reduction method is the installation of an acid/wet (absorptive) scrubber. Four of the 96 foundries had uncontrolled TEA emissions from their mold- and core-making TEA gas binder systems. For other binder systems, there may be restrictions on the HAP content of the binder system components. Alternative binder systems are available that can meet the HAP restrictions pertaining to methanol with no further costs associated with adaptation, for example. However, requirements for the use of naphthalene-depleted solvents (see Section 6.3.2) are expected to increase the operating costs of 61 of the 96 foundries.

6.4.1 Acid/Wet Scrubber Control Costs

Costs associated with the installation and operation of two acid/wet scrubbers to control emissions of TEA were calculated using the cost algorithms reported in the *OAQPS Control Cost Manual* (EPA, 1996). Based on the TEA usage rates at the two foundries with uncontrolled TEA mold- and core-making lines, two scrubbers were sized based on removing 25 tons/yr and 125 tons/yr, approximately a 25-percent excess capacity compared to current usage rates. From the available source test data, TEA inlet (uncontrolled) concentrations ranged from 10 to 130 ppm. However, the systems with the highest flow rates also had the highest TEA concentrations. Therefore, the smaller (actually a median size compared to the available test data) scrubber that could remove 25 tons/yr of TEA was assumed to operate 4,000 hr/yr with an inlet TEA concentration of 50 ppmv (median value from the test data). The larger scrubber, capable of removing 125 tons/yr of TEA, was assumed to operate 4,000 hr/yr and at an inlet TEA concentration of 100 ppmv.

The cost functions presented in the *OAQPS Control Cost Manual* are provided in third-quarter 1991 dollars. These costs were scaled to 1998 dollars by using the Chemical Engineering Plant Cost Index (using 361 for 1991 and 389.5 for 1998). The calculated control costs for the two acid/wet scrubbers are shown in Table 6-3.

TABLE 6-3. SUMMARY OF CONTROL COSTS FOR ACID/WET SCRUBBING SYSTEMS: 1998 $

Model scrubber	Total capital, $$10^3$	Annual capital*	Annual operating, $$10^3$/yr	Total annual, $$10^3$/yr
Scrubber 1 (25 tons/yr)	$157	$22.3	$31.6	$53.9
Scrubber 2 (125 tons/yr)	$309	$44.1	$50.8	$94.9

* Reflects capital recovery based on a 20-year life and a 7-percent interest rate.

6.4.2 Naphthalene-Depleted Solvent Pollution Prevention Costs

Naphthalene-containing solvents are used primarily in phenolic urethane binder systems. The phenolic urethane binder system types were the ones most commonly used by the major source foundries. These binder systems use a naphthalene-containing solvent that is approximately 10 percent naphthalene. The naphthalene content of this solvent can be reduced to approximately 3 percent by using a naphthalene-depleted solvent, effectively reducing the air emissions of naphthalene from these mold- and core-making lines by approximately 70 percent.

The naphthalene-depleted solvent costs 3 to 5 cents more per pound than the typical naphthalene- containing solvent (in 1998 dollars). No additional or modified equipment is needed to use the naphthalene-depleted solvent.

Twenty-two foundries were using the phenolic urethane binder system in at least one mold- and core-making line in 1998. It was estimated that 2,773 tons/yr of naphthalene solvent were being used by these 22 foundries. At 4 cents per pound, the estimated nationwide increase in operating costs to use naphthalene-depleted solvent would be $222,000/yr.

6.5 MONITORING, REPORTING, AND RECORDKEEPING

Cost estimates are provided for continuous CO monitors for cupolas and continuous VOC monitors for scrap preheaters. The costs of the continuous emission monitoring systems (CEMSs) were estimated using EPA's CEMS Cost Model, Version 3.0 (in 1998 dollars). Beyond the CEMS, other monitoring requirements considered for the control options are continuous parameter monitoring requirements. For example, each baghouse is assumed to install and operate a bag leak detection system. Foundries with TEA scrubber systems are assumed to install and operate a pH-monitoring system, and gas and liquid flow rate monitors. For venturi wet scrubbers used to meet a PM emission limit, the monitored parameters include the pressure drop and gas and liquid flow rates. Finally, some recordkeeping and reporting costs were estimated for developing a scrap selection and inspection plan, conducting performance tests, and evaluating low-HAP-emitting binder formulations as required in the proposed rule. These costs are described in the following sections. All capital costs for monitoring and recordkeeping equipment were annualized using a capital recovery factor of 0.1424 based on 10-year equipment life and 7-percent interest rate.

6.5.1 Continuous CO Monitoring Systems

CEMS costs for an *in situ* continuous CO monitor placed after a control device at an existing plant were estimated in 1998 dollars. The purchase cost of the continuous CO monitor was estimated to be $55,000. Annual operating costs—which include operation and maintenance of the monitor, annual relative accuracy test audit (RATA), periodic quality assurance (QA) reviews, recordkeeping, and annual training and update—were estimated to be $19,900/yr. Based on a capital recovery factor of 0.1424, the total annualized cost for operating a continuous CO monitor was $27,700/yr. For the 63 cupolas operated at the 96 foundries, the total annualized cost for CO monitors should be $1.75 million. However, because of an error in the spreadsheet calculation, certain cupolas were double counted so that the total annualized cost for CO monitors used in the EIA was $2.08 million.

6.5.2 Continuous VOC Monitoring Systems

CEMS costs for an extractive continuous VOC monitor placed after a control device at an existing plant were estimated (using the total hydrocarbon concentration [THC] monitoring costs from EPA's CEMS Cost Model) in 1998 dollars. The purchase cost of the continuous VOC monitor was estimated to be $73,700. Annual operating costs—which include operation and maintenance of the monitor, annual RATA, periodic QA reviews, recordkeeping, and annual training and update—were estimated to be $18,500/yr. Based on a capital recovery factor of 0.1424, the total annualized cost for operating a continuous VOC monitor was estimated to be $29,000/yr. Of the 96 foundries anticipated to be major sources of HAP emissions, 33 were operating scrap preheaters. If a foundry had multiple scrap preheaters, it was assumed the exhausts from the scrap preheaters were combined and a single stack per foundry was monitored. The total annualized cost for VOC monitors, therefore, was estimated to be $957,000.

6.5.3 Bag Leak Detection Systems

Each baghouse will need to be equipped with a bag leak detection system. These systems will have an installed capital cost of $9,000 each, with an annual operating cost of $500/yr (EPA, 1998a). There are a total of 339 baghouses, either existing or required to be installed, at the 96 major source iron and steel foundries. Consequently, the total capital cost for bag leak detectors was calculated as $3.05 million, with an annual operating cost of $170,000/yr.

6.5.4 Parameter Monitoring Systems

The costs for parameter monitoring systems were estimated using a generic parameter monitoring system. Monitoring system costs were evaluated from control equipment supply company catalogues for pH, pressure, temperature, and flow measurement systems and associated electronic recording systems. These costs ranged from $1,500 to $3,000 per monitoring and data recording system (in 1998 dollars). Therefore, the general cost of equipment for any parameter monitoring system was estimated to be $2,500. It was estimated that the installation, calibration, troubleshooting, training, and QA procedure development costs for a new monitoring system would be $5,000, so that the total installed cost per new monitoring system would be $7,500.

The annual operating costs were estimated to be \$2,000/yr. These costs are largely for calibration and maintenance of the equipment, but also include summarizing and annual reporting of the data.

6.5.4.1 Parameter Monitoring Systems for Venturi (PM) Wet Scrubbers. Existing venturi wet scrubbing systems are expected to be able to meet PM emission limits from EIFs, scrap preheaters, and pouring stations. If a venturi scrubbing system is employed, both the pressure drop and scrubbing liquid flow rate must be monitored. Both of these monitoring systems were assumed to be in place at each venturi scrubber control device. Annual operating costs for both parameter monitoring systems were assumed to be \$4,000/yr (\$2,000 × 2). There were 21 existing venturi wet scrubbing systems associated with EIFs, scrap preheaters, and pouring stations at the major source foundries, so that the total annualized monitoring costs for these systems would be \$84,000.

6.5.4.2 Parameter Monitoring Systems for Acid/Wet Scrubbing Systems. The acid/wet scrubbing systems used to control TEA emissions from mold- and core- making operations are required to monitor flow rate and pH of the scrubbing liquor. All acid/wet scrubbing systems were assumed to have flow monitors already in place, and it was assumed that all systems would have to have a pH monitor installed. Consequently, the monitoring costs per scrubbing system would be \$7,500 capital costs and \$4,000 annual operating and maintenance costs. Forty-seven foundries were using TEA gas in their mold- and core-making lines.

6.5.5 Foundry Recordkeeping, Reporting, and Compliance Costs

Several work practice standards were also considered as possible control options. These work practices generally require foundries to prepare plans and maintain records of certain emission-reducing activities. It was assumed that all foundries manually ignited mold vents after pouring if these vents did not auto-ignite. Therefore, no control costs were attributed to these activities. Costs were estimated, however, for developing a scrap selection and inspection plan, conducting performance tests, and evaluating low-HAP- emitting binder formulations. These costs were calculated based on an estimate of the technical person-hours required to complete each activity and the frequency of occurrence.

Labor rates and associated costs were based on Bureau of Labor Statistics (BLS) data. Technical, management, and clerical average hourly rates for civilian workers were taken from the March 2002 Employment Cost Trends (http://stats.bls.gov). Wages for civilian workers (white-collar occupations) were used as the basis for the labor rates, with a total compensation of $28.49/hr for technical, $42.20/hr for managerial, and $18.41/hr for clerical. These rates represent salaries plus fringe benefits and do not include the cost of overhead. An overhead rate of 110 percent was used to account for these costs. The fully burdened wage rates used to represent respondent labor costs were technical at $59.83, management at $88.62, and clerical at $38.66.

The number of technical hours needed for each compliance activity was first estimated. For each technical hour needed, 0.05 managerial hours and 0.10 clerical hours were also assumed to be required. Consequently, the total labor cost, including technical, managerial, and clerical labor, for a compliance activity would be $68.125 per technical hour expended.[2] The 2002 labor costs were multiplied by 0.8837 (139.8/158.2) to estimate the compliance costs in fourth-quarter 1998 dollars. Therefore, the compliance costs were calculated using $60.20 per technical hour expended.

6.5.5.1 <u>Performance Tests</u>. A total of 70 technical hours was estimated for each performance test. This included time to prepare a site-specific QA test plan, conduct the performance test, and prepare the final source test report. The total number of stacks requiring performance testing was estimated to be 431. Some stacks will require both a performance test and a CEMS performance evaluation. It is assumed that both of these activities can be performed at the same time without a significant increase in the technical hours needed for the initial compliance demonstration. Additionally, annual performance evaluations of the CEMS were included in the CEMS monitoring costs.

The performance tests are required once every 5 years. The compliance period is 3 years. Therefore, the required performance tests can be fairly evenly distributed across the compliance period. The average annual compliance cost associated with conducting performance tests at a given foundry was calculated as the total costs for conducting all required performance tests at that foundry and distributing those costs evenly over 5 years. Thus, 6,034 technical hr/yr were estimated for conducting performance tests, for a total annual cost of $363,000/yr.

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[2] As stated, these labor rates are based on March 2002 statistics. According to BLS data, the Employment Cost Index (ECI) for civilian workers in March 2002 was 158.2, while the ECI for civilian workers in December 1998 was 139.8.

6.5.5.2 Scrap Selection and Inspection. Most of the 96 foundries had a scrap selection and inspection program; however, it is anticipated that many foundries will have increased the number of technical hours spent on scrap selection and inspection to comply with requirements in the proposed MACT standard. It was assumed that the scrap inspection requirements would increase a typical foundry's inspection process by 0.5 hr/day or 182 hr/yr (assuming 365 operating days/yr). A one-time scrap selection plan must be prepared and communicated within the foundry. This activity was assumed to require an additional 10 hr/yr. Therefore, a total of 192 technical hr/yr per foundry were estimated. Of the 96 facilities considered to be major sources of HAP emissions, two of these foundries each operate two adjacent plants. Although they are considered a single facility under the CAA, these adjacent plants have separate scrap-receiving areas. Thus, the scrap selection and inspection costs were estimated based on 98 foundry plants. The total nationwide costs for the scrap selection and inspection program were estimated to be $1.13 million.

6.5.5.3 Low-HAP-Emitting Binder Evaluation. Under this control option, each foundry is required to evaluate the potential to substitute currently used binder systems with alternative binder formulations that have lower HAP emissions. This evaluation must be performed once every 5 years so that newly developed low-HAP-emitting binder systems can be periodically evaluated. Eighty technical hours were estimated for each evaluation. As evaluations are required once every 5 years, the average annual technical hours required to complete these evaluations would be 16 hr/yr per foundry. Again, the binder evaluations were calculated based on 98 foundry plants so that the total nationwide costs for evaluating low-HAP-emitting binder systems were estimated to be $94,400/yr.

6.5.5.4 Miscellaneous Recordkeeping Costs. Costs associated with maintaining required records at the foundry level were estimated based on two filing cabinets (for capital equipment costs of $400) and a pack of 10 writeable CDs (for annual operating costs of $32). Again, these costs were estimated for 98 foundry plants.

6.6 TOTAL NATIONWIDE COSTS

The total nationwide costs for each of the major control or monitoring systems are provided in Table 6-4. Table 6-4 also summarizes the estimated recordkeeping and reporting costs. The total annual nationwide cost of the proposed MACT for iron and steel foundries is projected to be $21.7 million.

TABLE 6-4. NATIONWIDE COST ESTIMATES FOR IRON FOUNDRY MACT: 1998 $

Source	Total capital, $1,000	Annual capital*	Annual operating, $1,000/yr	Total annual, $1,000/yr
Baghouse replacement of cupola venturi scrubbers	108,754	10,266	(7,407)	2,859
Cupola afterburners	555	79	228	307
Baghouses on EIF and scrap preheaters	13,190	1,245	5,550	6,795
Baghouses on pouring stations	7,770	733	4,747	5,480
Acid/wet scrubber systems for TEA control	933	133	165	298
Use of naphthalene-depleted solvents	0	0	427	427
Total Emission Control Costs	131,202	12,457	3,710	16,167
Continuous CO monitoring system	4,125	587	1,493	2,080
Continuous VOC monitoring system	2,432	346	611	957
Bag leak detection systems	3,051	434	170	604
Venturi scrubber monitoring systems	0	0	84	84
Acid/wet scrubber parameter monitoring systems	353	50	188	238
Performance tests	0	0	363	363
Scrap selection and inspection	0	0	1,133	1,133
Binder system evaluation	0	0	94	94
Other recordkeeping costs	39	6	3	9
Total Monitoring, Recordkeeping and Reporting Costs	10,000	176	4,139	5,563
Total Engineering Control Costs	**141,202**	**6,802**	**7,849**	**21,730**

* Reflects capital recovery based on a 20-year life and 7-percent interest rate for baghouse emission controls and a 10-year life and 7-percent interest rate for cupola afterburners, TEA scrubbers, and all monitoring equipment.

6.7 REFERENCES

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APPENDIX A

IRON AND STEEL FOUNDRIES REPORTING IN THE 1998 EPA SURVEY

APPENDIX A. IRON AND STEEL FOUNDRIES REPORTING IN THE 1998 EPA SURVEY.

ID	Name	City	State	Metal poured, tons per year		
				Iron	Steel	Total
AL-01	U.S. Pipe & Foundry Co., Inc.	Birmingham	AL	189,287	0	189,287
AL-02	Southern Ductile Casting Co	Bessemer	AL	26,258	0	26,258
AL-03	Alabama Ductile Casting Co.	Brewton	AL	89,560	0	89,560
AL-04	Talladega Foundry & Machine Co.	Talladega	AL	4,235	0	4,235
AL-05	Mueller Co.	Albertville	AL	40,780	0	40,780
AL-06	Glidewell Specialties Foundry Co	Calera	AL	8,537	824	9,361
AL-07	Barry Pattern & Foundry Co., Inc.	Birmingham	AL	1,217	0	1,217
AL-08	Vermont American, Auburn Division	Auburn	AL	0	897	897
AL-09	McWane Cast Iron Pipe Co.	Birmingham	AL	109,164	0	109,164
AL-10	Southern Alloy Corporation	Sylacauga	AL	88	1,225	1,313
AL-11	Griffin Wheel Company	Bessemer	AL	0	87,075	87,075
AL-12	Imperial Casting Co.	Florence	AL	4,042	0	4,042
AL-13	Robinson Foundry Inc.	Alexander City	AL	17,514	0	17,514
AL-14	Aliceville Cast Products	Aliceville	AL	5,404	0	5,404
AL-15	Southern Tool, Inc.	Oxford	AL	0	328	328
AL-16	M&H Valve Company	Anniston	AL	20,000	0	20,000
AL-17	Southern Ductile Casting Co.	Centreville	AL	2,421	0	2,421
AL-18	Southern Ductile Casting Co.	Selma	AL	7,260	0	7,260
AL-19	Citation Foam Casting Co.	Columbiana	AL	20,849	0	20,849
AL-20	American Alloy Products, Inc.	Cullman	AL	10	389	399
AL-21	Lawler Machine & Foundry Co.	Birmingham	AL	3,750	0	3,750
AL-22	Stockham Valves & Fittings, Inc.	Birmingham	AL	35,993	0	35,993
AL-23	U.S. Pipe & Foundry Company	Bessemer	AL	183,957	0	183,957
AL-24	U.S. Pipe & Foundry Co., Inc.	Anniston	AL	19,837	0	19,837
AL-25	Jacobs Manufacturing, Inc.	Bridgeport	AL	600	0	600
AL-26	ABC Rail Corp.	Calera	AL	0	134,883	134,883
AL-27	The Foundry of the Shoals, Inc.	Florence	AL	13,244	0	13,244
AL-28	Mobile Pulley & Machine Works, Inc.	Mobile	AL	1,930	6,111	8,041
AL-29	Bama Foundry, Inc.	Montgomery	AL	241	0	241
AL-30	American Safety Tread Co.	Pelham	AL	875	0	875
AL-31	Phenix Foundry	Phenix City	AL	1,326	0	1,326
AL-32	Talladega Castings & Machine Co.	Talladega	AL	20	1,320	1,340
AL-33	Tommie Corporation	Thorsby	AL	4,630	0	4,630
AL-34	American Cast Iron Pipe Co.	Birmingham	AL	386,965	0	386,965
AL-35	Denver Thomas, Inc.	Birmingham	AL	4,609	9,314	13,923
AL-36	Union Foundry Co.	Anniston	AL	32,059	0	32,059
AL-37	Opelika Foundry Co.	Opelika	AL	8,225	0	8,225
AL-38	Brewton Iron Works, Inc.	Brewton	AL	825	0	825
AL-39	Bells Novelty Casting Co.	Anniston	AL	650	0	650

				Metal poured, tons per year		
ID	**Name**	**City**	**State**	**Iron**	**Steel**	**Total**
AR-01	Southern Cast Products, Inc.	Jonesboro	AR	392	0	392
AR-02	Central Foundry and Stove Works	Clarksville	AR	28	0	28
AR-03	Bentonville Castings Co.	Bentonville	AR	7,927	0	7,927
AR-04	Nibco Inc.- Blytheville Division	Blytheville	AR	23,055	0	23,055
AZ-01	American Aerospace Technical Castings	Phoenix	AZ	0	339	339
AZ-02	Ruger Investment Casting,	Phoenix	AZ	0	508	508
AZ-03	Arizona Castings Inc.	Tempe	AZ	73	0	73
AZ-04	ME-West Castings, Inc.	Tempe	AZ	13	26,117	26,130
AZ-05	Dolphin, Incorporated	Phoenix	AZ	0	2,928	2,928
CA-01	Techni-Cast Corp.	South Gate	CA	103	558	661
CA-02	Acme Castings, Inc.	Huntington Park	CA	329	1,055	1,384
CA-03	Westelectric Castings, Inc.	Commerce	CA	0	4,000	4,000
CA-04	Image Casting	Oxnard	CA	0	150	150
CA-05	Bell Foundry Company	South Gate	CA	6,214	0	6,214
CA-06	Precision Cast Products, Inc.	Oakland	CA	360	400	760
CA-07	Amcast Precision Products	Rancho Cucamonga	CA	0	200	200
CA-08	Alhambra Foundry Company, Ltd.	Alhambra	CA	4,500	0	4,500
CA-09	K.P. Iron Foundry	Fresno	CA	1,639	0	1,639
CA-10	Grass Valley Steelcast	Grass Valley	CA	0	389	389
CA-11	Lodi Iron Works, Inc.	Lodi	CA	2,462	0	2,462
CA-12	Lodi Iron Works, Inc.	Galt	CA	0	220	220
CA-13	Wyman-Gordon Company	San Leandro	CA	0	338	338
CA-14	Richmond Micro Metals	Richmond	CA	188	188	375
CA-15	Macaulay Foundry, Inc.	Berkeley	CA	11,330	0	11,330
CA-16	Coastcast Corporation	Rancho Dominguez	CA	0	2,199	2,199
CA-17	California Electric Steel	Angels Camp	CA	0	806	806
CA-18	Pomona Foundry Inc.	Pomona	CA	578	30	608
CA-19	Commercial Castings	Fontana	CA	5,000	0	5,000
CA-20	PAC Foundries	Port Hueneme	CA	0	840	840
CA-21	Waterman Foundry	Exeter	CA	7,437	0	7,437
CA-22	Pacific Steel Casting Co.	Berkeley	CA	0	12,000	12,000
CA-23	Pacific Steel Casting Company	Berkeley	CA	0	7,900	7,900
CA-24	Pacific Steel Casting Company	Berkeley	CA	0	7,700	7,700
CA-25	Covert Iron Works	Huntington Park	CA	1,825	0	1,825
CA-26	American Brass & Iron Foundry	Oakland	CA	41,193	10,298	51,491
CA-27	U.S. Pipe & Foundry Co., Inc.	Union City	CA	77,343	0	77,343
CA-28	Soundcast Co.	Costa Mesa	CA	927	927	1,853
CA-29	Gregg Industries	El Monte	CA	31,279	0	31,279
CA-30	West Coast Stainless Products	Vernon	CA	0	850	850
CA-31	Pacific Alloy Castings, Inc.	South Gate	CA	4,100	0	4,100
CA-32	Modern Pattern & Foundry Co	Vernon	CA	0	383	383
CA-33	Dameron Alloy Foundries	Compton	CA	0	756	756
CA-34	Globe Iron Foundry, Inc.	Commerce	CA	4,500	0	4,500

ID	Name	City	State	Metal poured, tons per year Iron	Steel	Total
CA-35	Strategic Materials Corp.	South Gate	CA	53	1,017	1,070
CO-01	Svedala Industries Pumps & Process	Colorado Springs	CO	1,639	250	1,889
CO-02	Fountain Foundry, Inc.	Pueblo	CO	2,668	232	2,900
CO-03	Western Foundries	Longmont	CO	969	340	1,309
CO-04	Goltra Castings Co., Inc.	Golden	CO	0	578	578
CO-05	The Electron Corp.	Littleton	CO	25,359	0	25,359
CT-01	The Noank Foundry	Noank	CT	5	0	5
CT-02	Wyman Gordon Investment Castings	Groton	CT	0	1,075	1,075
CT-03	The Taylor and Fenn Company	Windsor	CT	2,475	275	2,750
CT-04	Philbrick Booth & Spencer, Inc.	Hartford	CT	0	1,127	1,127
CT-05	American Industrail FerroCast	Pawcatuck	CT	0	75	75
FL-01	Miami Castings	Miami	FL	0	259	259
FL-02	Precision Castings Incorporated	Boca Raton	FL	0	41	41
FL-03	Consolidated Castings, Inc.	Jacksonsville	FL	10	0	10
FL-04	Florida Cast Products	Tampa	FL	0	216	216
FL-05	Maddox Foundry & Machine Works	Archer	FL	713	320	1,033
FL-06	U.S. Pipe & Foundry Co., Inc.	Medley	FL	58,912	0	58,912
GA-01	Wheland Foundry - Warrenton	Warrenton	GA	32,000	0	32,000
GA-02	West Point Foundry & Machine Co.	West Point	GA	1,169	0	1,169
GA-03	Grinnell Corporation	Statesboro	GA	113,000	0	113,000
GA-04	Goldens' Foundry & Machine Co.	Columbus	GA	10,610	0	10,610
IA-01	Seabee Corp Steel Foundry	Hampton	IA	94	2,246	2,340
IA-02	Quality Foundry Co.	Stockton	IA	493	0	493
IA-03	Griffin Wheel Company	Keokuk	IA	0	142,084	142,084
IA-04	Bloomfield Foundry, Inc.	Bloomfield	IA	5,225	0	5,225
IA-05	Griffin Pipe Products Co.	Council Bluffs	IA	152,890	0	152,890
IA-06	Seneca Foundry, Inc.	Webster City	IA	5,174	0	5,174
IA-07	Sivyer Steel Corporation	Bettendorf	IA	0	31,313	31,313
IA-08	Max-Cast	Kalona	IA	3	0	3
IA-09	Clow Valve Company—Foundry	Oskaloosa	IA	25,050	0	25,050
IA-10	Alloys Foundry	Cedar Falls	IA	0	1,664	1,664
IA-11	Iron Foundry	Cedar Falls	IA	10,450	0	10,450
IA-12	Quinn Machine & Foundry Inc.	Boone	IA	7,570	0	7,570
IA-13	Progessive Foundry, Inc.	Perry	IA	9,833	0	9,833
IA-14	Crane Valves	Washington	IA	24,146	0	24,146
IA-15	Blackhawk Foundry & Machine	Davenport	IA	25,238	0	25,238
IA-16	Eagle Iron Works	Des Moines	IA	2,500	0	2,500
IA-17	John Deere Foundry Waterloo	Waterloo	IA	251,535	0	251,535
IA-18	Russelloy Foundry, Inc.	Durant	IA	2,100	0	2,100
IA-19	The Dexter Company	Fairfield	IA	69,307	0	69,307
IL-01	Wagner Castings Company	Decatur	IL	200,000	0	200,000
IL-02	Wagner Havana	Havana	IL	60,000	0	60,000
IL-03	Chicago Heights Gray Iron Foundry	Chicago Heights	IL	646	0	646

ID	Name	City	State	Metal poured, tons per year Iron	Steel	Total
IL-04	American Steel Foundries	Granite City	IL	0	58,096	58,096
IL-05	Caterpiller Inc., Mapleton Foundry	Mapleton	IL	175,000	0	175,000
IL-06	National Castings Inc.	Chicago	IL	0	23,475	23,475
IL-07	National Castings Inc.	Melrose Park	IL	0	19,407	19,407
IL-08	Cast-Rite Steel Castings Corp.	Chicago	IL	0	630	630
IL-09	Excelsior Foundry Co.	Belleville	IL	3,911	0	3,911
IL-10	Lemfco Inc.	Galena	IL	5,105	0	5,105
IL-11	Aurora Industries, Inc.	Montgomery	IL	67	36	103
IL-12	Penberthy, Inc	Prophetstown	IL	228	283	512
IL-13	Rockbridge Castings Inc.	Rockbridge	IL	17	0	17
IL-14	Prime Cast, Inc.	South Beloit	IL	15,968	0	15,968
IL-15	Fansteel/Escast, Inc.	Addison	IL	0	2,014	2,014
IL-16	Gunite Corporation	Rockford	IL	224,250	0	224,250
IL-17	Castwell Products, Inc.	Skokie	IL	55,051	0	55,051
IL-18	The Francis & Nygren Foundry Co	Chicago	IL	4,052	0	4,052
IL-19	Sterling Steel Foundry Inc.	Sauget	IL	0	1,234	1,234
IL-20	Marengo Foundry Corp.	Marengo	IL	3,959	208	4,167
IL-21	Sarcol, Inc	Chicago	IL	0	46	46
IN-01	Chrysler Indianapolis Foundry	Indianapolis	IN	189,150	0	189,150
IN-02	ABC Rail Corp.	Anderson	IN	0	4,600	4,600
IN-03	Weil-McLain	Michigan City	IN	39,150	0	39,150
IN-04	Shenango Industries, Inc.	Terre Haute	IN	1,233	1,176	2,409
IN-05	Tate Model & Engineering	Kokomo	IN	4	0	4
IN-06	Harrison Steel Castings Co.	Attica	IN	2,717	65,211	67,928
IN-07	Electric Steel Castings Company	Indianapolis	IN	0	5,530	5,530
IN-08	Urschel Laboratories, Inc.	Valparaiso	IN	0	41	41
IN-09	Grede New Castle, Inc.	New Castle	IN	70,448	0	70,448
IN-10	Richmond Casting Company	Richmond	IN	9,853	0	9,853
IN-11	Indianapolis Casting Corporation	Indianapolis	IN	192,000	0	192,000
IN-12	Auburn Foundry Plant #1	Auburn	IN	239,536	0	239,536
IN-13	Auburn Foundry Plant #2	Auburn	IN	149,022	0	149,022
IN-14	Bremen Castings, Inc.	Bremen	IN	30,840	0	30,840
IN-15	Columbia City Engineering, Inc.	Columbia City	IN	361	0	361
IN-16	Decatur Casting Division	Decatur	IN	14,000	0	14,000
IN-17	Elkhart Foundry & Machine Co.	Elkhart	IN	7,100	0	7,100
IN-18	InterState Castings	Indianapolis	IN	3,500	0	3,500
IN-19	Precision Propeller, Inc.	Indianapolis	IN	0	200	200
IN-20	Dalton Corporation	Kendallville	IN	101,411	0	101,411
IN-21	Casteel Service, Inc.	Kingsbury	IN	94	690	784
IN-22	Aero Metals, Inc.	LaPorte	IN	31	2,561	2,592
IN-23	Teledyne Casting Service	LaPorte	IN	44,484	0	44,484
IN-24	Atlas Foundry Company, Inc.	Marion	IN	18,832	0	18,832
IN-25	RMG Foundry	Mishawaka	IN	44,797	0	44,797
IN-26	Kendon Corporation	Muncie	IN	153	0	153
IN-27	North Manchester Foundry Inc.	North Manchester	IN	13,280	0	13,280

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IN-28	Plymouth Foundry, Inc.	Plymouth	IN	866	0	866
IN-29	Rochester Metal Products	Rochester	IN	35,687	0	35,687
IN-30	Gartland Foundry Company, Inc.	Terre Haute	IN	11,266	0	11,266
IN-31	MedCast	Warsaw	IN	0	195	195
IN-32	Sterling Casting Corporation	Buffton	IN	8,800	0	8,800
IN-33	Intat Precision, Inc.	Rushville	IN	75,900	0	75,900
IN-34	Waupaca Foundry, Inc., Plant 5	Tell City	IN	148,212	0	148,212
IN-35	Golden Casting Corporation	Columbus	IN	33,239	0	33,239
IN-36	Sibley Machine and Foundry	South Bend	IN	9,826	0	9,826
IN-37	American Steel Foundries	East Chicago	IN	0	25,061	25,061
IN-38	OMCO Cast Metals	Winchester	IN	21,000	0	21,000
KS-01	Farrar Corporation	Norwich	KS	9,600	0	9,600
KS-02	ACME Foundry	Coffeyville	KS	44,533	0	44,533
KS-03	Grede Foundries Inc.	Wichita	KS	34,327	0	34,327
KS-04	Griffin Wheel Company	Kansas City	KS	0	86,348	86,348
KS-05	Metlcast Products, Inc.	Salina	KS	4,673	0	4,673
KS-06	Ferroloy Foundry, Inc.	Wichita	KS	3,400	0	3,400
KS-07	Atchinson Casting Corp.	Atchinson	KS	0	46,158	46,158
KY-01	Grede Foundries Inc.	Cynthiana	KY	44,681	0	44,681
KY-02	Carrollton Casting Center	Carrollton	KY	41,340	0	41,340
LA-01	Bogalusa Iron Works, Inc.	Bogalusa	LA	1,040	0	1,040
LA-02	Nadler Incorporated	Plaquemine	LA	119	145	264
LA-03	Vulcan Foundry	Denham Springs	LA	18,581	0	18,581
LA-04	Hendrix Manufacturing Co.	Mansfield	LA	0	3,566	3,566
LA-05	HICA Steel Foundry & Upgrade Co	Shreveport	LA	0	1,480	1,480
LA-06	Pearce Foundry, Inc.	Prairieville	LA	1,373	343	1,716
MA-01	Rodney Hunt Company	Orange	MA	3,250	0	3,250
MA-02	Ware Foundry, Inc.	Ware	MA	168	0	168
MA-03	Harmony Pattern & Casting Co	Swansea	MA	907	0	907
MA-04	Trident Alloys, Inc.	Springfield	MA	0	303	303
MA-05	LeBaron Foundry Inc.	Brockton	MA	15,253	0	15,253
MA-06	Charlette Bros Foundry, Inc.	Blackstone	MA	480	0	480
MA-07	KomTek	Worcester	MA	0	54	54
MA-08	Wollaston Alloys, Inc	Braintree	MA	0	1,627	1,627
MA-09	Jahn Foundry Corp.	Springfield	MA	12,300	0	12,300
MA-10	Belcher Corporation	Easton	MA	9,348	0	9,348
MD-01	Kaydon Ring & Seal Co.	Baltimore	MD	1,135	23	1,158
MD-02	ABC Rail Corp.	Baltimore	MD	10,240	0	10,240
MD-03	Pangborn Corporation	Hagerstown	MD	1,127	1,076	2,203
ME-01	Enterprise Foundry, Inc.	Lewiston	ME	2,141	0	2,141
ME-02	Etheridge Foundry & Machine Co.	Portland	ME	561	0	561
MI-01	Shellcast, Inc.	Montague	MI	0	95	95
MI-02	Village Castings Company	Caseville	MI	116	0	116

ID	Name	City	State	Metal poured, tons per year Iron	Steel	Total
MI-03	Midland Iron Works, Inc.	Midland	MI	216	0	216
MI-04	Giddings & Lewis Casting Technology	Menominee	MI	11,921	0	11,921
MI-05	Dock Foundry Company	Three Rivers	MI	767	0	767
MI-06	Northland Castings Corp.	Hart	MI	1,600	0	1,600
MI-07	Grede Foundries Inc.	Kingsford	MI	89,480	0	89,480
MI-08	Astech, Inc.	Vassar	MI	644	1,196	1,840
MI-09	Hayes Albion Corporation	Albion	MI	171,980	0	171,980
MI-10	Thunder Bay Manufacturing Corp	Alpena	MI	13,355	0	13,355
MI-11	Omega Castings, Inc.	Battle Creek	MI	0	420	420
MI-12	Bay Cast Incorporated	Bay City	MI	814	7,322	8,135
MI-13	CMI- Cast Parts, Inc.	Cadillac	MI	108,246	0	108,246
MI-14	East Jordan Iron Works, Inc.	East Jordan	MI	235,455	0	235,455
MI-15	Hastings Manufacturing Company	Hastings	MI	1,949	0	1,949
MI-16	Pioneer Foundary	Jackson	MI	2,770	0	2,770
MI-17	Great Lakes Casting Corp.	Ludington	MI	59,707	0	59,707
MI-18	Midwest Metallurgical Lab.	Marshall	MI	3,321	369	3,690
MI-19	Eagle Alloy, Inc.	Muskegon	MI	0	11,667	11,667
MI-20	West Michigan Steel	Muskegon	MI	0	10,048	10,048
MI-21	New Haven Foundry	New Haven	MI	57,190	0	57,190
MI-22	RLM Industries, Inc.	Oxford	MI	0	850	850
MI-23	Huron Casting, Inc.	Pigeon	MI	0	29,639	29,639
MI-24	Process Prototype Inc.	Romulus	MI	125	0	125
MI-25	Sparta Foundry	Sparta	MI	34,680	0	34,680
MI-26	Sturgis Foundry Corporation	Sturgis	MI	19,595	0	19,595
MI-27	Grede-Vassar, Inc.	Vassar	MI	61,964	0	61,964
MI-28	Briggs & Stratton	Revenna	MI	55,000	0	55,000
MI-29	Bernier Cast Metals, Inc.	Saginaw	MI	84	0	84
MI-30	Kurdziel Industries	Rothbury	MI	113,216	0	113,216
MI-31	Steeltech Ltd.	Grand Rapids	MI	0	1,200	1,200
MI-32	Specialty Castings, Inc.	Springport	MI	1,494	0	1,494
MI-33	GM Powertrain-Saginaw Metal Casting Operations	Saginaw	MI	448,682	0	448,682
MI-34	GM Powertrain - Saginaw Malleable Iron Plant	Saginaw	MI	315,276	0	315,276
MI-35	Burgess-Norton Mfg. Co. Plant 3	Muskegon	MI	4,538	0	4,538
MI-36	Temperform Corporation	Novi	MI	11	1,076	1,087
MI-37	CWC Castings--Textron Inc.	Muskegon	MI	52,704	0	52,704
MN-01	Municipal Castings, Inc.	Madison	MN	5,840	0	5,840
MN-02	Dezurik Foundry	Sartell	MN	12,133	0	12,133
MN-03	M E International - Duluth	Duluth	MN	16,620	30,867	47,487
MN-04	AEGoetze - Lake City	Lake City	MN	12,600	0	12,600
MN-05	Invest Cast, Inc.	Minneapolis	MN	0	883	883
MN-06	Minncast Inc.	Fridley	MN	0	2,340	2,340
MN-07	Grede Foundries Inc.	St. Cloud	MN	38,000	0	38,000
MN-08	Pier Foundry	St. Paul	MN	5,180	0	5,180

				Metal poured, tons per year		
ID	Name	City	State	Iron	Steel	Total
MN-09	Badger Foundry Company	Winona	MN	17,625	0	17,625
MN-10	Gorman Company	Winona	MN	4,102	0	4,102
MN-11	United Machine & Foundry	Winona	MN	1,267	0	1,267
MN-12	Northern Castings Company	Hibbing	MN	30,150	0	30,150
MN-13	Brom Machine & Foundry Co., Inc.	Winona	MN	457	0	457
MN-14	Waltek Inc.	Anoka	MN	0	500	500
MN-15	The Dotson Company, Inc.	Mankato	MN	20,821	0	20,821
MO-01	Gold Foundry & Machine Works	Independence	MO	0	166	166
MO-02	Milton Gold D/B/A Foundry & Machine Works	Independence	MO	0	191	191
MO-03	The Carondelet Corporation	Pevely	MO	0	1,054	1,054
MO-04	Mans-Steel Foundary	Mansfield	MO	0	6,071	6,071
MO-05	Gardner Denver Industrial Machinery	LaGrange	MO	19,243	0	19,243
MO-06	Monett Steel Castings	Monett	MO	0	729	729
MO-07	Ralston Purina Comp. Pet Products Support Center	St. Louis	MO	0	50	50
MO-08	Midwest Alloys Foundry, Inc.	O'Fallon	MO	0	353	353
MO-09	Missouri Precision	Joplin	MO	0	4,668	4,668
MO-10	St. Louis Precision Casting Co.	St. Louis	MO	250	500	750
MO-11	Didion & Sons Foundry Co.	St. Peters	MO	14,604	0	14,604
MO-12	Standard Electric Steel Corp.	Springfield	MO	0	414	414
MS-01	Dews Foundry	Hattiesburg	MS	2,105	0	2,105
MS-02	Laurel Machine & Foundry	Sandersville	MS	1,000	0	1,000
MS-03	ESCO Corporation	Newton	MS	0	22,190	22,190
MS-04	Southern Cast Products	Meridian	MS	328	6,232	6,560
MT-01	AFFCO, Inc.	Anaconda	MT	1,161	806	1,967
NC-01	Sanders Co., Inc.	Elizabeth City	NC	66	0	66
NC-02	Hallman Foundry, Inc.	Sanford	NC	2,812	0	2,812
NC-03	Stovall Foundry, Inc.	Gastonia	NC	1,886	0	1,886
NC-04	Foundry Service Company	Biscoe	NC	33,759	0	33,759
NC-05	Charlotte Pipe & Foundry Co.	Charlotte	NC	157,075	0	157,075
NE-01	Sioux City Foundry Company	South Sioux City	NE	7,724	0	7,724
NE-02	Spitz Foundry, Inc.	Hastings	NE	292	0	292
NE-03	Omaha Steel Castings Co.	Omaha	NE	0	12,608	12,608
NE-04	Deeter Foundry, Inc.	Lincoln	NE	23,397	0	23,397
NE-05	Paxton-Mitchell Company	Omaha	NE	6,073	0	6,073
NE-06	Phoenix Casting & Machining	Juniata	NE	150	0	150
NH-01	Joy Technologies Inc	Claremont	NH	0	4,660	4,660
NH-02	Pine Tree Castings, Division of Sturm, Ruger & Co.	Newport	NH	0	3,454	3,454
NH-03	Hitchiner Mfg. Co., Inc	Milford	NH	0	6,109	6,109
NH-04	Nashua Foundries, Inc.	Nashua	NH	1,600	0	1,600
NH-05	K.W. Thompson Tool Co.	Rochester	NH	0	171	171
NJ-01	General Foundry	Flagtown	NJ	1,000	0	1,000
NJ-02	Bierman-Everett Foundry Co.	Irvington	NJ	700	0	700

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NJ-03	U.S. Pipe & Foundry Co., Inc.	Burlington	NJ	121,229	0	121,229
NJ-04	Atlantic States Cast Iron Pipe	Phillipsburg	NJ	112,129	0	112,129
NJ-05	Griffin Pipe Products Co.	Florence	NJ	100,000	0	100,000
NV-01	Wyman Gordon Sierra Cast Division	Carson City	NV	0	730	730
NY-01	Oneida Foundries, Inc.	Oneida	NY	430	0	430
NY-02	Jamestown Iron Works Inc.	Falconer	NY	500	0	500
NY-03	Kennedy Valve	Elmira	NY	33,190	0	33,190
NY-04	Frazer & Jones Co.	Solvay	NY	30,000	0	30,000
NY-05	Gray-Syracuse, Inc.	Chittenango	NY	0	1,434	1,434
NY-06	Wormuth Brothers Foundry, Inc.	Athens	NY	5,600	0	5,600
NY-07	Pohlman Foundry Co., Inc.	Buffalo	NY	3,676	0	3,676
OH-01	Griffin Wheel Company	Groveport	OH	0	136,469	136,469
OH-02	Rimer Enterprises, Inc.	Waterville	OH	0	466	466
OH-03	Columbia Foundry Company	Columbiana	OH	1,623	2,836	4,459
OH-04	MorCast Precision, Inc.	Columbus	OH	0	9	9
OH-05	The Wagnerware Copr. - Sidney Division	Sidney	OH	1,088	0	1,088
OH-06	Quaker City Castings, Inc.	Salem	OH	9,550	5,140	14,690
OH-07	T & B Foundry Company	Cleveland	OH	6,352	0	6,352
OH-08	SanCasT, Inc.	Coshocton	OH	10,933	0	10,933
OH-09	Foundry Division	Dayton	OH	1,407	4,006	5,413
OH-10	Tri-Cast, Inc.	Akron	OH	1,827	0	1,827
OH-11	The Blanchester Foundry Co.	Blanchester	OH	4,560	0	4,560
OH-12	Clow Water Systems Co.	Coshocton	OH	125,536	0	125,536
OH-13	OSCO Industries, Inc.	Portsmouth	OH	74,555	0	74,555
OH-14	Cast-Fab Technologies, Inc.	Cincinnati	OH	30,216	0	30,216
OH-15	Babcock & Wilcox Company	Barberton	OH	0	4,025	4,025
OH-16	The Pioneer City Casting Company	Belpre	OH	769	58	827
OH-17	Plant #3 & #4 - Foundry	Blanchester	OH	1,100	0	1,100
OH-18	United Foundries - Canton Plant	Canton	OH	25,671	0	25,671
OH-19	Chris Erhart Foundry & Machine Co.	Cincinnati	OH	1,684	0	1,684
OH-20	Minster Machine Company	Minster	OH	8,310	0	8,310
OH-22	Buckeye Steel Castings Co.	Columbus	OH	0	89,070	89,070
OH-23	Funk FineCast Inc.	Columbus	OH	0	690	690
OH-24	Elano Corp., Casting Division	Xenia	OH	0	28	28
OH-25	Webster Manufacturing Co.	Tiffin	OH	3,600	0	3,600
OH-26	Concorde Castings, Inc.	Eastlake	OH	0	323	323
OH-27	Hamilton Foundry Division	Harrison	OH	29,500	0	29,500
OH-28	Ironton Iron, Inc.	Ironton	OH	105,270	0	105,270
OH-29	Ohio Foundry	Lima	OH	29,700	0	29,700
OH-30	The Sawbrook Steel Castings Co	Cincinnati	OH	0	7,323	7,323
OH-31	Alloy Cast Steel Company	Marion	OH	0	404	404
OH-32	Miami-Cast Inc.	Miamisburg	OH	1,350	0	1,350
OH-33	The Quality Castings Co.	Orrville	OH	55,513	0	55,513
OH-34	Quincy Castings, Inc.	Quincy	OH	11,710	0	11,710
OH-35	St. Marys Foundry, Inc.	St. Marys	OH	11,584	0	11,584

ID	Name	City	State	Metal poured, tons per year Iron	Steel	Total
OH-36	Sandusky International, Inc.	Sandusky	OH	0	10,291	10,291
OH-37	Ohio Foundry, Inc.	Tallmadge	OH	21	401	422
OH-38	Fisher Cast Steel Prod. Inc.	West Jefferson	OH	0	1,500	1,500
OH-39	Bescast, Inc.	Willoughby	OH	0	34	34
OH-40	Xenia Foundry	Xenia	OH	1,480	0	1,480
OH-42	Precision Metalsmiths, Inc.	Euclid	OH	2	170	172
OH-43	OSCO Industries, Inc.	New Boston	OH	5,439	0	5,439
OH-44	Kurdziel Iron of Wauseon	Wauseon	OH	23,288	0	23,288
OH-45	Electro-Alloys Corp.	Elyria	OH	0	4,434	4,434
OH-46	Ford Motor Company	Brookpark	OH	526,000	0	526,000
OH-47	GM Powertrain - Defiance Plant	Defiance	OH	1,368,167	0	1,368,167
OH-48	U.S. Casting Company	Canal Fulton	OH	27	2,653	2,680
OH-49	American Steel Foundries	Alliance	OH	0	35,200	35,200
OH-51	The General Casting Co.	West Liberty	OH	7,677	0	7,677
OH-52	The General Casting Co.	Delaware	OH	8,461	0	8,461
OH-53	The General Casting Co.	Cincinnati	OH	2,800	0	2,800
OH-54	The General Casting Co.	Columbus	OH	2,526	0	2,526
OH-55	The General Casting Co.	Delaware	OH	19,449	0	19,449
OH-56	The General Casting Co.	Grafton	OH	8,997	0	8,997
OH-58	Kenton Iron Products, Inc.	Kenton	OH	2,564	0	2,564
OH-59	Eljer Plumbingware, Inc.	Salem	OH	31,181	0	31,181
OH-60	Commercial Casting Co.	New Philadelphia	OH	134	0	134
OH-61	The G & C Foundry Co.	Sandusky	OH	18,675	0	18,675
OH-62	The Knapp Foundry Company	Akron	OH	803	0	803
OH-63	OSCO Industries, Inc.	Jackson	OH	33,355	0	33,355
OH-64	The O.S. Kelly Company	Springfield	OH	5,000	0	5,000
OH-65	The Bimac Corporation	Dayton	OH	0	394	394
OK-01	Big Four Alloy Castings	Tulsa	OK	0	156	156
OK-02	B&L Foundry, Inc.	Tonkawa	OK	34	50	84
OK-03	American Alloy Division 2	Muskogee	OK	0	2,484	2,484
OK-04	American Foundry Group, Inc	Bixby	OK	0	151	151
OK-05	American Alloy Division	Bixby	OK	0	717	717
OK-06	Grede-Pryor Foundry Inc.	Pryor	OK	105,000	0	105,000
OK-07	Flanagan Iron Works	Tulsa	OK	1,426	49	1,474
OK-08	The Electron Corporation	Blackwell	OK	33,000	0	33,000
OK-09	Central Machine & Tool Co.	Enid	OK	979	74	1,053
OK-10	Tonkawa Foundry, Inc.	Tonkawa	OK	860	0	860
OK-11	Jencast,-Jensen International	So. Coffeyville	OK	3,580	4,037	7,617
OR-01	ESCO Corp. - Main Plant	Portland	OR	392	19,213	19,605
OR-02	PED Manufacturing, Ltd.	Oregon City	OR	0	434	434
OR-03	Durametal Corporation	Tualatin	OR	3,367	459	3,826
OR-04	ESCO - Plant 3	Portland	OR	0	16,031	16,031
OR-05	Eagle Foundry Company	Eagle Creek	OR	8,234	3,529	11,763
OR-06	Varicast, Inc. (Portland Plant)	Portland	OR	3,021	500	3,521
OR-07	Wolf Steel Foundry, Inc.	Hubbard	OR	0	6,594	6,594

ID	Name	City	State	Metal poured, tons per year Iron	Steel	Total
OR-08	PCC Standards, Inc.	Portland	OR	0	4,920	4,920
OR-09	Columbia Steel Casting Co	Portland	OR	2,938	29,710	32,648
PA-01	Brighton Electric Steel Casting	Beaver Falls	PA	0	1,344	1,344
PA-02	Ward Manufacturing, Inc.	Blossburg	PA	122,211	0	122,211
PA-03	Zurn Cast Metals Operations	Erie	PA	16,847	0	16,847
PA-04	Goulds Pumps, Inc.	Ashland	PA	1,747	2,413	4,160
PA-05	T.B.Wood's Sons Company	Chambersburg	PA	31,166	0	31,166
PA-06	Tyler Pipe- Ransom Industries Inc.	Macungie	PA	37,274	0	37,274
PA-07	Grinnell	Columbia	PA	126,997	0	126,997
PA-08	Tom Ondrejko Co.	Washington	PA	57	13	69
PA-09	Empire Steel Castings, Inc.	Reading	PA	63	4,105	4,168
PA-10	EAFCO, Inc.	Boyertown	PA	28,541	0	28,541
PA-11	WHEMCO Midland Foundry	Midland	PA	0	32,279	32,279
PA-12	Centec Roll Corporation	Bethlehem	PA	9,309	249	9,558
PA-13	Benton Foundry, Inc	Benton	PA	18,248	0	18,248
PA-14	United Foundry Company, Inc	Johnstown	PA	80	80	160
PA-15	Weatherly Casting & Machine Co.	Weatherly	PA	2,824	0	2,824
PA-16	Somerset Foundry & Machine	Somerset	PA	2,321	0	2,321
PA-17	Wyano Foundry	Wyano	PA	1,384	0	1,384
PA-18	Hazleton Pumps, Inc.	Hazelton	PA	601	324	925
PA-19	Delvest, Inc	West Chester	PA	0	216	216
PA-20	Urick Foundry	Erie	PA	33,026	0	33,026
PA-21	Victaulic Company of America	Easton	PA	49,244	0	49,244
PA-22	Victaulic Company of America	Alburtis	PA	39,687	0	39,687
PA-23	Ephrata Manufacturing Co.	Ephrata	PA	3,444	0	3,444
PA-24	Pennsylvania Steel Foundry & Machine	Hamburg	PA	0	8,147	8,147
PA-25	CMI- Quaker Alloy, Inc.	Myerstown	PA	0	5,187	5,187
PA-26	Investment Casting Corp.	Meadville	PA	0	6	6
PA-27	Damascus Steel Casting Co.	New Brighton	PA	0	1,500	1,500
PA-28	Muncy Foundry	Muncy	PA	2,814	3,582	6,396
PA-29	McConway & Torley Corporation	Kutztown	PA	0	28,017	28,017
PA-30	Duraloy Technologies, Inc.	Scottdale	PA	0	3,756	3,756
PA-31	Saxonburg Foundry Co.	Saxonburg	PA	660	0	660
PA-32	Hamburg Mfg., Inc.	Hamburg	PA	5,300	0	5,300
PA-33	Washington Mould Company	Washington	PA	1,165	0	1,165
PA-34	Donsco, Inc.	Wrightsville	PA	49,331	0	49,331
PA-35	Mt. Joy Foundry	Mt. Joy	PA	18,404	0	18,404
PA-36	Wrightsville Foundry - Building #8	Belleville	PA	18,421	0	18,421
PA-37	W.O. Hickok Mfg. Co.	Harrisburg	PA	328	0	328
PA-38	McConway & Torley Corporation	Pittsburgh	PA	0	20,041	20,041
PA-39	The Frog, Switch & Manufacturing Co.	Carlisle	PA	0	25,145	25,145
PA-40	Hodge Foundry	Greenville	PA	18,000	0	18,000
PA-41	Advanced Cast Products, Inc.	Meadville	PA	25,000	0	25,000
PA-42	Frontier Foundry, Inc.	Titusville	PA	0	34	34
PA-43	Penncast Corporation	Marietta	PA	0	3,341	3,341

ID	Name	City	State	Metal poured, tons per year Iron	Steel	Total
PA-44	The General Casting Co.	Shippensburg	PA	9,659	0	9,659
PA-45	Kennametal Castings	Bedford	PA	0	358	358
PA-46	EMI Company	Erie	PA	69,800	0	69,800
PA-47	Spring City Foundry Company	Spring City	PA	1,042	0	1,042
PA-48	CMI- Tech Cast, Inc.	Myerstown	PA	0	2,244	2,244
PA-49	Hempfield Foundry	Greensburg	PA	2,289	0	2,289
PA-50	Quality Investment Castings, Inc.	Blandon	PA	3	281	284
PA-51	Monaca Plant	Monaca	PA	76	1,824	1,900
PA-52	Nova Precision Casting Corp.	Auburn	PA	0	200	200
PA-53	Hale Pump - Foundry Division	Conshohocken	PA	700	0	700
PA-54	Harcast Co., Inc.	Chester	PA	0	87	87
RI-01	Seaboard Foundry Inc.	Johnston	RI	1,280	0	1,280
RI-02	Cumberland Foundry Co., Inc.	Cumberland	RI	925	0	925
RI-03	Fairmount Foundry Inc.	Woonsocket	RI	850	0	850
SC-01	Conbraco Industries, Inc.	Conway	SC	0	4,172	4,172
SC-02	Cast Products Co., Inc.	Westminster	SC	100	0	100
SC-03	Carolina Casting Corporation	Hardeeville	SC	66	265	332
SC-04	Pinebrook Foundry	Great Falls	SC	25	0	25
SC-05	Grede Foundries Inc. - Greenwood	Greenwood	SC	85,400	0	85,400
SC-06	Synehi Castings	Greenwood	SC	750	0	750
SC-07	US Filter/Wheelabrator Cast Products	Walterboro	SC	975	525	1,500
SC-08	Bahan Machine & Foundry	Taylors	SC	1,200	0	1,200
SD-01	Mereen Johnson Machine Co.	Webster	SD	3,975	0	3,975
TN-01	Wheland Foundry - No. 2 Foundry	Chattanooga	TN	200,000	0	200,000
TN-02	U.S. Pipe & Foundry Co., Inc.	Chattanooga	TN	49,656	0	49,656
TN-03	Tennessee Investment Casting Co.	Bristol	TN	8	400	408
TN-04	Lodge Manufacturing Co.	South Pittsburg	TN	18,637	0	18,637
TN-05	Camden Casting Center	Camden	TN	50,800	0	50,800
TN-06	Clinch River Casting, Inc.	Caryville	TN	850	0	850
TN-07	Accu-Cast	Chattanooga	TN	0	600	600
TN-08	Acheson Foundry & Machine	Chattanooga	TN	540	60	600
TN-09	Mueller Company	Chattanooga	TN	50,000	0	50,000
TN-10	Wheland Foundry - Middle Street	Chattanooga	TN	262,800	0	262,800
TN-11	Wheland Foundry - #1 Foundry	Chattanooga	TN	164,820	0	164,820
TN-12	Cleveland Foundry & Mfg. Co, Inc.	Cleveland	TN	844	0	844
TN-13	John Bouchard & Sons Foundry	Nashville	TN	4,403	0	4,403
TN-14	American Magotteaux Corporation	Pulaski	TN	57,323	16,378	73,701
TN-15	Eureka Foundry	Chattanooga	TN	5,670	0	5,670
TN-16	Clarksville Foundry, Inc.	Clarksville	TN	817	12	829
TN-17	Vestal Manufacturing Co.	Sweetwater	TN	14,104	0	14,104
TX-01	Manufactured Alloys, Inc.	Luling	TX	0	6	6
TX-02	National Foundry & Mfg. Inc.	Crane	TX	0	350	350
TX-03	Texaloy Foundry	Floresville	TX	1,345	0	1,345
TX-04	Dal-Air Investment Castings, Inc.	Point	TX	0	180	180
TX-05	Consolidated Castings Corp.	Hutchins	TX	0	1,640	1,640

ID	Name	City	State	Metal poured, tons per year Iron	Steel	Total
TX-06	American Spincast, Inc.	Belton	TX	0	5,390	5,390
TX-07	Alamo Iron Works Foundry	San Antonio	TX	2,125	0	2,125
TX-08	Texcast, Inc	Houston	TX	0	111	111
TX-09	Oil City Iron Works, Inc.	Corsicana	TX	14,640	0	14,640
TX-10	Greens Bayou Foundry, Inc.	Houston	TX	500	0	500
TX-11	Western Iron Works, Inc.	San Angelo	TX	10,000	0	10,000
TX-12	Taylor Foundry Company	Wichita Falls	TX	8,690	0	8,690
TX-13	Mabry Foundry Inc. of Beaumont	Beaumont	TX	18,000	0	18,000
TX-14	Texas Foundries	Lufikin	TX	123,286	0	123,286
TX-15	Goulds Pumps - Turbine Division	Slaton	TX	4,866	0	4,866
TX-16	Delta Centrifugal Corporation	Temple	TX	0	2,303	2,303
TX-17	Victoria Precision Alloys, Inc.	Victoria	TX	140	220	360
TX-18	Lufkin Industries, Inc	Lufkin	TX	75,000	0	75,000
TX-19	Hensley Industries, Inc.	Dallas, Dallas County	TX	0	34,895	34,895
TX-20	Harrisburg Woolley Tool Co.	Odessa	TX	2,539	0	2,539
TX-21	Penatek Industries, Inc.	Odessa	TX	2,040	1,005	3,045
TX-22	Sure Cast, Inc.	Burnet	TX	6	676	682
TX-23	Centrifugal Castings, Inc.	Temple	TX	0	1,975	1,975
TX-24	Gulf Star Foundry	Corpus Christi	TX	12	0	12
TX-25	A A Foundries, Inc.	San Antonio	TX	193	1	194
TX-26	Texas Precision Metalcraft, Inc.	Sugar Land	TX	0	250	250
TX-27	Tyler Pipe Company	Tyler	TX	219,308	0	219,308
TX-28	Southwest Steel Casting Company	Longview	TX	0	17,170	17,170
TX-29	Gainesville Foundry, Inc.	Gainesville	TX	5,038	0	5,038
TX-30	Texas Steel Company	Fort Worth	TX	0	33,341	33,341
TX-31	Martin Foundry- Martin Sprocket & Gear	Dallas	TX	8,338	0	8,338
TX-32	Smith Steel Casting Co., Inc.	Marshall	TX	0	1,170	1,170
TX-33	Henderson Manufacturing Co., Inc.	Pittsburg	TX	0	2,100	2,100
UT-01	Star Foundry & Machine	Salt Lake City	UT	234	1,248	1,482
UT-02	Maca Supply Company	Springville	UT	0	558	558
UT-03	Torry Metals Corp.	Spanish Fork	UT	20	33	53
UT-04	Pacific States Cast Iron Pipe	Provo	UT	103,440	0	103,440
UT-05	GSC Foundries, Inc., Steel Division	Ogden	UT	0	270	270
VA-01	O.K. Foundary Co., Inc.	Richmond	VA	1,289	0	1,289
VA-02	Emporia Foundry, Inc.	Emporia	VA	14,508	0	14,508
VA-03	Walker Machine & Foundry Corp	Roanoke	VA	7,929	0	7,929
VA-04	Intermet Corporation	Radford	VA	98,600	0	98,600
VA-05	Intermet Corporation	Radford	VA	135,600	0	135,600
VA-06	Graham-White Manufacturing Co	Salem	VA	2,921	0	2,921
VA-07	Newport News Shipbuilding and Dry	Newport News	VA	0	517	517
VA-08	Intermet Corporation	Lynchburg	VA	148,213	0	148,213
VA-09	Griffin Pipe Products Co.	Lynchburg	VA	137,600	0	137,600
VT-01	Vermont Castings - Foundry Division	Randolph	VT	20,704	0	20,704

ID	Name	City	State	Metal poured, tons per year Iron	Steel	Total
VT-02	Brown Foundry	Swanton	VT	1,780	0	1,780
VT-03	Vestshell Vermont, Inc.	St. Albans	VT	0	163	163
WA-01	Vancouver Foundry Co (DBA Varicast)	Vancouver	WA	0	5,137	5,137
WA-02	Mackenzie Specialty Castings	Arlington	WA	436	498	934
WA-03	Western Steel Casting Co.	Seattle	WA	90	2,910	3,000
WA-04	Northwest Castings	Seattle	WA	0	2,643	2,643
WA-05	D & L Foundry, Inc.	Moses Lake	WA	12,288	0	12,288
WA-06	N.E.W. Castings Inc.	Spokane	WA	809	0	809
WA-07	Dyko Foundry	Spokane	WA	938	902	1,840
WA-08	Sather Mfg. Co.	Everett	WA	2,643	0	2,643
WA-09	Meltec-Division of Young Corp	Seattle	WA	0	3,000	3,000
WA-10	Spokane Steel Foundry	Spokane	WA	7,032	3,014	10,046
WA-11	Spokane Precision Castings	Spokane	WA	0	332	332
WA-12	Quali-Cast Foundry, Inc.	Chehalis	WA	0	1,954	1,954
WA-13	Atlas Foundry & Machine Co	Tacoma	WA	0	10,632	10,632
WA-14	SeaCast/ Eagle, Inc.	Marysville	WA	0	832	832
WI-01	Waupaca Foundry, Inc. - Plant 1	Waupaca	WI	206,916	0	206,916
WI-02	Tomahawk Foundry Inc.	Rice Lake	WI	740	0	740
WI-03	Cast Tools, Inc.	Racine	WI	0	154	154
WI-04	Shelmet Precision Casting Co.	Wild Rose	WI	0	276	276
WI-05	Pelton Casteel, Inc.	Milwaukee	WI	0	15,168	15,168
WI-06	Austin Gray Iron Foundry	Sheboygan	WI	3,504	0	3,504
WI-07	Northern Precision Casting Co., Inc.	Lake Geneva	WI	0	1,600	1,600
WI-08	Belgium Foundry	Belgium	WI	3,889	0	3,889
WI-09	Washburn Iron Works, Inc.	Washburn	WI	3,001	0	3,001
WI-10	Willman Industries, Inc.	Cedar Grove	WI	10,469	0	10,469
WI-11	Modern Plate Co. Inc. of WI	Racine	WI	39	0	39
WI-12	Racine Steel Castings	Racine	WI	0	13,732	13,732
WI-13	Roloff Manufacturing Corporation	Kaukauna	WI	4,842	0	4,842
WI-14	Baker Manufacturing Co.	Evansville	WI	8,597	0	8,597
WI-15	Kirsch Foundry Inc.	Beaver Dam	WI	9,898	0	9,898
WI-16	Prime Cast, Inc.	Beloit	WI	6,299	2,870	9,169
WI-17	Castalloy Corporation	Waukesha	WI	0	3,753	3,753
WI-18	Iroquois Foundry Co.	Browntown	WI	20,439	0	20,439
WI-19	Vilter Manufacturing Corporation	Milwaukee	WI	820	100	920
WI-20	Bay Engineered Castings	DePere	WI	12,949	0	12,949
WI-21	Investment Casting Plant	Fond du Lac	WI	0	1,310	1,310
WI-22	Torrance Casting, Inc.	La Crosse	WI	5,380	0	5,380
WI-23	Aelco Foundries	Milwaukee	WI	0	4,322	4,322
WI-24	Briggs & Stratton	West Allis	WI	101,000	0	101,000
WI-25	The Falk Corporation	Milwaukee	WI	0	23,266	23,266
WI-26	Grede Foundries Inc.	Milwaukee	WI	2,009	42,113	44,122
WI-27	Kramer International, Inc.	Milwaukee	WI	218	372	590
WI-28	Brillion Iron Works	Brillion	WI	251,430	0	251,430
WI-29	Maynard Steel Casting Co.	Milwaukee	WI	0	23,560	23,560

				Metal poured, tons per year		
ID	Name	City	State	Iron	Steel	Total
WI-30	Milwaukee Malleable & Grey Iron Works	Milwaukee	WI	3,663	0	3,663
WI-31	OMC Milwaukee	Milwaukee	WI	0	425	425
WI-32	Stainless Foundry & Engineering	Milwaukee	WI	6	5,846	5,852
WI-33	Badger Iron Works, Inc.	Menomonie	WI	3,963	0	3,963
WI-34	Northern Stainless Steel Corp.	Pewaukee	WI	0	490	490
WI-35	Grede Foundries, Inc.	Reedsburg	WI	273,987	0	273,987
WI-36	Richland Center Foundry Co.	Richland Center	WI	19,529	0	19,529
WI-37	Wisconsin Investcast	Watertown	WI	12	500	512
WI-38	Navistar International, Transportation Co	Waukesha	WI	73,811	0	73,811
WI-39	Wisconsin Centrifugal	Waukesha	WI	0	12,494	12,494
WI-40	J&L Fiber Services	Waukesha	WI	3,669	5,503	9,172
WI-41	Waunakee Alloy Casting Corp.	Waunakee	WI	0	508	508
WI-42	Waupaca Foundry Plant 2/3	Waupaca	WI	615,353	0	615,353
WI-43	Waupaca Foundry, Inc. - Plant 4	Marinette	WI	325,133	0	325,133
WI-44	Liberty Foundry	Wauwatosa	WI	32,978	0	32,978
WI-45	Northern Steel Castings, Inc.	Wisconsin Rapids	WI	0	4,100	4,100
WI-46	Precision Metalsmiths, Inc.	Markesan	WI	221	883	1,104
WI-47	Berlin Foundry Corporation	Berlin	WI	43,939	0	43,939
WI-48	Spuncast Inc.	Watertown	WI	51	5,048	5,099
WI-49	Neenah Foundry Company Plant #2	Neenah	WI	137,586	0	137,586
WI-50	Neenah Foundry Company Plant #3	Neenah	WI	118,343	0	118,343
WI-52	Waukesha Foundry Inc.	Waukesha	WI	0	807	807
WI-53	Mid-City Foundry Co., Inc.	Milwaukee	WI	6,348	0	6,348
WI-54	Mid-City Foundry Co., Inc.	Grafton	WI	2,258	0	2,258
WI-55	Winsert, Inc.	Marinette	WI	0	509	509
WI-56	Craft Cast	Jackson	WI	0	345	345
WV-01	Kelly Foundry & Machine Co., Inc.	Elkins	WV	1,632	0	1,632
WV-02	Centre Foundry & Machine Co	Wheeling	WV	20,364	0	20,364
WV-03	Sturm Inc.	Barboursville	WV	0	4,000	4,000
		TOTALS		**15,595,229**	**1,904,131**	**17,499,360**

APPENDIX B

ESTIMATED HAP EMISSIONS FROM MOLD AND CORE MAKING OPERATIONS

B.1 ESTIMATED HAP EMISSIONS FROM MOLD AND CORE MAKING OPERATIONS

The EPA made emission estimates for mold- and core-making operations by determining the HAP content of the binder systems and estimating the fractions of HAP that were evaporated during mixing and curing. Actual chemical usage for foundries plus information on Material Safety Data Sheets was used to determine HAP content whenever this information was available. When no data were available, usage was estimated from the amount of sand reported used for each system, the proportion of chemical to sand (reported or estimated), and typical values for HAP constituents of the binder components. Table B-1 gives HAP content in the components, and Table B-2 gives typical proportions of the constituents; information in these tables was furnished by the chemical supplier industry. Table B-3 shows the overall HAP content of the systems based on information from Tables B-1 and B-2 and also shows typical proportions of chemicals to sand, which were determined from information reported by foundries.

Because no actual emission data were available, estimates of the fraction of HAP emitted were made using information provided by the AFS, which consists of values for the fractions of HAP that react during the mold- and core-making process, evaporate during the process, and remain in the mold or core after it is cured but before it is exposed to molten metal. These values are given in Table B-4.

In determining emission factors, some of the values reported in Table B-4 were modified based either on more definitive information or on the premise that a more conservative estimate was appropriate. First, the fraction of phenol reacted in the phenolic Novolac system was assumed to be 35, not 95, percent based on information from an industry supplier. Second, the values given for nonreacting constituents (naphthalene, cumene, xylene, and biphenyl) of the phenolic urethane no-bake and cold-box systems were recalculated. The values given by the AFS were weight loss data determined from a study made by supplier companies for the Ohio Cast Metals Association and the AFS (RMT, 1998). The values assume that the fraction of weight lost by all chemicals is the same. In fact, the formaldehyde, phenol, and MDI in these systems react almost completely and cannot evaporate. The proportions of the nonreacting constituents that evaporate must therefore be greater that the overall weight loss. Taking this fact into account and using the composition information in Tables B-1 and B-2, the EPA estimates that approximately 9 percent instead of 3.25 percent of the nonreacting chemicals in the phenolic urethane cold-box system and 16 percent instead of 5.85 percent of those chemicals in the phenolic urethane no-bake system are emitted.

Finally, because the basis for estimates for the other systems is not given, EPA made the conservative assumption that all of the chemicals that do not react are emitted, which includes the fractions reported emitted plus those reported remaining in the mold or core. Taking into account the above considerations, Table B-5 shows the fractions of chemicals that the EPA assumes are emitted.

To summarize all of the above information, Table B-6 is a list of emission factors derived from the information presented in Tables B-1 through B-5. These factors were used to estimate average or nominal mold- and core-making emissions from foundries.

The EPA also made worst-case emission estimates based on the highest reported HAP content of binder systems and the highest reported chemical-to-sand ratios, in order to identify foundries that are obviously not major sources of HAP based on mold- and core-making operations alone. Table B-7 gives estimates of HAP emissions per 50,000 tons of sand processed; this level of operation results in HAP emissions on the order of 10 and 25 tons based on individual and total HAP, respectively, for several systems. This basis of estimation also allows estimates to be made easily based on tons of metal poured, assuming that the sand-to-metal metal ratio is known. Table B-8 gives data needed to develop Table B-7, and tables B-9 and B-10 show intermediate determinations in terms of emissions per 100 pounds of chemicals and tons of sand, respectively.

Tables B-1 through B-10 use nomenclature for binder systems that is used by the industry as reported in an AFS guidance document for estimating emissions from these systems. The nomenclature used in EPA's 1998 industry survey is somewhat different. To avoid confusion, Table B-11, which gives a comparison between the two systems, is included in this discussion.

TABLE B-1. HAP CONTENT OF SAND BINDER SYSTEM COMPONENTS[1,2]

Binder system	Component	HAP present	Amount of HAP in component, percent	
			Range	Typical
Acrylic/epoxy/SO_2	Resin	Cumene	5. minimum[3]	5.
Furan hot box	Resin	Formaldehyde	2. - 5.	3.
Furan nobake	Resin	Phenol	0. - 4.	0.
		Formaldehyde	0. - 1.	0.1
		Methanol	2. - 4.	3.
	Catalyst	Methanol	20. - 30.	27.
Furan/SO_2	Resin	Formaldehyde	1. - 4.	2.
		Methanol	1. - 3.	2.
	Oxidizer	Dimethyl phthalate	40. - 50.	45.
		Methyl ethyl ketone	0. 2.	2.
Furan warm box	Resin	Formaldehyde	0. - 1.	0.5
	Catalyst	Methanol	45. - 55.	50.
Phenolic baking	Resin	Phenol	3. - 14.	8.
		Formaldehyde	0. - 2.	1.
Phenolic ester nobake and cold box	Resin	Phenol	2. - 8.	4.
		Formaldehyde	0. - 2.	0.5
Phenolic hot box	Resin	Phenol	2. - 8.	5.
		Formaldehyde	1. - 4.	2.
Phenolic nobake	Resin	Phenol	8. - 14.	12.
		Formaldehyde	0. - 2.	0.5
		Methanol	2. - 4.	3.
	Catalyst	Methanol	20. - 30.	27.
Phenolic Novolac liquid	Resin	Phenol	1. - 4.	2.
		Formaldehyde	0. - 3.	0.5
		Methanol	0. - 15.	5.
Phenolic Novolac flake	Resin	Phenol	1.5 - 8.0[4]	5.5[4]
		Formaldehyde	0. - 0.2[4]	0.[4]
		Methanol	0. 10.4[4]	0.[4]

TABLE B-1. HAP CONTENT OF SAND BINDER SYSTEM COMPONENTS [1,2]

Binder system	Component	HAP present	Amount of HAP in component, percent	
			Range	Typical
Phenolic urethane nobake and cold box	Resin	Phenol	3. - 8.	6.
		Formaldehyde	0. - 1.	0.1
		Naphthalene	0. - 2.	1.
		Cumene	0. 2.	0.5
		Xylene	0. - 1.	0.1
	Coreactant	Naphthalene	0. - 3.	1.
		Cumene	0. 1.	0.1
		Xylene	0. - 1.	0.1
Urea formaldehyde	Resin	Formaldehyde	1. - 4.	1.

1 Source: Stone, 1999, and Jonathan A. Stone, Delta Resins and Refractories, Delta-HA (private communication to J. H. Maysilles, U.S. EPA., November 15, 1999) except where noted.

2 Only HAP that could be emitted because of incomplete reaction or nonreaction are listed.

3 Information supplied by Joe Fox, Ashland Chemical, Inc. Private communication to J. H. Maysilles, U.S. EPA, August 16, 2000.

4 Information is based on Material Safety Data Sheets from foundries that use this system.

TABLE B-2. PROPORTION OF COMPONENTS IN BINDER SYSTEMS[1]

Binder system	Component	Proportion in system, percent	
		Range	Typical
Furan nobake	Resin	55 - 80	70
	Catalyst	20 - 45	30
Furan/SO_2	Resin	50 - 55	55
	Oxidizer	45 - 50	45
Furan warmbox	Resin	75 - 85	80
	Catalyst	15 - 25	20
Phenolic nobake	Resin	55 - 75	68
	Catalyst	25 - 45	32
Phenolic urethane nobake and coldbox	Resin	50 - 60	55
	Coreactant	40 - 50	45

1 Information supplied by Jonathan A. Stone, Delta Resins and Refractories, Delta-HA.. Private communication to J. H. Maysilles, U.S. EPA.

TABLE B-3. AVERAGE CHEMICALS/SAND RATIOS AND TYPICAL CHEMICAL CONTENT IN BINDER SYSTEMS

Binder system	Pounds chemical per ton of sand [1]	Chemical content of system, percent. [2]										
		Phenol	Formal-dehyde	Naph thalene	Cumene	Xylene	Biphenyl	Methanol	Glycol ethers	Dimethyl phthalate	Methyl ethyl ketone	TEA
Acrylic/Epoxy/SO_2	34.				5.							
Furan hot box	40.		3.									
Furan nobake	24.	0.	0.07					10.2				
Furan/SO_2	30.		1.1					1.1		20.2	0.9	
Furan warm box	32.		0.4					10.				
Phenolic baking	30. [3]	8.	1.									
Phenolic ester nobake	33.	4.	0.5									
Phenolic ester cold box	32.	4.	0.5					0. [4]	0. [4]			
Phenolic hot box	30. [3]	5.	2.									
Phenolic nobake	27.	8.2	0.34					10.7				
Phenolic-Novolac flake	50.	5.5	0.					0.				
Phenolic-Novolac liquid	50.	2.	0.5					5.				
Phenolic urethane nobake	25.	3.3	0.055	1.	0.32	0.1						
Phenolic urethane cold box - resin plus coreactant	30.	3.3	0.055	1.	0.32	0.1						
Phenolic urethane cold box - gas	3.						0. [4]					100. [5]
Urea formaldehyde	30. [3]		1.									

1 Source: EPA, 1998.
2 MDI is not included because essentially all MDI is reacted and therefore not available for evaporation.
3 Values are based on nominal values for other systems; not enough information is available for these systems to establish values.
4 Not mentioned in the source of information for table C-1; assumed to be zero.
5 Assumes that the catalyst gas is triethylamine; dimethylethylamine, which is not a HAP, is used in some operations.

TABLE B-4. HAP EMITED FROM CHEMICAL BINDER SYSTEMS USED FOR SAND CORES AND MOLDS (AFS, 1998)

Binder system	HAP and component in which it is used	Percent reacted	Percent emitted during core and mold making[1]	Percent remaining in mold or core
Furan hotbox	Formaldehyde, resin	95	5	0
Furan nobake	Phenol, resin	98+	0	2
	Formaldehyde, resin	98	2	0
	Methanol, resin	0	50	50
	Methanol, catalyst	0	50	50
Furan/SO_2	Formaldehyde, resin	98	2	0
	Methanol, resin	0	50	50
	Dimethyl phthalate, oxidizer	0	50	50
	Methyl ethyl ketone, oxidizer	0	50	50
Furan warmbox	Formaldehyde, resin	95	5	0
	Methanol, catalyst	0	100	0
Phenolic baking	Phenol, Part I	95	0	5
	Formaldehyde, Part I	95	5	0
Phenolic hotbox	Formaldehyde, resin	95	5	0
	Phenol, resin	95	0	5
Urea formaldehyde	Formaldehyde, Part I	98	2	0
Phenolic Novolac liquid (Shell)	Phenol, Part I	95	0	5
	Formaldehyde, Part I	95	5	0
	Methanol, Part I	0	100	0
Phenolic Novolac flake (Shell)	Phenol, resin	95	0	5
Phenolic nobake (Acid catalyzed)	Phenol, resin	98	0	2
	Formaldehyde, resin	98	2	0
	Methanol, resin	0	50	50
	Methanol, acid	0	50	50

TABLE B-4. HAP EMITED FROM CHEMICAL BINDER SYSTEMS USED FOR SAND CORES AND MOLDS (AFS, 1998)

Binder system	HAP and component in which it is used	Percent reacted	Percent emitted during core and mold making[1]	Percent remaining in mold or core
Phenolic urethane nobake	Formaldehyde, Part I	98	2	0
	Phenol, Part I	98	0	2
	Xylene, Part I	0	5.85	94.15
	Cumene, Part I	0	5.85	94.15
	Naphthalene, Part I	0	5.85	94.15
	Methylene phenylene isocyanate, Part II	99.99	0	0.01
	Xylene, Part II (catalyst)	0	5.85	94.15
	Cumene, Part II (catalyst)	0	5.85	94.15
	Naphthalene, Part II	0	5.85	94.15
Phenolic urethane coldbox	Formaldehyde, Part I	98	2	0
	Phenol, Part I	98	0	2
	Xylene, Part I	0	3.25	96.75
	Cumene, Part I	0	3.25	96.75
	Naphthalene , Part I	0	3.25	96.75
	Methylene phenylene isocyanate, Part II	99.99	0	0.01
	Naphthalene, Part II	0	3.25	96.75
	Xylene, Part II	0	3.25	96.75
	Biphenyl, Part II	0	3.25	96.75
Alkyd oil	Lead, resin	0	0	100
	Cobalt, resin	0	0	100
	Methylene phenylene isocyanate, coreactant	99.99	< 0.01	0.01
Phenolic ester nobake	Formaldehyde, resin	98	2	0
	Phenol, resin	98	0	2

TABLE B-4. HAP EMITED FROM CHEMICAL BINDER SYSTEMS USED FOR SAND CORES AND MOLDS (AFS, 1998)

Binder system	HAP and component in which it is used	Percent reacted	Percent emitted during core and mold making[1]	Percent remaining in mold or core
Phenolic ester cold box	Formaldehyde, resin	98	2	0
	Phenol, resin	98	0	2
	Methanol, coreactant	0	50	50
Acrylic/epoxy/SO_2	Cumene, Part I	0	1.5	98.5

[1] Percent emitted up to the time that metal is poured.

TABLE B-5. FACTORS USED IN MOLD AND CORE MAKING EMISSIONS ESTIMATES; PERCENTAGES OF CHEMICALS EMITTED[1,2]

Binder system	Percent of compound emitted				
	Phenol	Formaldehyde	Naphthalene	Cumene	Xylene
Acrylic/Epoxy/SO_2				100	
Furan hot box		5			
Furan nobake	2	2			
Furan/SO_2		2			
Furan warm box		5			
Phenolic baking	5	5			
Phenolic ester nobake	2	2			
Phenolic ester cold box	2	2			
Phenolic hot box	5	5			
Phenolic nobake	2	2			
Phenolic-Novolac flake or liquid	65[3]	5			
Phenolic urethane nobake	2	2	16[4]	16[4]	16[4]
Phenolic urethane cold box - resin plus coreactant	2	2	9[4]	9[4]	9[4]
Urea formaldehyde		2			

[1] Source: AFS, 1998, except where noted otherwise.
[2] 100 percent of all other compounds listed in table C-4 is assumed to be emitted.
[3] Industry supplier estimate: Kenneth C. Pyles, Acme Resin Corp. Private communication to J. H. Maysilles, U.S. EPA, February 14, 2000.
[4] EPA estimates.

TABLE B-6. EMISSION FACTORS BASED ON TYPICAL CHEMICAL CONTENT OF SYSTEM

Binder system	Pounds emitted per 100 lb. of binder chemicals.										
	Phenol	Formal-dehyde	Naphthalene	Cumene	Xylene	Biphenyl	Methanol	Glycol ethers	Dimethyl phthalate	Methyl ethyl ketone	Triethyl amine
Acrylic/Epoxy/SO_2				5.0							
Furan hot box		0.15									
Furan nobake	0.	0.0014					10.2				
Furan/SO_2		0.022					1.1		20.2	0.9	
Furan warm box		0.02					10.				
Phenolic baking	0.4	0.05									
Phenolic ester nobake	0.08	0.01									
Phenolic ester cold box	0.08	0.01					0.	0.			
Phenolic hot box	0.25	0.1									
Phenolic nobake	0.164	0.0068					10.7				
Phenolic-Novolac flake	3.6	0.					0.				
Phenolic-Novolac liquid	1.3	0.025					5.				
Phenolic urethane nobake	0.066	0.0011	0.16	0.051	0.016						
Phenolic urethane cold box - resin plus coreactant	0.066	0.0011	0.09	0.029	0.009						
Phenolic urethane cold box - gas						0.					100.
Urea formaldehyde		0.02									

TABLE B-7. ESTIMATES FOR EMISSIONS BASED ON HIGH ORGANIC COMPOUND CONTENT OF BINDER COMPONENTS, HIGH BINDER/SAND RATIOS

Binder system	Tons emitted per 50,000 tons of sand processed.									
	Phenol	Formal-dehyde	Naph-thalene	Cumene	Xylene	Methyl alcohol	Dimethyl phthalate	Methyl ethyl ketone	Triethyl amine	Total HAP
Acrylic/Epoxy/SO_2				150.						150.
Furan hot box		4.5								4.5
Furan nobake - with methyl alcohol	0.65	0.16				160.				161.
Furan nobake - no methyl alcohol	0.65	0.16				0.				0.81
Furan/SO_2		0.30				12.5	190.	7.5		210.
Furan warm box - with methyl alcohol		0.40				145.				145.
Furan warm box - no methyl alcohol		0.40				0.				0.40
Phenolic baking	10.5	1.50								12.0
Phenolic ester nobake	2.75	0.70								3.45
Phenolic ester cold box	2.25	0.55								2.80
Phenolic hot box	6.0	3.0								9.0
Phenolic nobake - with methyl alcohol	1.55	0.22				160.				162.
Phenolic nobake - no methyl alcohol	1.55	0.22				0.				1.77
Phenolic-Novolac flake - with methyl alcohol	155.	0.3				312.				467.
Phenolic-Novolac flake - no methyl alcohol	155.	0.3				0.				155.
Phenolic-Novolac liquid	78.	4.5				450.				533.
Phenolic urethane nobake	1.70	0.21	7.0	4.5	2.75					16.2
Phenolic urethane cold box	1.45	0.18	3.25	2.15	1.35				3.0[1]	11.4
Urea formaldehyde		1.2								1.2

[1] Assumes 99 percent control of gas.

TABLE B-8. HIGH CHEMICAL/SAND RATIOS AND HIGH CHEMICAL CONTENT OF BINDER SYSTEMS

Binder system	Pounds chemical per ton of sand	Chemical content of system, percent.										
		Phenol	Formal-dehyde	Naphthalene	Cumene	Xylene	Biphenyl	Methyl alcohol	Glycol ethers	Dimethyl phthalate	Methyl ethyl ketone	TEA
Acrylic/Epoxy/SO_2	60.				5.							
Furan hot box	70.		5.									
Furan nobake	40.	3.2	0.8					15.7				
Furan/SO_2	30.		2.2					1.65		25.	1.0	
Furan warm box	42.		0.75					13.8				
Phenolic baking	60. [1]	14.	2.									
Phenolic ester nobake	70.	8.	2.									
Phenolic ester cold box	56.	8.	2.									
Phenolic hot box	60. [1]	8.	4.									
Phenolic nobake	40.	7.7	1.1					15.7				
Phenolic-Novolac flake	120.	8.0	0.2					10.4				
Phenolic-Novolac liquid	120.	4.0	3.0					15.				
Phenolic urethane nobake	70.	4.8	0.6	2.4	1.6	1.						
Phenolic urethane cold box - resin plus coreactant	60.	4.8	0.6	2.4	1.6	1.						
Phenolic urethane cold box - gas	12.											100.
Urea formaldehyde	60. [1]		4.									

[1] Values are based on nominal values for other systems; not enough information is available for these systems to establish values.

TABLE B-9. EMISSION FACTORS BASED ON HIGH CHEMICAL CONTENT OF SYSTEM

Binder system	Pounds emitted per 100 lb. of binder chemicals.										
	Phenol	Formal-dehyde	Naphthalene	Cumene	Xylene	Biphenyl	Methyl alcohol	Glycol ethers	Dimethyl phthalate	Methyl ethyl ketone	Triethyl amine
Acrylic/Epoxy/SO_2				5.0							
Furan hot box		0.25									
Furan nobake	0.064	0.016					15.7				
Furan/SO_2		0.044					1.65		25.	1.0	
Furan warm box		0.038					13.8				
Phenolic baking	0.7	0.1									
Phenolic ester nobake	0.16	0.04									
Phenolic ester cold box	0.16	0.04									
Phenolic hot box	0.4	0.2									
Phenolic nobake	0.54	0.022					15.7				
Phenolic-Novolac flake	5.2	0.01					10.4				
Phenolic-Novolac liquid	2.6	0.15					15.				
Phenolic urethane nobake	0.096	0.012	0.38	0.26	0.16						
Phenolic urethane cold box - resin plus coreactant	0.096	0.012	0.22	0.14	0.09						
Phenolic urethane cold box - gas											100.
Urea formaldehyde		0.08									

TABLE B-10. EMISSION FACTORS BASED ON HIGH CHEMICAL/SAND RATIOS AND CHEMICAL CONTENT IN SYSTEM

Binder system	Pounds emitted per ton of sand processed.										
	Phenol	Formal-dehyde	Naphthalene	Cumene	Xylene	Biphenyl	Methyl alcohol	Glycol ethers	Dimethyl phthalate	Methyl ethyl ketone	Triethyl amine
Acrylic/Epoxy/SO_2				3.0							
Furan hot box		0.18									
Furan nobake	0.026	0.0064					6.3				
Furan/SO_2		0.013					0.50		7.5	0.30	
Furan warm box		0.016					5.8				
Phenolic baking	0.42	0.06									
Phenolic ester nobake	0.11	0.028									
Phenolic ester cold box	0.090	0.022									
Phenolic hot box	0.24	0.12									
Phenolic nobake	0.062	0.0088					6.3				
Phenolic-Novolac flake	6.2	0.012					12.5				
Phenolic-Novolac liquid	3.12	0.18					18.				
Phenolic urethane nobake	0.067	0.0084	0.27	0.18	0.11						
Phenolic urethane cold box - resin plus coreactant	0.058	0.0072	0.13	0.086	0.054						
Phenolic urethane cold box - gas											0.12[1]
Urea formaldehyde		0.048									

[1] Assumes 99 percent control.

TABLE B-11. COMPARISON OF NOMENCLATURE FOR CHEMICAL BINDER SYSTEM

Identification used in MACT Standards Development Information Request [1]	Identification used in AFS-CISA Form R reporting guidance document [2]
Thermosetting systems	
Shell	Phenolic Novolac flake Phenolic Novolac liquid
Hot box	Furan hotbox Phenolic hotbox
Warm box	Furan warmbox
Core oil	(Not identified)
Self-setting systems	
Furan	Furan nobake
Phenolic acid cured	Phenolic nobake - acid catalyzed
Phenolic ester cured	Phenolic ester nobake
Alkyd urethane	Alkyd oil
Phenolic urethane	Phenolic urethane nobake
Gas-cured systems	
Free radical-SO_2	(Not identified)
Epoxy-SO_2	Acrylic/Epoxy/SO_2
Furan-SO_2	Furan/SO_2
Phenolic urethane-amine	Phenolic urethane coldbox
Ester cured phenolic	Phenolic ester coldbox

[1] Questionnaire submitted by EPA to iron foundries in February 1998.
[2] Form R Reporting of Binder Chemicals Used in Foundries, Second Edition, American Foundrymen's Society, Inc. and Casting Industry Suppliers Association, 1998.

B.2 REFERENCES

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APPENDIX C

DEVELOPMENT OF EMISSION FACTORS FOR FOUNDRY PROCESSES

C.1 INTRODUCTION

This appendix details the evaluation of emissions test data and other information related to the development of emission factors used in estimating baseline emissions and emissions reductions effected by the regulatory alternatives.

The hierarchy used in evaluating emissions data assigned top priority to recent emissions source test reports that directly measured HAP emissions using EPA standard sampling and analytical methods or similar methods with the appropriate quality assurance indicators. The next priority was given to source test data reported in the literature or provided in response to EPA's MACT Standards Development Information Request (MSDIR) that measure only indicators of HAP emissions (i.e., particulate matter [PM]), and to HAP emissions test data that are more than 10 years old, or do not completely document the specific methods used and/or the results of quality assurance test samples. The last priority was given to baghouse catch data or other information that is an indirect assessment of emissions.

For the most part, this appendix presents average emissions data for each source test. A complete compendium of emissions data for melting furnaces and pouring/cooling/shakeout lines, including the results of individual runs, is given in Appendices D through G of this document.

C.1 SUMMARY OF RECENT FOUNDRY HAP EMISSION SOURCE TESTS

Four recent source tests directly measured HAP emissions from foundry operations and have complete documentation. In April and May of 1997, the stack test team from the Casting Emission Reduction Program (CERP) performed emission source tests at two green sand iron foundries in Mexico. The resulting data are summarized in a single test report. In September of 1997, the EPA performed emission source tests at two green sand iron foundries in the United States. Brief summaries of these source tests and the resulting emissions data are presented in the following sections.

C.1.1 CERP Source Tests

The CERP source tests were conducted at two automotive iron foundries operated in Mexico. The studies primarily investigated HAP emissions from pouring, cooling, and shakeout (PCS), although some emissions data were collected for induction furnace melting and core making. The CERP source test reported recommended emission factors for PCS based in terms of pounds of analyte per ton metal poured, and it primarily considered emissions from the casting of engine blocks. An independent review of the data, including emissions data for casting bearing caps and manifolds. The emission factors developed from EPA's analysis were essentially identical to those given in the CERP source test report. The recommended emission factors for PCS operations are provided in Table C-1. Note that the metal HAP emissions are less than the principal organic HAP emissions by a factor of 25 or more.

TABLE C-1. HAP EMISSION FACTORS FOR PCS OPERATIONS; CERP STUDY

HAP Compound	Emission factor (lb HAP per ton of metal poured)			
	Pouring	Cooling	Shakeout	Total PCS
Organic HAP				
Acetaldehyde	2.94×10^{-4}	3.20×10^{-3}	5.78×10^{-2}	6.13×10^{-2}
Benzene	2.19×10^{-3}	3.49×10^{-2}	2.68×10^{-2}	6.39×10^{-2}
Cresols (total)	1.65×10^{-6}	9.27×10^{-4}	1.46×10^{-2}	1.54×10^{-2}
Ethylbenzene	1.01×10^{-4}	1.87×10^{-3}	2.81×10^{-3}	4.88×10^{-3}
Formaldehyde	1.38×10^{-4}	1.73×10^{-3}	2.57×10^{-2}	2.76×10^{-2}
POM (total)	3.56×10^{-4}	4.64×10^{-3}	2.21×10^{-2}	2.71×10^{-2}
[Naphthalene]	1.81×10^{-4}	2.41×10^{-3}	8.37×10^{-3}	1.10×10^{-2}
Propanal	ND [1]	3.71×10^{-5}	5.70×10^{-3}	5.74×10^{-3}
Styrene	5.31×10^{-5}	4.35×10^{-4}	4.81×10^{-3}	5.30×10^{-3}
Toluene	1.05×10^{-3}	1.89×10^{-2}	2.21×10^{-2}	4.21×10^{-2}
Xylenes (total)	6.12×10^{-4}	1.14×10^{-2}	1.78×10^{-2}	2.99×10^{-2}
Metal HAP				
Cadmium	4.55×10^{-6}	2.03×10^{-5}	1.67×10^{-5}	4.16×10^{-5}
Chromium	4.85×10^{-5}	2.31×10^{-4}	1.71×10^{-4}	4.51×10^{-4}
Lead	1.79×10^{-4}	2.22×10^{-4}	7.29×10^{-5}	4.74×10^{-4}
Manganese	8.37×10^{-4}	5.21×10^{-4}	3.39×10^{-4}	1.70×10^{-3}

[1] ND - Not detected.

Table C-2 summarizes the emissions data for the induction melting furnace.

TABLE C-2. HAP EMISSION FACTORS FOR EIF; CERP STUDY

HAP compound	Emission factor, lb/ton metal melted
Cadmium	0.000102
Chromium	0.000074
Lead	0.00558
Manganese	0.014
Nickel	0.000897

The measured emissions from core making were small, generally several orders of magnitude less than PCS emissions when accounting for the amount of core sand used per ton of metal poured. However, the CERP report classified the capture efficiency of the exhaust system for the core-making machines as "very poor." Additionally, emissions from core storage were not measured, and these emissions may significantly contribute to the overall emissions of the core-making operations, based on the total VOC emission measurements conducted in the RMT study. Upon request from EPA, CERP provided data regarding the relative HAP composition VOC emissions from the core storage area. These data, which are provided in Table C-3, indicate that approximately 25 percent of the VOC emissions from core storage are HAP.

TABLE C-3. HAP CONTENT OF CORE ROOM STORAGE EXHAUST VENT

Parameter	Test 1	Test 2	Test 3
Total VOC (ng) [1]	16,309	21,036	43,538
Total HAP (ng) [1]	4,644	5,060	10,262
% HAP	28	24	23

[1] ng - nanograms.

C.1.2 Waupaca-Tell City Foundry Source Test

The Waupaca foundry in Tell City, Indiana, is a completely new grey iron foundry that started operation in February 1997. The foundry casts a diverse group of products, including brake drums, shoes, rotors, calipers, and other parts. EPA measured emissions from the cupola were measured by EPA during a source test in September 1997. During the time of the test, the plant operated one large water-cooled cupola that melts at a rate of approximately 60 tons per hr (tph), with a blast rate of 10,000 to 15,000 standard cubic feet per minute (scfm). Figure D-1 is a simplified schematic of the cupola gas handling system and emission control equipment.

The plant has four lines for pouring, cooling, and shakeout. Silica sand, bentonite, and seacoal constitute the molding sand, which is recycled about 50 times prior to disposal in a monofill. Resins and a catalyst are used to produce furan warm-box cores. Some of the company's cast products use cores; others do not. During the source test, cores were not being used on any of the lines. The properties of the molding sand measured during the test day are given below.

Sand Property	Value
Moisture (%)	3.5
Clay (%)	8.7
Loss on ignition (%, at 1800°F)	7.8
Volatile content (%, at 900°F)	4.0

A bonding agent was added to the sand in the amount of 38.1 pounds of bond per ton of sand mulled. The bonding agent is a dry mixture of coal, brittle asphalt, cellulose, bentonite, starch, and cereal. The material safety data sheet for the product indicates no volatile components and no hazardous ingredients other than coal dust and crystalline quartz.

Tables C-4 and C-5 summarize the emission test results for the cupola melting furnace. PCS emissions at Waupaca were measured only using Fourier transform infrared (FTIR) analysis. These results were deemed to be unreliable based on a comparison with a gas chromatography (GC) analysis performed during the EPA's second source test and therefore are not included in this data summary.

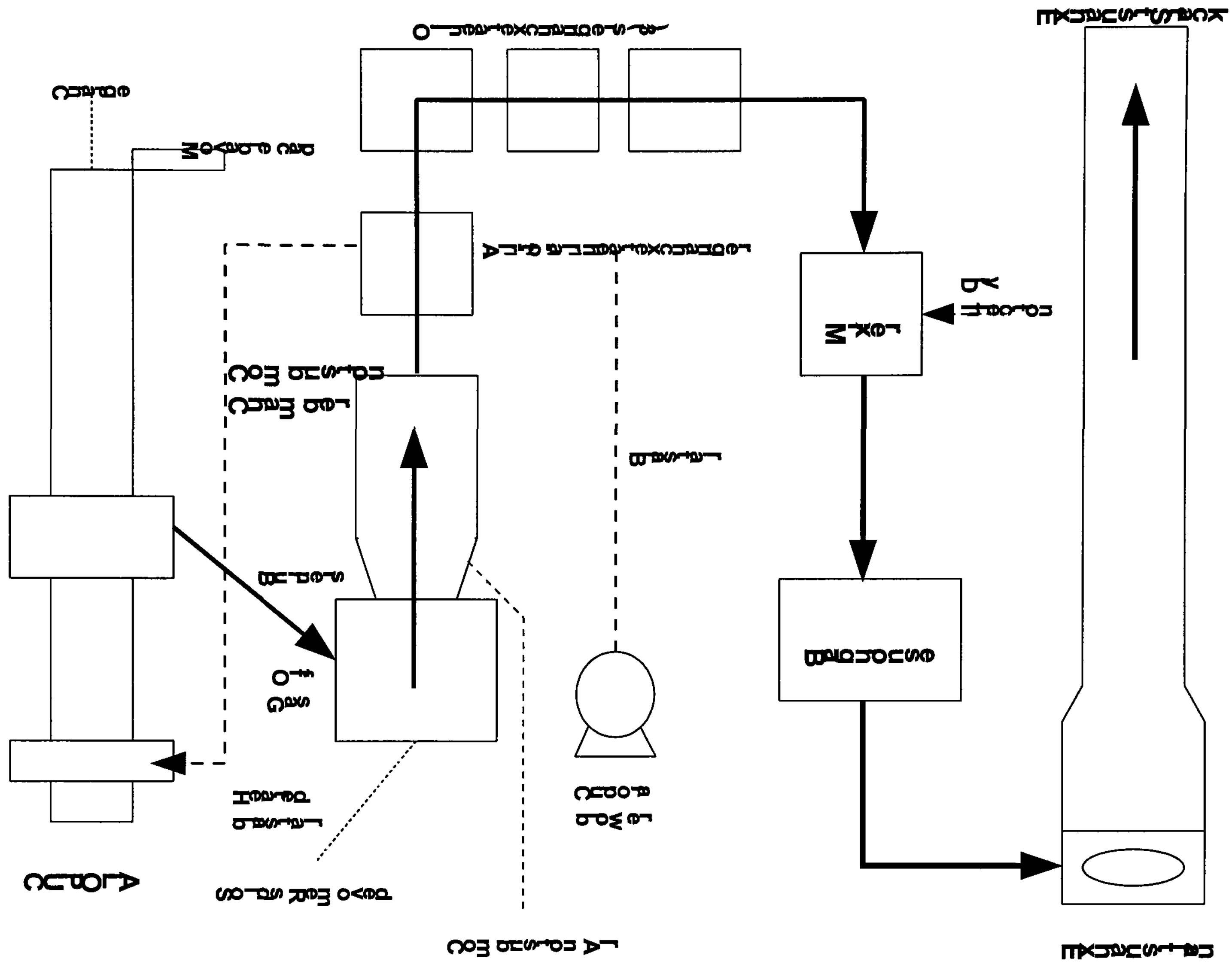

Figure C-1. Simplified Shematic of Cupola Gas Handling System at Waupaca-Tell City Foundry.

TABLE C-4. SUMMARY OF CUPOLA PM AND METAL HAP EMISSIONS FROM WAUPACA-TELL CITY FOUNDRY

	Parameter	Run 1	Run 2	Run 3	Average
Air flow rate	Inlet (dscfm)	26,800	38,200	38,500	34,500
	Outlet (dscfm)	32,100	49,700	48,500	43,400
Particulate matter	gr/dscf, inlet	0.62	1.44	1.07	1.04
	gr/dscf, outlet	0.0026	([1])	0.0011	0.0019 [1]
	lb/hr, inlet	143	472	354	323
	lb/hr, outlet	0.71	([1])	0.45	0.58 [1]
	Collection efficiency, %	99.5	99.997	99.87	99.88
Specific HAP metals	Mn lb/hr, inlet	3.67	9.16	7.15	6.66
	Mn lb/hr, outlet	0.0020	0.0029	0.0054	0.0034
	Collection efficiency, %	99.95	99.97	99.93	99.95
	Pb lb/hr, inlet	3.51	8.75	6.37	6.21
	Pb lb/hr, outlet	0.0096	0.0028	0.0056	0.0060
	Collection efficiency, %	99.73	99.97	99.91	99.89
Total HAP metals	lb/hr, inlet	7.36	18.28	13.82	13.15
	lb/hr, outlet	0.027	0.016	0.019	0.020
	Collection efficiency, %	99.64	99.91	99.87	99.84
Melt rate	tons/hr	41.4	48.7	45.7	45.3
Metals as percent of inlet PM	Mn	2.57	1.94	2.02	2.15
	Pb	2.45	1.85	1.80	2.03
	Total metal HAP	5.15	3.87	3.90	4.30
PM emission factor	lb/ton metal, inlet	3.45	9.69	7.75	6.96
	lb/ton metal, outlet	0.017	([1])	0.0098	0.013 [1]

[1] There appears to be an error in the filter weight measurement during run 2, which resulted in a negative value for the PM filter catch and an extremely low reported PM emission rate (filter catch plus rinse catch). The average PM emission rate was therefore calculated using data from runs 1 and 3 only.

TABLE C-5. SEMIVOLATILE HAP and PCDD/F[1] EMISSIONS FROM CUPOLA BAGHOUSE OUTLET; WAUPACA-TELL CITY SOURCE TEST

Parameter	Run 1	Run 2	Run 3	Average
Flow rate, dscfm	33,800	47,200	49,200	43,400
	Concentration (ppb)[2]			
Acetophenone	1.79	0.65	1.09	1.18
bis(2-ethylhexyl)pthalate	0.32	0.09	0.26	0.22
Naphthalene	1.25	0.21	0.87	0.78
Phenol	1.29	0.19	0.47	0.65
2-4-6 Trichlorophenol	0.86	0.06	0.64	0.52
	Concentration (ng/dscm, as measured)			
Total D/F TEQ [3]	1.07	2.60	6.36	2.52
	Emission rate (lb/hr)			
Acetophenone	1.13×10^{-3}	5.78×10^{-4}	1.01×10^{-3}	9.07×10^{-4}
bis(2-ethylhexyl)pthalate	6.48×10^{-4}	2.48×10^{-4}	7.62×10^{-4}	5.52×10^{-4}
Naphthalene	8.43×10^{-4}	2.00×10^{-4}	8.50×10^{-4}	6.31×10^{-4}
Phenol	6.39×10^{-4}	1.30×10^{-4}	3.42×10^{-4}	3.70×10^{-4}
246 Trichlorophenol	8.88×10^{-4}	8.84×10^{-5}	9.68×10^{-4}	6.48×10^{-4}
	Emission rate (µg/hr)[4]			
Total D/F TEQ [3]	65.4	217.	531.	202.
Total semivolatile HAP				3.11×10^{-3} lb/hr

[1] PCDD/F Polychlorinated dibenzo-*p*-dioxins/polychlorinated dibenzofurans.
[2] ppb - parts per billion.
[3] D/F TEQ = Dioxin/Furan Toxicity Equivalence to 2,3,7,8-TCDD.
[4] µg - micrograms.

C.1.3 GM-Saginaw Metal Castings Operations (SMCO) Foundry Source Test

The GM Powertrain Group, part of the General Motors Corporation, operates a foundry in Saginaw, Michigan, named Saginaw Metal Casting Operations (SMCO), which casts grey iron and aluminum. This foundry was constructed by GM in 1918 and is currently operating three cupolas ("B", "C", and "D") and two green sand lines for casting iron along with an electric melting furnace and one casting line for aluminum to produce engine blocks for use in GM automobiles. Cupola B was chosen by the EPA for testing, primarily because it had more modern and complete controls and instrumentation. Cupola B has a diameter of 114 inches and melts at a rate of about 55 tons per hour (tph) with a blast rate of 21,000 to 23,000 cfm, which makes it among the larger cupolas in use in the United States. The blast is enriched with oxygen at a rate of about 4 percent. Figure C-2 is a simplified schematic of the cupola gas handling system and emission control equipment. Table C-6 summarizes the emission test results for the cupola melting furnace.

The two iron pouring lines are labeled lines 3 and 4. Line 4 was selected for emissions testing because it is newer and the layout is more amendable to sampling. The line has a capacity of 270 molds per hour with two engine blocks per mold. Each horizontal mold contains 3,300 lbs of green sand (lake sand, sea coal, and bentonite). The typical properties that are measured and the range during the test days are given below.

Sand Property	Range
Moisture (%)	2.8 to 3.3
Clay (%)	6.8 to 7.4
Compactability (%)	3.6 to 4.8
Green strength	164 to 221
Permeability	114 to 130
Loss on ignition (%)	3.8 to 5.0

During the test days, both 4- and 6-cylinder engine blocks were poured on line 4. The pouring weight of iron for the 4-cylinder block is 202.8 lbs to produce a casting of 116.2 lbs. For the 6-cylinder block, the pouring weight is 250.4 lbs and the casting weight is 149.2 lbs. The cores used in the molds include both hot-box and cold-box binder systems with phenol-formaldehyde constituents. .

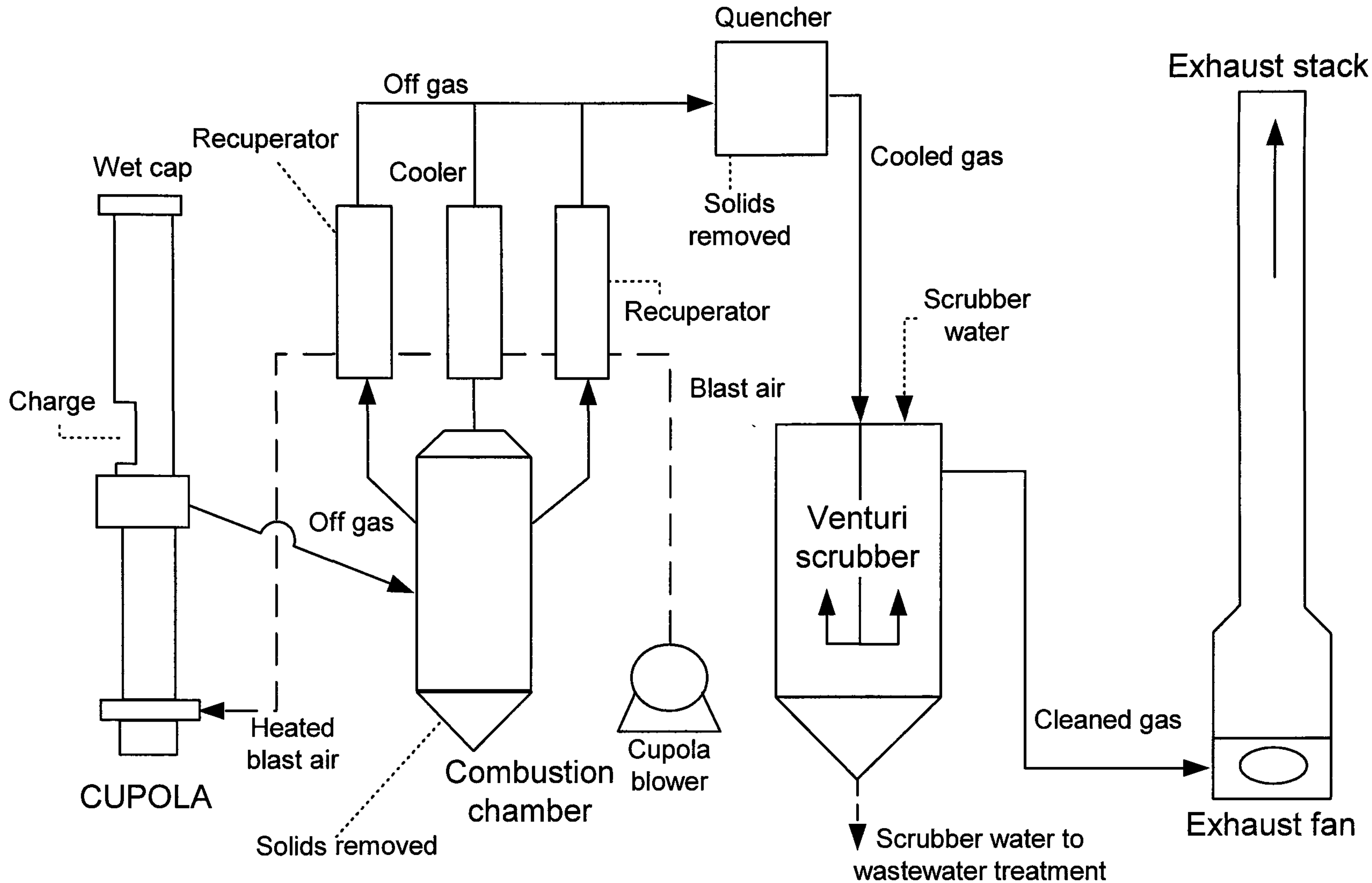

Figure C-2. SCHEMATIC OF THE CUPOLA GAS HANDLING SYSTEM AT GM-SMCO FOUNDRY

TABLE C-6. SUMMARY OF CUPOLA PM, METAL HAP, AND PCDD/F EMISSIONS FROM GM-SMCO FOUNDRY

Parameter		Run 1	Run 2	Run 3	Run 4	Average
Particulate matter	gr/dscf, inlet	0.27	0.34	0.39	0.46	0.36
	gr/dscf, outlet	0.015	0.016	0.0035	0.0035	0.0095
	lb/hr, inlet	139	169	186	215	177
	lb/hr, outlet	8.08	7.61	1.71	1.71	4.8
	Efficiency, %,	94.2	95.5	99.1	99.2	97.3
Specific HAP metals	Mn lb/hr, inlet	8.2	9.2	7.6	8.1	8.3
	Mn lb/hr, outlet	0.70	0.52	0.10	0.070	0.35
	Pb lb/hr, inlet	1.3	0.84	1.7	1.8	1.4
	Pb lb/hr, outlet	0.090	0.076	0.030	0.015	0.053
Total HAP metals	Total HAP lb/hr, inlet	9.6	10.1	9.4	10.0	9.8
	Total HAP lb/hr, outlet	0.80	0.60	0.14	0.09	0.41
	Efficiency for metal HAP, %	91.7	94.1	98.5	99.1	95.8
D/F TEQ	ng/dscm, outlet	0.26	0.36	0.11	0.10	0.21
	μg/hr, outlet	22.6	33.2	9.8	9.6	18.8
Scrubber ΔP	Inches of water column	33	35	38	42	37
Hot blast temperature	°F	488	464	366	364	421
Charging rate	tons/hr	38.8	41.7	45.4	43.5	42.4
Metals as percent of inlet PM	Mn	5.8	5.4	4.1	3.8	4.7
	Pb	0.9	0.5	0.9	0.8	0.8
	Total metal HAP	6.9	6.0	5.0	4.6	5.6
PM emission factor	lb/ton iron poured, inlet	3.58	4.05	4.10	4.94	4.29
	lb/ton iron poured, outlet	0.21	0.18	0.038	0.039	0.12

For the 4-cylinder engine, 15.7 lbs of hot-box cores and 74.5 lbs of cold-box cores are used for a total core weight of 90.2 lbs per block or 180.4 lbs per mold. For the 6-cylinder engine, 17.9 lbs of hot-box cores and 95.2 lbs of cold-box cores are used for a total core weight of 113 lbs per block or 226 lbs per mold. The PCS emissions were measured by EPA using both

FTIR and gas chromatography/mass spectroscopy (GC/MS) techniques. Additionally, GM employed its own GC sampling and analysis techniques to independently measure the PCS emissions. Table D-7 summarizes the PCS emission test results from the three different methods. Agreement between the EPA and GM measurements was not exact but nevertheless was much better than agreement between either set of measurements and the FTIR results.

TABLE C-7. SUMMARY OF PCS EMISSION TESTING AT GM-SCMO

Compound	Pouring emissions, lb/hr			Cooling emissions, lb/hr			Shakeout emissions, lb/hr		
	EPA FTIR	EPA GC/MS	GM GC	EPA FTIR	EPA GC/MS	GM GC	EPA FTIR	EPA GC/MS	GM GC
Toluene	ND	0.043	0.046	22.2	1.12	1.43	15.6	2	0.51
Hexane	0.98	ND	0.013	12.3	ND	0.11	8.8	ND	0.026
Benzene	ND	0.18	0.23	ND	3.52	6.16	ND	3.3	0.95
Naphthalene	ND	ND	0.019	ND	ND	0.47	ND	ND	0.73
Formaldehyde	ND	ND	0.015	ND	ND	0.15	ND	ND	0.11
Ethyl benzene	ND	ND	0.0031	ND	0.055	0.092	ND	1.4	0.062
m/p-Xylene	ND	ND	0.014	ND	0.28	0.84	ND	0.59	0.26
o-Xylene	ND	ND	0.0035	ND	0.08	0.13	ND	0.18	0.094
Styrene	ND	ND	0.0055	ND	0.024	0.063	ND	0.097	0.044
Total	0.98	0.22	0.35	34.5	5.08	9.45	24.4	7.57	2.79

C.1.4 1995 Wisconsin Study

Residuals Management Technology, Inc., performed source emission testing for the Wisconsin Cast Metals Association to characterize benzene and formaldehyde emissions from PCS operations (RMT, 1995). Process emissions from pouring, cooling, or shakeout were tested at eight different foundries, although none of the foundries were tested for all three processes (i.e., PCS operations combined). Five of the foundries tested used green sand molds, two of the foundries used no-bake molds, and one foundry used a shell process. From the data provided, most of these foundries would be classified as iron foundries (type of metal poured was specified for five foundries, all of which poured some type of iron). The direct emission measurement data were reported along with projected actual emissions based on estimated capture efficiency of each process at the given foundry. The resulting emissions data are provided in Table C-8.

TABLE C-8. HAP EMISSION FACTORS FOR PCS OPERATIONS; WISCONSIN STUDY [1]

HAP	Sand system	Emission factor, lb HAP/ton metal poured			
		Pouring	Cooling	Shakeout	Total PCS
Benzene	Green Sand	5.70×10^{-3}	4.50×10^{-2}	8.30×10^{-3}	5.90×10^{-2}
Benzene	Nobake	1.10×10^{-2}	3.20×10^{-2}	5.30×10^{-3}	4.80×10^{-2}
Benzene	Shell	1.30×10^{-2} [2]		Not Meas. [2]	(1.30×10^{-2}) [2]
Formaldehyde	Green Sand	3.20×10^{-3}	1.40×10^{-3}	3.90×10^{-3}	8.50×10^{-3}
Formaldehyde	Nobake	5.90×10^{-3}	3.10×10^{-3}	8.00×10^{-4}	9.80×10^{-3}
Formaldehyde	Shell	7.00×10^{-4} [2]		Not Meas. [2]	(7.00×10^{-4}) [2]

[1] Source: RMT, 1995.

[2] Pouring and cooling line for the shell system was combined in single exhaust vent. No shakeout emissions were measured for this system.

C.1.5 Summary and Comparison of Recent Source Test Results

Table C-9 provides a summary of the melting furnace emission test results for the studies described in this section. Table C-10 summarizes the PCS emission factors for these studies.

TABLE C-9. COMPARISON OF EMISSION SOURCE TEST RESULTS FOR CUPOLA MELTING

Parameter	Waupaca-Tell City	GM-Saginaw	Reported values
Cupola melting furnace			
Controlled PM emission factor, lb/ton metal	0.013	0.12	0.09 - 1.46 (WS) [1] 0.03 - 0.08 (FF) [1]
Uncontrolled PM emission factor, lb/ton metal	7.0	4.3	4.8 - 66. [2,3]
Controlled total metal HAP emission factor, lb/ton metal	0.00046	0.0097	0.005 - 0.02 [4,5]
Total metal HAP conc., % of PM	4.3	5.6	2.5 - 15. [6]
Mn conc. in collected PM, % of PM	2.2	4.7	1. - 10. [6]
Pb conc. in collected PM, % of PM	2.0	0.8	1.4 - 5. [6]
Dioxin/Furan TEQ emission factor, μg/ton metal	4.5	0.44	0.1 - 2.7 [4,5]

[1] From test data provided in response to detailed ICR; see Table D-13. WS - wet scrubber; FF - fabric filter.

[2] Source: Kearney, 1971.

[3] Source: Wallace, 1981.

[4] Source: EMCON, 1990. Source test at U.S. Pipe and Foundry Company, Inc., Union City, CA, 1990. Reported in response to detailed ICR (CA-27). Metals emissions reported for one test run on 10/23/1990 were excluded because they were an order of magnitude greater than those reported for the other two runs.

[5] Source: Ecoserve, 1992.

[6] Source: Davis, 1975.

TABLE C-10. COMPARISON OF EMISSION SOURCE TEST RESULTS FOR PCS

Source/HAP	Emission factor, lb/ton metal poured			
	CERP	GM-Saginaw[1]	WI Study Green sand[2]	WI Study Nobake[2]
Pouring				
Benzene	0.00219	0.0054	0.0057	0.011
Toluene	0.00105	0.0011		
Formaldehyde	0.000138	0.000354	0.0032	0.0059
Total organic HAP	0.0050	0.0082		
Cooling				
Benzene	0.0349	0.14	0.045	0.032
Toluene	0.0189	0.033		
Formaldehyde	0.00173	0.0035	0.0014	0.0031
Total organic HAP	0.078	0.22		
Shakeout				
Benzene	0.0349	0.022	0.0083	0.0053
Toluene	0.0189	0.012		
Formaldehyde	0.00173	0.0026	0.0039	0.0008
Total organic HAP	0.20	0.065		
PCS combined				
Benzene	0.0268	0.167	0.059	0.048
Toluene	0.0221	0.046		
Formaldehyde	0.0257	0.064	0.0085	0.0098
Total organic HAP	0.283	0.294		

[1] Values reported by GM using their GC method.
[2] Source: RMT, 1995.

C.2 SUMMARY OF REPORTED FOUNDRY EMISSIONS TEST DATA

This section summarizes the recent emissions test data reported in the literature or in response to the MSDIR that is generally lacking complete documentation or that focused primarily on PM emissions data or other surrogates for HAP emissions rather than directly measuring HAP emissions. The primary data reported in this section include a compilation of 1990 to 1992 test data accumulated by the Wisconsin Department of Natural Resources (DNR), the Ohio Cast Metals Association study of VOC emissions from mold/core making, and source test data reported in response to the MSDIR.

C.2.1 Wisconsin Department of Natural Resources Compilation

This reference is simply a compilation of source test data results with no description of the methods used and little information about the foundries. Like a subsequent 1995 Wisconsin study, the data focuses on benzene and formaldehyde emissions from PCS operations. Results for individual runs were provided, but no information was provided regarding the sampling and analytical protocols, nor was information provided regarding quality assurance procedures.

Emissions from six foundries were tested; process data were available for five of these foundries. A summary of the average emission factors calculated for each pouring line tested is given in Table C-11.

C.2.2 Ohio Cast Metal Association Study

The Ohio Cast Metals Association study (RMT, 1998) tested phenolic urethane cold-box and phenolic urethane no-bake binder systems from three different vendors. VOC emissions were determined by weight loss measurements by each of the three vendors for each of the three vendor products for each binder system over a 12-hour storage period. The average VOC emissions from each binder system were reported per mass of binder added and per ton of sand used. The average VOC emission factors for the two binder types are summarized in Table C-12.

TABLE C-11. HAP EMISSION FACTORS FOR PCS OPERATIONS; WISCONSIN DNR STUDY[1].

HAP	Foundry/Line	Emission factor (lb HAP/ton metal poured)			
		Pouring	Cooling	Shakeout	Total PCS
Benzene	Foundry 1, 12 tph	1.56×10^{-2}	5.24×10^{-2}	5.04×10^{-2}	1.18×10^{-1}
	Foundry 1, 20 tph		1.84×10^{-2}	4.88×10^{-2}	6.72×10^{-2} [2]
	Foundry 1, 4 tph			2.81×10^{-2}	
	Foundry 2, oil core	1.05×10^{-4}		7.41×10^{-2}	7.42×10^{-2} [3]
	Foundry 2, GS isocure			2.59×10^{-2}	
	Foundry 3		1.03×10^{-2}		
	Foundry 4	3.59×10^{-2}			3.59×10^{-2}
	Foundry 5	4.59×10^{-2}		6.62×10^{-3}	5.25×10^{-2}
	Average for GS foundries	7.90×10^{-3}	2.70×10^{-2}	3.35×10^{-2}	6.84×10^{-2}
Formaldehyde	Foundry 1, 12 tph	7.50×10^{-4}	2.67×10^{-3}	5.36×10^{-3}	8.78×10^{-3}
	Foundry 1, 20 tph		1.68×10^{-3}		
	Foundry 2, oil core	2.87×10^{-4}		7.18×10^{-5}	3.59×10^{-4} [3]
	Foundry 2, GS isocure			2.80×10^{-3}	
	Foundry 4	5.84×10^{-3}			5.84×10^{-3}
	Foundry 5	5.83×10^{-3}		2.51×10^{-3}	8.34×10^{-3}
	Average for GS foundries	1.83×10^{-3} [4]	2.18×10^{-3}	3.64×10^{-3}	7.65×10^{-3}

[1] Source: WI-DNR, 1992 .
[2] Includes only measurements of cooling and shakeout emissions.
[3] Includes only measurements of pouring and shakeout emissions.
[4] Calculated as average total PCS - average cooling - average shakeout.

TABLE C-12. VOC EMISSIONS FROM 12-HOUR STORAGE OF MOLDS

Parameter	Phenolic urethane cold box	Phenolic urethane nobake
Binder emitted, %	3.26	5.74
VOC emission factor, lb VOC/ton sand	0.65	1.17

C.2.3 Source Test Data Provided in Response to the MSDIR

Most of the emissions source test data submitted in response to the MSDIR pertained to PM emission measurements. The one notable exception is the GM data, which is included in the summary of the EPA's source test at the GM foundry (see Section C.1.3). Table C-13 summarizes the average PM emission factors calculated from the data obtained in response to the detailed ICR. The data are organized by the emission source and control device used. When results of individual runs were provided, Table C-13 indicates the number of individual runs that were made and used in calculating the average. When only summary results were provided, these data are identified as "Avg as reported" in the "Basis of reported values" column.

TABLE C-13 . SUMMARY OF PM EMISSIONS DATA SUBMITTED IN RESPONSE TO THE MSDIR

Facility ID	Emission source	Control device	Production rate, tph	Basis of reported values	Emission rate, lb/hr	Emission factor, lb/ton	Foundry type
Cupolas controlled with wet scrubbers							
181	Cupola	AB[1]/WS	16.6	11/11/93 Avg 3 runs	10.9	0.654	Iron
181	Cupola	AB/WS	17.8	6/13/95 Avg 3 runs	14.7	0.829	Iron
181	Cupola	AB/WS	20.7	6/12/96 Avg 3 runs	18.3	0.894	Iron
31	Cupola	WS	40.2	Avg of 3 runs	12.32	0.306	Iron
77	Cupola	WS		Avg as reported		0.240	Iron
105	Cupola	WS	29.5	Avg as reported	16.53	0.560	Iron
107	Cupola	WS	36.4	Avg as reported	3.27	0.090	Iron
140	Cupola	WS	5.7	Avg as reported	8.31	1.460	Iron
143	Cupola	WS	43	Avg of 4 runs	16.20	0.265	Iron
157	Cupola	WS	57	Avg of 3 runs	28.66	0.451	Iron
202	Cupola	WS	8	Avg of 3 runs	5.72	0.715	Iron
Cupolas controlled with fabric filters							
505	Cupola	FF	20	Avg of 3 runs	1.63	0.082	Iron
36	Cupola	FF	22	Avg of 3 runs	1.69	0.077	Iron
111	Cupola	FF	10	Avg as reported	0.30	0.030	Iron
Electric arc furnaces (EAF) controlled with fabric filters							
9	EAF	FF	14.6	Avg of 3 runs	1.41	0.096	Steel
41	EAF	FF	3.51	Avg of 3 runs	0.13	0.037	Steel
814	EAF	FF	22.9	Avg of 3 runs	4.71	0.206	Steel
771	EAF	FF	12.7	Avg of 3 runs	6.27	0.558	Steel
EAFs uncontrolled							
17	EAF	FF (inlet?)	20.6	Avg of 3 runs	493	23.9	Iron
Electric induction furnaces (EIF) with PM control							
201	EIF	Cyclone	4.435	Avg of 3 runs	2.47	0.558	Iron
52	EIF	FF	4.65	Avg as reported	0.37	0.080	Iron
200	EIF	FF	3	Avg as reported	0.4	0.133	Iron
200	EIF/Inoculation	FF	2.75	Avg as reported	0.22	0.080	Iron
200	EIF + pouring/cooling	WS	4.38	Avg as reported	2.92	0.667	Iron
Induction furnaces uncontrolled							
201	EIF	Before APCD	4.435	Avg of 3 runs	39.7	8.940	Iron
31	EIF	None	6	Avg of 2 runs	2.62	0.437	Iron

TABLE C-13 . SUMMARY OF PM EMISSIONS DATA SUBMITTED IN RESPONSE TO THE MSDIR

Facility ID	Emission source	Control device	Production rate, tph	Basis of reported values	Emission rate, lb/hr	Emission factor, lb/ton	Foundry type
	Miscellaneous processes						
31	Mold cooling	None	4.62	Avg of 2 runs	1.51	0.326	Iron
181	Pouring/cooling	"Dust colllector"	17.88	Avg of 3 runs '96	1.52	0.085	Iron
181	Pouring/cooling	"Dust colllector"	20.22	Avg of 3 runs '98	2.85	0.141	Iron
198	Pouring/cooling/shakeout	FF	2.4	Avg as reported	1.49	0.621	Iron
201	Pouring/cooling/shakeout	None	9.4	Avg of 2 runs	0.80	0.085	Iron
201	Cooling/shakeout	WS	13.91	Avg of 2 runs	1.38	0.099	Iron
200	Shakeout	WS	4.97	Avg as reported	1.18	0.237	Iron
200	Grinding/cutoff	FF	1.9	Avg as reported	0.27	0.142	Iron
31	Shot blast	FF	20.3	Avg of 3 runs	1.33	0.066	Iron
181	Cleaning room	Cartridge	17.88	Avg of 3 runs	0.70	0.039	Iron

[1] AB - Afterburner.

C.3 SUMMARY OF HISTORIC AND ADDITIONAL DATA REGARDING FOUNDRY EMISSIONS

This section summarizes the emissions test data performed over 10 years ago and additional data reported in response to the MSDIR regarding baghouse catch data. It includes a summary of the Scott, Bates, and James studies, which are well documented but were performed more than 20 years ago. Binder formulations have changed dramatically over the past 20 years, and the binder materials used in these studies probably are not representative of the binder formulations used by industry. Historical data on PM emissions are also summarized as well as estimates of uncontrolled PM emission factors based on baghouse catch data reported in response to the MSDIR.

Table C-14 provides a listing of the emissions data for pouring and cooling processes from the studies of Scott, Bates, and James and associated bench-scale emission studies. The primary criticism of these studies is that they were performed approximately 20 years ago and, according to representatives of the American Foundry Society, binder formulations have changed significantly (with reduced HAP content) since these studies were done. It is apparent from the median and average emission factor values that there are some high emission factors that appear to skew the average emission factors toward the high end. Consequently, the median emission factors from these studies appear to be the most appropriate for comparison with more recent studies.

Historical data on PM emissions, primarily from melting operations, is summarized in Table C-15. Table C-16 provides a summary of emission factors for uncontrolled melting furnace and metal treatment operations estimated based on baghouse catch data. Table C-17 provides a similar summary of emission factors for finishing operations.

TABLE C-14. EMISSION FACTOR SUMMARY FROM BENCH SCALE STUDIES

HAP/Binder system	Metal pour rate, tph	Sand use, tph	Emission rate, lb/hr	Emission factor, lb/ton	Metal type	Reference[1]
Benzene						
Pouring/cooling - green sand	0.044	0.110	3.84E-03	0.0870	Iron (grey)	A
Pouring/cooling - dry sand	0.044	0.106	3.84E-03	0.0870	Iron (grey)	A
Pouring/cooling - silicate ester	0.044	0.126	1.98E-03	0.0450	Iron (grey)	A
Pouring/cooling - core oil	0.044	0.152	6.48E-03	0.1470	Iron (grey)	A
Pouring/cooling - alkyd isocyanate	0.044	0.115	1.93E-02	0.4380	Iron (grey)	A
Pouring/cooling - phenolic urethane	0.044	0.106	1.61E-02	0.3660	Iron (grey)	A
Pouring/cooling - phenolic no-bake	0.044	0.123	3.04E-02	0.6900	Iron (grey)	A
Pouring/cooling - low N_2 furan-H_3PO_4	0.044	0.121	2.12E-03	0.0480	Iron (grey)	A
Pouring/cooling - med N_2 furan-TSA	0.044	0.115	1.48E-02	0.3360	Iron (grey)	A
Pouring/cooling - furan hot box	0.044	0.112	2.25E-03	0.0510	Iron (grey)	A
Pouring/cooling - phenolic hot box	0.044	0.117	4.37E-03	0.0990	Iron (grey)	A
Pouring/cooling - shell (phenolic)	0.017	0.015	7.54E-03	0.4560	Iron (grey)	A
Cooling - shell (phenolic)	0.030	0.023	3.05E-03	0.1020	Steel (1025)	B
Cooling - N_2 furan-TSA	0.170	0.374	9.99E-03	0.0588	Steel (1025)	B
Cooling - phenolic urethane	0.170	0.374	6.73E-03	0.0396	Steel (1025)	B
Cooling - alkyd isocyanate	0.170	0.255	7.92E-03	0.0466	Steel (1025)	B
			Median emission factor:	**0.0930**		
			Average emission factor:	**0.1940**		
Formaldehyde						
Pouring/cooling - green sand	0.044	0.110	2.65E-05	0.0006	Iron (grey)	A
Pouring/cooling - dry sand	0.044	0.106	6.61E-05	0.0015	Iron (grey)	A
Pouring/cooling - core oil	0.044	0.152	2.65E-04	0.0060	Iron (grey)	A
Pouring/cooling - alkyd isocyanate	0.044	0.115	3.84E-04	0.0087	Iron (grey)	A
Pouring/cooling - phenolic urethane	0.044	0.106	6.61E-05	0.0015	Iron (grey)	A
Pouring/cooling - phenolic no-bake	0.044	0.123	2.65E-05	0.0006	Iron (grey)	A
Pouring/cooling - low N_2 furan-H_3PO_4	0.044	0.121	8.73E-04	0.0198	Iron (grey)	A
Pouring/cooling - med N_2 furan-TSA	0.044	0.115	2.12E-04	0.0048	Iron (grey)	A
Pouring/cooling - furan hot box	0.044	0.112	3.97E-05	0.0009	Iron (grey)	A
Pouring/cooling - phenolic hot box	0.044	0.117	2.65E-05	0.0006	Iron (grey)	A
Pouring/cooling - shell (phenolic)	0.017	0.015	3.97E-05	0.0024	Iron (grey)	A
Pooling - shell (phenolic)	0.030	0.023	2.44E-05	0.0008	Steel (1025)	B
Cooling - N_2 furan-TSA	0.170	0.374	8.98E-03	0.0528	Steel (1025)	B
Cooling - phenolic urethane	0.170	0.374	1.30E-04	0.0008	Steel (1025)	B
			Median Emission Factor:	**0.0015**		
			Average Emission Factor:	**0.0076**		
Hydrogen cyanide						
Pouring/cooling - green sand	0.044	0.110	5.22E-03	0.1190	Iron (grey)	A
Pouring/cooling - dry sand	0.044	0.106	2.65E-04	0.0060	Iron (grey)	A
Pouring/cooling - silicate ester	0.044	0.126	2.51E-04	0.0057	Iron (grey)	A
Pouring/cooling - core oil	0.044	0.152	2.38E-04	0.0054	Iron (grey)	A
Pouring/cooling - alkyd isocyanate	0.044	0.115	6.35E-04	0.0144	Iron (grey)	A
Pouring/cooling - phenolic urethane	0.044	0.106	3.17E-03	0.0720	Iron (grey)	A

TABLE C-14. EMISSION FACTOR SUMMARY FROM BENCH SCALE STUDIES

HAP/Binder system	Metal pour rate, tph	Sand use, tph	Emission rate, lb/hr	Emission factor, lb/ton	Metal type	Reference[1]
Pouring/cooling - phenolic no-bake	0.044	0.123	7.94E-05	0.0018	Iron (grey)	A
Pouring/cooling - low N_2 furan-H_3PO_4	0.044	0.121	1.20E-03	0.0273	Iron (grey)	A
Pouring/cooling - med N_2 furan-TSA	0.044	0.115	1.98E-03	0.0450	Iron (grey)	A
Pouring/cooling - furan hot box	0.044	0.112	1.46E-02	0.3300	Iron (grey)	A
Pouring/cooling - phenolic hot box	0.044	0.117	5.16E-03	0.1170	Iron (grey)	A
Pouring/cooling - shell (phenolic)	0.017	0.015	1.19E-02	0.7200	Iron (grey)	A
Hydrogen cyanide (continued)						
Cooling - shell (phenolic)	0.030	0.023	2.30E-03	0.0766	Steel (1025)	B
Cooling - N_2 furan-TSA	0.170	0.374	2.30E-03	0.0135	Steel (1025)	B
Cooling - phenolic urethane	0.170	0.374	9.37E-04	0.0055	Steel (1025)	B
Cooling - alkyd isocyanate	0.170	0.255	6.00E-04	0.0035	Steel (1025)	B
Cooling - alkyd isocyanate	0.170	0.425	3.27E-03	0.0192	Iron	C
Cooling - phenolic urethane	0.170	0.425	3.24E-03	0.0191	Iron	C
Cooling - shell	0.170	0.425	1.19E-02	0.0700	Iron	C
Cooling - phenolic no-bake	0.170	0.425	7.94E-05	0.0005	Iron	C
Cooling - furan N_2 free	0.170	0.425	1.06E-04	0.0006	Iron	C
Cooling - furan no-bake (med N_2?)	0.170	0.425	1.98E-03	0.0117	Iron	C
			Median emission factor:	**0.0167**		
			Average emission factor:	**0.0765**		
Phenol						
Pouring/cooling - green sand	0.044	0.110	8.07E-04	0.0183	Iron (grey)	A
Pouring/cooling - dry sand	0.044	0.106	5.03E-04	0.0114	Iron (grey)	A
Pouring/cooling - silicate ester	0.044	0.126	3.70E-04	0.0084	Iron (grey)	A
Pouring/cooling - core oil	0.044	0.152	1.59E-04	0.0036	Iron (grey)	A
Pouring/cooling - alkyd isocyanate	0.044	0.115	3.97E-04	0.0090	Iron (grey)	A
Pouring/cooling - phenolic urethane	0.044	0.106	1.18E-02	0.2670	Iron (grey)	A
Pouring/cooling - phenolic no-bake	0.044	0.123	2.65E-03	0.0600	Iron (grey)	A
Pouring/cooling - low N_2 furan-H_3PO_4	0.044	0.121	5.29E-05	0.0012	Iron (grey)	A
Pouring/cooling - med N_2 furan-TSA	0.044	0.115	3.17E-04	0.0072	Iron (grey)	A
Pouring/cooling - furan hot box	0.044	0.112	7.94E-05	0.0018	Iron (grey)	A
Pouring/cooling - phenolic hot box	0.044	0.117	4.89E-04	0.0111	Iron (grey)	A
Pouring/cooling - shell (phenolic)	0.017	0.015	1.46E-03	0.0880	Iron (grey)	A
Cooling - shell (phenolic)	0.030	0.023	3.26E-03	0.1090	Steel (1025)	A
Cooling - phenolic urethane	0.170	0.374	4.08E-04	0.0024	Steel (1025)	B
Cooling - alkyd isocyanate	0.170	0.255	2.55E-04	0.0015	Steel (1025)	B
			Median emission factor:	**0.0090**		
			Average emission factor:	**0.0400**		
POM (benzene soluble particulates)						
Cooling - N_2 furan-TSA	0.080	0.120	1.68E-05	0.0002	Steel	D
Cooling - phenolic hot-box	0.080	0.120	1.65E-04	0.0021	Iron (grey)	E
Cooling - phenolic no-bake	0.080	0.120	3.53E-05	0.0004	Iron (grey)	E
Cooling - phenolic urethane	0.080	0.120	3.53E-05	0.0004	Steel	D
Cooling - phenolic urethane	0.080	0.120	1.54E-05	0.0002	Iron (gray)	E
Cooling - alkyd isocyanate	0.080	0.120	2.36E-04	0.0030	Steel	D
Cooling - shell (phenolic)	0.080	0.120	2.36E-04	0.0030	Iron (grey)	E
Cooling - alkyd isocyanate	0.080	0.120	2.87E-05	0.0004	Iron (grey)	E
Cooling - silicate ester	0.080	0.120	2.87E-05	0.0004	Iron (grey)	E
Cooling - core oil	0.080	0.120	7.83E-04	0.0098	Iron (grey)	E
Cooling - dry sand	0.080	0.120	8.93E-04	0.0112	Iron (grey)	E
Cooling - furan hot-box	0.080	0.120	3.99E-04	0.0050	Iron (grey)	E
Cooling - furan med. N_2	0.080	0.120		0.1750	Iron (grey)	E
Cooling - furan N_2 free	0.080	0.120	2.76E-04	0.0034	Iron (grey)	E

TABLE C-14. EMISSION FACTOR SUMMARY FROM BENCH SCALE STUDIES

HAP/Binder system	Metal pour rate, tph	Sand use, tph	Emission rate, lb/hr	Emission factor, lb/ton	Metal type	Reference[1]
Cooling - green sand	0.080	0.120	2.25E-03	0.0281	Iron (grey)	E
		Median emission factor:		**0.0030**		
		Average emission factor:		**0.0162**		
Toluene						
Pouring/cooling - green sand	0.044	0.110	3.97E-04	0.0090	Iron (grey)	A
Pouring/cooling - dry sand	0.044	0.106	1.06E-03	0.0240	Iron (grey)	A
Pouring/cooling - silicate ester	0.044	0.126	3.97E-04	0.0090	Iron (grey)	A
Pouring/cooling - core oil	0.044	0.152	1.32E-03	0.0300	Iron (grey)	A
Pouring/cooling - alkyd isocyanate	0.044	0.115	5.56E-03	0.1260	Iron (grey)	A
Pouring/cooling - phenolic urethane	0.044	0.106	2.51E-03	0.0570	Iron (grey)	A
Pouring/cooling - phenolic no-bake	0.044	0.123	1.72E-03	0.0390	Iron (grey)	A
Pouring/cooling - low N_2 furan-H_3PO_4	0.044	0.121	3.97E-04	0.0090	Iron (grey)	A
Pouring/cooling - med N_2 furan-TSA	0.044	0.115	2.88E-02	0.6540	Iron (grey)	A
Pouring/cooling - furan hot box	0.044	0.112	1.19E-04	0.0027	Iron (grey)	A
Pouring/cooling - phenolic hot box	0.044	0.117	7.94E-04	0.0180	Iron (grey)	A
Pouring/cooling - shell (phenolic)	0.017	0.015	3.17E-03	0.1920	Iron (grey)	A
Cooling - shell (phenolic)	0.030	0.023	9.52E-04	0.0317	Steel (1025)	B
Cooling - N_2 furan-TSA	0.170	0.374	3.84E-02	0.2260	Steel (1025)	B
Cooling - phenolic urethane	0.170	0.374	2.10E-03	0.0124	Steel (1025)	B
Cooling - alkyd isocyanate	0.170	0.255	3.46E-03	0.0203	Steel (1025)	B
		Median emission factor:		**0.0270**		
		Average emission factor:		**0.0912**		
Xylenes						
Pouring/cooling - green sand	0.044	0.110	1.32E-05	0.0003	Iron (grey)	A
Pouring/cooling - dry sand	0.044	0.106	7.94E-04	0.0180	Iron (grey)	A
Pouring/cooling - silicate ester	0.044	0.126	2.65E-04	0.0060	Iron (grey)	A
Pouring/cooling - core oil	0.044	0.152	1.46E-03	0.0330	Iron (grey)	A
Pouring/cooling - alkyd isocyanate	0.044	0.115	2.30E-02	0.5220	Iron (grey)	A
Pouring/cooling - phenolic urethane	0.044	0.106	1.72E-03	0.0390	Iron (grey)	A
Pouring/cooling - phenolic no-bake	0.044	0.123	3.57E-04	0.0081	Iron (grey)	A
Pouring/cooling - low N_2 furan-H_3PO_4	0.044	0.121	9.66E-03	0.2190	Iron (grey)	A
Pouring/cooling - med N_2 furan-TSA	0.044	0.115	9.26E-04	0.0210	Iron (grey)	A
Pouring/cooling - furan hot box	0.044	0.112	1.59E-04	0.0036	Iron (grey)	A
Pouring/cooling - phenolic hot box	0.044	0.117	6.61E-04	0.0150	Iron (grey)	A
Pouring/cooling - shell (phenolic)	0.017	0.015	7.94E-04	0.0480	Iron (grey)	A
Cooling - shell (phenolic)	0.030	0.023	4.02E-04	0.0134	Steel (1025)	B
Cooling - N_2 furan-TSA	0.170	0.374	5.17E-04	0.0030	Steel (1025)	B
Cooling - phenolic urethane	0.170	0.374	3.22E-03	0.0189	Steel (1025)	B
Cooling - alkyd isocyanate	0.170	0.255	4.60E-03	0.0270	Steel (1025)	B
		Median emission factor:		**0.0185**		
		Average emission factor:		**0.0622**		

[1] Key to references: A - Scott, 1977; B - Scott, 1976; C - Emory, 1978; D - Scott, 1978; E - Southern Research Institute, 1979.

TABLE C-15. SUMMARY OF HISTORIC DATA FOR PM EMISSION FACTORS

Reference[1]	Metal rate, tons/hr	PM emission rate, lb/hr	PM emission factor, lb/ton	Foundry type	Comments
Cupola - uncontrolled					
A	25		7.50	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	45		9.60	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	35		11.4	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	55		12.1	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	17		15.1	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	4		17.4	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	10		18.3	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	22		19.5	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	20		19.9	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	26		20.4	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	50		20.6	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	60		20.8	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	38		22.9	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	18		36.0	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	11		37.6	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	13		40.4	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	34		40.5	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	42.5		44.7	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	35		45.7	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	15		46.6	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	8		48.5	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	45		50.0	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	16		53.4	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
A	50		66.3	Iron	Melt rate in Vol 3, Em.Factor in Vol. 2 Exhibit VI-9
EAF - controlled with FF					
B	29.7	3.86	0.13	Iron	Average total catch - Facility A
B	31.8	4.27	0.13	Iron	Average total catch - Facility B
B	3.9	2.71	0.70	Iron (grey)	Average probe and filter catch - Facility C
B	4.3	1.46	0.34	Iron (grey)	Average total catch - Facility D
B	7	2.43	0.35	Iron	Average probe and filter catch - Facility E
B	16	2.43	0.15	Iron (grey)	Average probe and filter catch - Facility F
B	15	3.78	0.25	Steel	Average of four runs - Facility G
B	16	1.65	0.10	Steel	Average of two runs - Facility H
B	7.3	0.38	0.05	Steel	Average of three runs - Facility I
B	15	2.56	0.17	Steel	One 4-hour test - Facility J
B	5.5	0.64	0.12	Steel	Average of 3 runs - Facility K
EAF - uncontrolled					
B	29.7	195	6.57	Iron	Average total catch - Facility A
B	4.3	69.8	16.2	Iron (grey)	Average total catch - Facility D
A	13		12.0	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16
A	13		6.00	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16
A	5		20.0	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16
A	8		18.3	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16
A	1.7		10.0	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16
A	6.25		4.00	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16
A	5		40.0	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16

TABLE C-15. SUMMARY OF HISTORIC DATA FOR PM EMISSION FACTORS

Reference[1]	Metal rate, tons/hr	PM emission rate, lb/hr	PM emission factor, lb/ton	Foundry type	Comments
	EAF - uncontrolled (continued)				
A	1.7		12.7	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16
A	1		10.7	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16
A	1.5		13.4	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16
A	1.5		5.30	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16
A	2.6		15.3	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16
A	3		12.8	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16
A	6		6.10	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16
A	5		29.4	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16
A	3.4		12.7	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16
A	2		11.0	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16
A	8		7.50	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16
A	11		15.0	Iron	Melt rate = charge/cycle time; Em.Fact. from Vol. 2 Exhibit VI-16
	Induction furnace - uncontrolled				
C			1.50	Iron (nodular)	Cold scrap
C			1.10	Iron (malleable)	Cold scrap
C			0.75	Iron (malleable)	Hot scrap
C	3.9		0.35	Iron (malleable)	Includes charging, melting, superheating, pouring
C	3.6		0.57	Iron (malleable)	Includes charging, melting, superheating, pouring
C	3.6		0.55	Iron (malleable)	Includes charging, melting, superheating, pouring
C	0.65		0.34	Iron (ductile)	Includes charging, melting, superheating, pouring
C	0.38		0.57	Iron (ductile)	Includes charging, melting, superheating, pouring
C			0.66	Iron (ductile)	2-ton furnace
C			0.26	Iron (graphite)	2-ton furnace
C			0.31	Iron (graphite)	2-ton furnace
C	2		0.77	Iron (ductile)	
C	0.5		1.30	Steel	
C	4		3.30	Iron	30% oily borings

[1] Key to references: A - Kearney, 1971; B - EPA, 1980; C - Shaw, 1982.

TABLE C-16. UNCONTROLLED EMISSION FACTORS FOR MELTING FURNACES AND METAL TREATMENT BASED ON BAGHOUSE CATCH DATA REPORTED IN MSDIR

Facility ID	Source	PM collected, lb	Metal processed, tons	Collection period, hours	Emission factor, lb/ton	Metal type
495	Cupola	70,740	8,690	1459	8.14	Iron
465	Cupola	340	39	4.5	8.72	Gray and ductile iron
519	Cupola	548,000	44,532	2670	12.31	Gray iron
670	Cupola	200	14	4	14.29	Iron
497	Cupola	82,000	5,668	750	14.47	Gray iron
778	Cupola	3,000,000	150,000	4000	20.00	Ductile iron
81	Cupola	5,258,000	235,455	4461	22.33	Gray and ductile iron
36	Cupola	140,000	6,000	400	23.33	Iron
231	Cupola	600	25	1	24.00	Gray iron
296	Cupola	34,000	1,300	80	26.15	Iron
809	Cupola	800	28.9	1	27.68	Ductile iron pipe
808	Cupola	25,000	820	12	30.49	Ductile iron pipe
286	Cupola	1,000	30	8	33.33	Gray iron
573	Cupola	9,000	268	24	33.58	Iron
605	Cupola	3,600	100	9	36.00	Cast iron
554	Cupola	3,600	80	11	45.00	Iron
367	Cupola	20,000	312	20	64.10	Ductile iron
76	EAF	24,000	7,321	1820	3.28	Steel
358	EAF	88,000	26,137	4712	3.37	Mn steel
516	EAF	2,760,000	630,720	8760	4.38	Iron
9	EAF	506,200	87,075	6072	5.81	Steel
496	EAF	209,860	29,980		7.00	Low alloy, stainless, Mn steel.
16	EAF	1,800	239.8	24	7.51	Steel
765	EAF	726,000	86,348	5816	8.41	Steel
138	EAF	23,360	2,474	2891	9.44	Steel
814	EAF	1,557,740	136,469	5568	11.41	Steel
481	EAF	136.5	10.5	8	13.00	Low carbon and stainless steel
546	EAF	1,080	60	10	18.00	Gray and ductile iron
512	EAF	120	5.5	1	21.82	Iron
76	EAF	216,000	7,321	1820	29.50	Steel
641	EIF	20	60	24	0.33	Gray and ductile iron
534	EIF	18	20	56	0.90	Steel and stainless steel
780	EIF	24.4	23.2	1	1.05	Gray and ductile iron
561	EIF	4,080	2750	1000	1.48	Iron and steel
818	EIF	370,000	184,000	8760	2.01	Ductile iron
177	EIF	100	35	24	2.86	Gray iron
666	EIF	54,600	16,906		3.23	Gray and ductile iron
560	EIF	400	100	172	4.00	Steel and stainless steel
157	Metal treatment	360	500	9	0.72	Ductile iron
818	Metal treatment	22	12	1	1.83	Ductile iron
808	Ductile treatment	2,000	820	12	2.44	Ductile iron
649	Ductile treatment	2,000	700	10	2.86	Ductile iron
802	Ductile treatment	5,000	1,000	500	5.00	Gray and ductile iron

TABLE C-17. SUMMARY OF EMISSION FACTORS FOR UNCONTROLLED FINISHING OPERATIONS BASED ON BAGHOUSE CATCH DATA REPORTED IN MSDIR

Facility ID	Operation(s), as reported	PM collected, lb	Metal processed, tons	Collection period, hours	Emission factor, lb/ton	Metal type
802	Journal grinder	2,000	9,500	4.2	0.21	Iron, steel
453	Shot blast, finishing	0.3	1.25	1	0.24	Stainless steel
433	Arc wash riser contacts	500	1,200	320	0.42	Steel
433	Riser removal	500	1,200	320	0.42	Steel
358	Scrap preparation	11,400	26,000	4,712	0.44	Mn steel
406	Electric grinding	25	50	8	0.50	Gray Iron Castings
609	Grinding, grit blasting	2,500	4,205	2,000	0.59	Iron
462	Grinding	1,500	1476	2,838	1.02	Ni-hard iron
149	Dry grinding and welding	12,660	11,250	4,500	1.13	Carbon, low alloy steel
2	Shot blasting	8	6	·8	1.33	Carbon steel
433	Shot blasting	500	320	160	1.56	Steel
433	Shot blasting	2,000	1,200	320	1.67	Steel
542	Shot blast	400	205	2,000	1.95	Ductile & Gray Iron
332	Casting cleaning	100	50	80	2.00	Iron and steel
16	No. 5 shot blast	3,000	1400	24	2.14	Steel
516	Mechanical finishing	469,100	1,881	8,760	2.49	Iron
262	Shotblast	250	100	150	2.50	Iron
268	Shot blast	20	8	8	2.50	Iron
466	Cleaning	10	4	8	2.50	Cast iron & ductile iron
519	Shot blasting	112,000	44,532	2,670	2.52	Gray Iron Castings
465	Shotblasting	100	39	8	2.56	Gray iron and ductile iron
587	Blast Cleaning	16,200	6,000	1,774	2.70	Iron and steel
512	Iron grinding	200	70	24	2.86	Iron
609	Grit blasting	1,000	350	450	2.86	Iron
95	Casting Cleaning	20,000	6,885	1,997	2.90	Steel
385	Cutoff grinding	2,000	600	400	3.33	Iron and steel
358	Cutoff	30,000	8,500	5,814	3.53	Mn steel
358	Cutoff	30,000	8500	5,814	3.53	Mn steel
519	Grinding	170,000	44,532	2,670	3.82	Gray Iron Castings
230	Grinding	200	45	40	4.44	Unspecified
72	Shotblasting	94,000	21,000	5,000	4.48	Iron
16	No. 7 shot blast	24,000	5,152	24	4.66	Steel
384	Shotblast machines	76	16.3	16	4.66	Steel, iron
389	Grinding	14,000	3,000	6,000	4.67	Steel
599	Finishing	480	100	16	4.80	Steel
225	Blasting and Grinding	6,000	1,215	150	4.94	Grey, ductile, & malleable iron
207	Shotblast	240	48	24	5.00	Gray and ductile iron
159	Cutoff	2,000	394	2,080	5.08	Steel & stainless steel investment castings.
619	Jet blast	44,000	8,191	3,840	5.37	Steel
619	Sand blasting	44,000	8,191	3,840	5.37	Steel
619	Sand blasting	44,000	8,191	3,840	5.37	Steel
127	Shot blasting	60	11	8	5.45	Iron

TABLE C-17. SUMMARY OF EMISSION FACTORS FOR UNCONTROLLED FINISHING OPERATIONS BASED ON BAGHOUSE CATCH DATA REPORTED IN MSDIR

Facility ID	Operation(s), as reported	PM collected, lb	Metal processed, tons	Collection period, hours	Emission factor, lb/ton	Metal type
227	Cutoff	158	28.9	64	5.47	Steel
349	Electric Air Arc	2,000	340	960	5.88	Iron and steel
14	Grinding	8,000	1,300	2,000	6.15	Iron
581	Air arc cutoff	50	8.1	160	6.17	Stainless steel and superalloy
780	Grinding/shotblast	62.6	10.1	1	6.20	Gray iron and ductile iron
358	Cutoff	40,000	6,000	5,814	6.67	Mn steel
608	Shot blasting	22,500	3,250	4,500	6.92	Grey, ductile and ni-resist iron
541	Shot blast	500	72	8	6.94	Ductile & Gray Iron
147	Shotblast Castings	40	5	1	8.00	Iron
323	Blast Cleaning	40	5	1	8.00	Iron and Steel
138	Cutoff, grinding etc.	40,000	4,948	2,891	8.08	Steel
276	Cleaning	100	12	8	8.33	Iron
72	Shotblasting	176,000	21,000	5,000	8.38	Iron
358	Cutoff	134,000	15,586	5800	8.60	Mn steel
358	Cutoff	140,200	15,586	4,845	9.00	Mn steel
519	Shot blasting	410,000	44,532	2,670	9.21	Gray Iron Castings
567	Shot blast	3,600	388.8	1,920	9.26	Mild and low alloy steel
433	Sand blast castings	6,000	640	320	9.38	Steel
112	Shot blasting, grinding	3,000	300	20	10.0	Gray Iron
376	Shotblast (steel shot)	10,000	1,000	400	10.0	Steel
537	Cut-off, shot blast, grinding	500	50	24	10.0	Steel
762	Cleaning & finishing	1,000	100	20	10.0	Gray & ductile iron
810	Shotblast	2,000	192	16	10.4	Ductile iron
286	Finishing	220	20	8	11.0	Gray iron
384	Cutoff, grinding, chopping	10	0.85	16	11.8	Steel, iron
818	Grinding	1,216,000	96,360	8,760	12.6	Ductile iron
818	Grinding	1,438,000	113,880	8,760	12.6	Ductile iron
811	Grinding	38	3	1	12.7	Ductile iron
818	Grinding	13	1	1	13.0	Ductile iron
214	Grinding	80	6	16	13.3	Steel investment castings
255	Table blast	800	60	80	13.3	Steel
255	Shot blast, grinding	1,000	75	120	13.3	Steel
184	Blasting - shot	82	6.03	24	13.6	Ductile, gray, steel, niresist
529	Grinding	100	7	120	14.3	Steel
19	Grit blasting	286,000	18,739	4,000	15.3	Steel
413	Shot blast	3,360	220	20	15.3	Ductile and Gray Iron
413	Cutoff grinding	3,360	220	20	15.3	Ductile and Gray Iron
760	Shot blast	100	6.5	40	15.4	Steel
16	No. 6 shot blast	6,000	384	24	15.6	Steel
159	Grinding	4,000	256	2,080	15.6	Steel & stainless steel investment castings.
516	Mechanical finishing	2,996,000	187,753	8,760	16.0	Iron
811	Grinding	25	1.5	1	16.7	Ductile iron
811	Grinding	25	1.5	1	16.7	Ductile iron
811	Grinding	25	1.5	1	16.7	Ductile iron
818	Grinding	50	3	1	16.7	Ductile iron
140	Grinding	52,000	3,098	2,080	16.8	Gray iron castings

TABLE C-17. SUMMARY OF EMISSION FACTORS FOR UNCONTROLLED FINISHING OPERATIONS BASED ON BAGHOUSE CATCH DATA REPORTED IN MSDIR

Facility ID	Operation(s), as reported	PM collected, lb	Metal processed, tons	Collection period, hours	Emission factor, lb/ton	Metal type
388	Shot blasting	280	16.68	8	16.8	Mn steel, stainless steel, carbon steel, and nickel alloy (heat resistant)
818	Shot blasting	1,064,000	63,072	8,760	16.9	Ductile iron
818	Rotary drum cleaning	1,290,000	76,212	8,760	16.9	Ductile iron
811	Shot blasting	85	5	1	17.0	Ductile iron
811	Grinding	51	3	1	17.0	Ductile iron
811	Shot blasting	43	2.5	1	17.2	Ductile iron
811	Shot blasting	43	2.5	1	17.2	Ductile iron
388	Grinding	240	13.9	8	17.3	Mn steel, stainless steel, carbon steel, and nickel alloy (heat resistant)
255	Shotblast & grind	1,200	65	120	18.5	Steel
768	Blast cleaning/grinding	12,000	630	24	19.0	Iron
86	Shot blast, chip & spool	760	39	24	19.5	Gray iron
86	Shot blast, chip & spool	760	39	24	19.5	Gray iron
166	Casting removal	3,400	172	4,000	19.8	Steel
481	Shot blasting	200	10	9	20.0	Low carbon and stainless steel
522	Shot blast, grinding	300	15	10	20.0	Ductile iron
537	Sand blasting	200	10	24	20.0	Steel
619	Cut-off	70,000	3,454	3,840	20.3	Steel
365	Grinding	72,200	3,444	1,353	21.0	Iron
216	Manual & auto grinding	16,000	750	4,000	21.3	Iron and steel
72	Grinding	460,000	21,000	5,000	21.9	Iron
76	Shot blast	4,080	181	120	22.5	Steel
780	Shotblast	79.8	3.46	1	23.1	Gray iron and ductile iron
812	Shot blast	1,500	64.4	18	23.3	Ductile iron
385	Grinding	46,420	1,950	5,856	23.8	Iron and steel
363	Cutoff saw	12	0.5	40	24.0	Ductile and malleable iron
282	Cleaning, grinding	3,040	123.2	40	24.7	Gray iron
493	Cleaning	250	10	14	25.0	Stainless steel centrifugal castings.
493	Cleaning	250	10	7	25.0	Stainless steel centrifugal castings.
611	Finishing	500	20	40	25.0	Gray & Ductile Iron
23	Shot blast	15,200	599	2,652	25.4	Ductile iron, stainless steel, carbon steel, bronze, nickel alloys
500	Mechanical Finishing	142,000	5,545	5,297	25.6	Iron castings
306	Grinding/shotblasting	6,000	234	18	25.6	Iron
599	Finishing	260	10	16	26.0	Steel
365	Tumblast	90,200	3,444	1,722	26.2	Iron
14	Shot blasting	800	30	30	26.7	Iron
774	Cleaning & Finishing	4,000	144	24	27.8	Gray and Ductile Iron
808	Cutoff, grinder	2,000	72	12	27.8	Ductile iron pipe
363	Grinding	500	17.5	40	28.6	Ductile and malleable iron
363	Shot blast	500	17.5	40	28.6	Ductile and malleable iron
760	Grinding	100	3.25	80	30.8	Steel
492	Cleaning	4,000	127	504	31.5	Stainless and low alloy carbon steels.
818	Grinding, shot blast	1,266,000	39,420	8,760	32.1	Ductile iron
213	Blasting - shot	13,960	425	434	32.8	Iron
818	Shot blast	70	2.1	1	33.3	Ductile iron

TABLE C-17. SUMMARY OF EMISSION FACTORS FOR UNCONTROLLED FINISHING OPERATIONS BASED ON BAGHOUSE CATCH DATA REPORTED IN MSDIR

Facility ID	Operation(s), as reported	PM collected, lb	Metal processed, tons	Collection period, hours	Emission factor, lb/ton	Metal type
93	Grinding	100	3	8	33.3	Iron
93	Shot blasting	200	6	5	33.3	Iron
557	Mechanical finishing cutoff	200	6	24	33.3	Iron
818	Shot blast	590,000	17,520	8,760	33.7	Ductile iron
100	Shotblast	6,000	168	12	35.7	Gray iron
516	Mechanical finishing	3,064,000	84,998	8,760	36.0	Iron
533	High speed grinding	300	8	10	37.5	Steel
166	Gate grinding/finishing	13,000	334	4,000	38.9	Steel
140	Shot blasting	122,000	3,098	2,080	39.4	Gray iron castings
533	Pull through shot blast	200	5	10	40.0	Steel
533	Tumblast, grinding	320	8	10	40.0	Steel
533	Tumblast	320	8	10	40.0	Steel
282	Cleaning, grinding	3040	74	40	41.1	Gray iron
666	Shotblasting	153,000	3,711	1	41.2	Gray & Ductile Iron
636	Cut-off, shot blast	3,000	72	8	41.7	Iron and steel
257	Shotblast	1,800	43.1	80	41.8	Gray and ductile iron
645	Shot blasting	6,000	140	80	42.9	Iron
541	Grinding	500	11.5	8	43.5	Ductile & Gray Iron
262	Grinding	13,500	300	150	45.0	Iron
512	Rotoblast Shotblasting	3,200	70	24	45.7	Iron
471	Abrasive cleaning, blasting	220	4.8	8	45.8	Steel
581	Abrasive cutoff	2,200	44.1	160	49.9	Stainless steel and superalloy
1	Cleaning/finishing	1,500	30	40	50.0	Gray and ductile iron
169	Casting finishing	5,000	100	24	50.0	Ductile Iron
294	Finishing	200	4	175	50.0	Steel
581	Gate grinding	100	2	40	50.0	Stainless steel and superalloy
762	Cut-off, shot blast	1,000	20	10	50.0	Gray & ductile iron
7	Grinding/cleaning/deburing	544	10	40	54.4	Iron
60	Cleaning and finishing	1,500	27.5	8	54.5	Gray and ductile iron, alloy steel
523	Finishing	1,000	18	12	55.6	Grey and ductile iron
669	Grinding, shot blast	1,000	18	24	55.6	Iron, Steel, Alloy steel, Stainless steel
23	Cut-off, grinding	33,400	599	2,652	55.7	ductile iron, stainless steel, carbon steel, bronze, nickel alloys
232	2013 DISA Shotblast	10,000	175	22	57.1	Ductile iron
169	Casting cleaning	6,000	100	24	60.0	Ductile Iron
282	Cleaning	4,040	65.6	40	61.6	Gray iron
110	Shot blasting	4,000	64	40	62.5	Gray and ductile iron
309	Tumblast	1,000	16	16	62.5	Iron and steel
682	Shot blast	3,000	48	80	62.5	Iron
666	Shotblast	224,000	3,549		63.1	Gray & Ductile Iron
214	Sand blast	400	6	16	66.7	Steel investment castings
666	Shotblast	347,220	5,149	0	67.4	Gray & Ductile Iron
486	Shot blast	3,400	50	10	68.0	Iron
570	Clean castings	80,000	1,134	4,032	70.5	Iron
216	Casting removal	53,000	750	4,000	70.7	Iron and steel
1	Cleaning/finishing	3000	42	40	71.4	Gray and ductile iron
270	Grinding	480,000	6,600	1,200	72.7	Gray iron

TABLE C-17. SUMMARY OF EMISSION FACTORS FOR UNCONTROLLED FINISHING OPERATIONS BASED ON BAGHOUSE CATCH DATA REPORTED IN MSDIR

Facility ID	Operation(s), as reported	PM collected, lb	Metal processed, tons	Collection period, hours	Emission factor, lb/ton	Metal type
507	Cutoff, Grind, Shotblast	2,000	27	40	74.1	Steel
552	Shotblast	6,000	80	10	75.0	Steel
86	Shot blast, stand grind, chip & spool	4,000	52	24	76.9	Gray iron
516	Cleaning room	16,150,000	207,292	8,760	77.9	Iron
389	Shot blast	1,060,000	12,884	6,000	82.3	Steel
33	Cleaning/grinding	620	7.5	40	82.7	Gray Iron
534	Shot blasting	374	4.46	40	83.9	Steel
560	Cut off saw and stand grinding	1,320	14	30	94.3	Steel & stainless steel
499	Mechanical Finishing	56000	588	1,920	95.2	Stainless steel and steel castings
581	Grit blasting	100	1.02	40	98.0	Stainless steel and superalloy
231	Hydro shotblast	10,000	100	20	100	Grey iron
525	Shot blast, grinding	4,000	40	90	100	Gray and ductile iron
172	Blasting	3,000	28	8	107	White iron, gray iron, Ni hard & ductile/iron
508	Finishing	1,000	9	1,000	111	Iron
782	Casting cleaning	2,000	18	8	111	Gray iron
44	Cutoff, blasting, grinding	22,800	198	3,810	115	Steel
194	Hand grinding	54	0.47	40	115	Steel-cobalt-inconel
244	Surface Grinders	6,000	50	160	120	Ductile iron, carbon & low alloy steel, stainless & high alloy steel
782	Casting cleaning	3,000	25	8	120	Gray iron
63	Cutoff, shot blast, grinding	3,200	25	24	128	Gray & ductile castings
60	Heat treating, cleaning	1,000	7.5	8	133	Gray and ductile iron, alloy steel
184	Shotblast	400	3	24	133	Ductile, gray, steel, niresist
216	Casting cleaning	100,000	750	4,000	133	Iron and steel
241	Tumbleblast	180	1.3	8	138	Iron
37	Grinding and finishing	1,000	6.6	8	152	Gray iron
60	Casting cleaning	1,500	8	8	188	Gray and ductile iron, alloy steel
610	Grit blasting	2,000	10	100	200	Steel
37	Casting cleaning	1,500	7	8	214	Gray iron
166	Casting cleaning	76,000	334	4,000	228	Steel
581	Sand/grit blasting	1,520	6.1	80	249	Stainless steel and superalloy
110	Grinding	8,000	32	40	250	Gray and ductile iron
282	Cleaning	5,060	19.6	40	258	Gray iron
782	Casting cleaning	5,000	15	8	333	Gray iron
123	Heat treating, grinding	20,000	53	40	377	Steel and stainless steel
782	Casting cleaning	3,000	6	8	500	Gray iron
214	Sand blasting	3,120	6	16	520	Steel investment castings
16	Tumble blast	6,000	8	24	750	Steel

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APPENDIX D

SOURCE TEST PARTICULATE MATTER DATA FOR CUPOLA BAGHOUSES

D.1 SOURCE TEST PARTICULATE MATTER DATA FOR CUPOLA BAGHOUSES

This appendix presents the individual sampling run data for the source tests available to characterize the control performance for baghouses applied to cupolas (Chapter 4). Summary test data are given in Table D-1 along with information on melting rates and capacities and a description of the control systems and the processes they serve.

The data in Table D-1 represent a range of cupola sizes and types of baghouses. The design melting rates range from 3.5 to 80 tons per hour, and ventilation rates range from 30,000 to 195,000 actual cubic feet per minute. The cupolas include both recuperative and non-recuperative, and both above and below charge take off. The baghouses include both negative and positive pressure operating modes and employ both shaker and pulse jet cleaning systems. Some were installed about 30 years ago, and some are relatively new (rebuilt). The design air-to-cloth ratios cover a range of 1.68 to 5.1 feet per minute. No information is available on the ages of the bags in service when the tests were conducted.

The reported results were checked to ensure the weights of PM from the filter and the probe catch were above detection limits. When the reported catch was less than 3 mg, a detection limit value of 3 mg and the sample volume were used to estimate the detection limit in gr/dscf. Values calculated in this manner are reported as "less than" (<).

TABLE D-1. PM SOURCE TEST RESULTS FOR BAGHOUSES SERVING CUPOLAS

Foundry WI-35 (tested March 1998)									
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air:cloth ratio (ft/min)	Melt rate (tph)	Cupola information	Baghouse information
1	<0.0006	<0.4	75,974	107,297	271	1.7		45 tph capacity, afterburner, recuperative, above charge takeoff	Installed 1998, negative pressure, pulse jet, horizontally-supported bags, 10.8 oz Nomex fabric, air:cloth = 2.4 ft/min, design for 280°F and 148,000 acfm
2	<0.0006	<0.4	75,412	107,145	273	1.7			
3	<0.0006	<0.4	74,847	105,854	274	1.7			
Avg	<0.0006	<0.4	75,411	106,765	273	1.7			
Foundry WI-35 (tested November 1998)									
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air:cloth ratio (ft/min)	Melt rate (tph)		
1	<0.0007	<0.4	59,651	86,905	279	1.4	40		
2	<0.0008	<0.4	56,350	81,221	270	1.3	40		
3	<0.0008	<0.4	57,002	82,220	271	1.3	42.5		
Avg	<0.0008	<0.4	57,668	83,449	273	1.3	41		
Foundry WI-35 (tested May 2000)									
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air:cloth ratio (ft/min)	Melt rate (tph)		
1	<0.0007	<0.4	61,074	88,945	271	1.4			
2	<0.0007	<0.4	60,856	88,346	269	1.4			
3	<0.0007	<0.4	61,132	88,483	267	1.4			
Avg	<0.0007	<0.4	61,021	88,591	269	1.4			

Foundry IN-01 (tested March 2000)									
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air:cloth ratio (ft/min)	Melt rate (tph)	Cupola information	Baghouse information
1	0.00086	0.43	58,178	81,782	259		69.5	75 tph capacity, afterburner, below charge takeoff	New baghouse, pulse jet, horizontally-supported bags
2	0.00079	0.42	61,481	87,303	270		61.8		
3	0.00069	0.39	65,454	95,494	293		68.6		
Avg	0.00078	0.41	61,704	88,193	274		66.6		
Foundry MI-26 (tested December 1995)									
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air:cloth ratio (ft/min)	Melt rate (tph)	Cupola information	Baghouse information
1	0.0012	0.22	20,987				10	15 tph capacity, afterburner, above charge takeoff	Installed 1995, positive pressure, shaker, fiberglass fabric, air:cloth = 0.75 ft/min, design for 500°F and 25,700 acfm
2	0.0023	0.40	20,987						
3	0.0017	0.29	21,029						
Avg	0.0017	0.30	21,001						
Foundry NC-05 (tested February 2000)									
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air:cloth ratio (ft/min)	Melt rate (tph)	Cupola information	Baghouse information
1	0.0019	1.15	65,932	102,298	288	2.3	62.9	70 tph capacity, afterburner, above charge takeoff	New baghouse, negative pressure, pulse jet, air:cloth = 1.76 ft/min, design for 350°F and 79,000 acfm
2	0.0027	1.69	64,883	105,026	292	2.3	59.8		
3	0.0019	1.14	64,879	102,995	296	2.3	65.3		
Avg	0.0022	1.33	65,231	103,440	292	2.3	62.7		

Foundry NJ-3 (tested August 1991)									
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air:cloth ratio (ft/min)	Melt rate (tph)	Cupola information	Baghouse information
1	0.0048	12.7	306,488	390,656	213	3.5	87	2 cupolas with 64 tph capacity (only one operates at a time), afterburner, recuperative, below charge takeoff	Installed 1974, positive pressure, shaker, fiberglass fabric, air:cloth = 1.75 ft/min, design for 500°F and 195,000 acfm, controls melting
2	0.0055	11.2	238,254	305,489	217	2.7	67		
3	0.0026	3.5	159,297	211,491	241	1.9	88		
Avg	0.0043	8.9	234,680	304,017	224	2.7	81		

Foundry NJ-3 (tested September 1997)							
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air:cloth ratio (ft/min)	Melt rate (tph)
1	0.0012	3.06	219,000	263,000	175	2.4	80
2	0.0023	1.89	220,100	282,000	216	1.9	90
3	0.0014	2.99	240,200	316,000	235	2.8	75
Avg	0.0016	2.6	226,433	287,000	209	2	82

Foundry IN-34 (tested September 1997)									
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air:cloth ratio (ft/min)	Melt rate (tph)	Cupola information	Baghouse information
1	0.0026	0.71	32,100	45,000	231	1.2	53	80 tph capacity, afterburner, recuperative, below charge takeoff	Installed 1997, negative pressure, pulse jet, Nomex, air:cloth = 1.8 ft/min, design for 320°F and 70,000 acfm, controls melting and charging
2	<0.0003	<0.14	49,700	69,600	253	1.8	41		
3	0.0011	0.46	48,500	68,200	254	1.8	47		
Avg	<0.0013	<0.5	40,300	56,600	243	1.5	50		

Foundry VA-8 (tested January 1998)									
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air:cloth ratio (ft/min)	Melt rate (tph)	Cupola information	Baghouse information
1	0.0039	1.64	48,697	70,363	278	2.6	49	2 cupolas with 65 tph capacity (only one operates at a time), afterburner, recuperative, below charge takeoff	Installed 1997, negative pressure, pulse jet, Nomex, air:cloth = 3.74 ft/min, design for 375°F and 100,000 acfm, controls melting and charging
2	0.0028	1.14	47,588	69,934	281	2.6	51		
3	0.0026	1.08	48,934	72,472	283	2.7	53		
Avg	0.0031	1.29	48,407	70,923	281	2.6	51		

Foundry FL-6 (tested February 1998)									
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air:cloth ratio (ft/min)	Melt rate (tph)	Cupola information	Baghouse information
1	0.0028	0.52	21,976	35,420	246	0.9	17.7	22 tph capacity, afterburner, recuperative, above charge takeoff	Installed 1998, negative pressure, reverse air, fiberglass fabric, air:cloth = 1.68 ft/min, design for 460°F and 65,000 acfm, controls melting and charging
2	0.0031	0.67	25,178	42,114	266	0.7	19.8		
3	0.0051	1.11	25,288	41,495	272	0.7	25.1		
Avg	0.0037	0.77	24,147	39,676	261	0.8	20.9		

Foundry IA-19 (tested February 1998)									
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air:cloth ratio (ft/min)	Melt rate (tph)	Cupola information	Baghouse information
1	0.0026	0.92	41,861	58,271	245	4.2	13.5	20 tph capacity, afterburner, recuperative, below charge takeoff	Installed 1992, negative pressure, pulse jet, Nomex felt fabric, air:cloth = 5.1 ft/min, design for 450°F and 70,000 acfm, controls melting, charging, tapping
2	0.0015	0.58	46,281	63,363	233	4.6	13.5		
3	0.0022	0.90	46,811	64,433	238	4.7	13.5		
Avg	0.0021	0.80	44,984	62,022	239	4.5	13.5		

Foundry IN-35 (tested November 1997)									
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air:cloth ratio (ft/min)	Melt rate (tph)	Cupola information	Baghouse information
1	0.0044	1.71	45,055	66,407	213	4.1		22 tph capacity, afterburner, nonrecuperative, above charge takeoff	Installed 1997, positive pressure, pulse jet, Tuflex fabric, air:cloth = 4.65 ft/min, design for 400°F and 75,000 acfm, controls melting
2	0.0043	1.68	44,780	66,018	215	4.1			
3	0.0043	1.66	44,773	66,532	212	4.1			
Avg	0.0043	1.69	44,869	66,319	213	4.1			

Foundry SD-1 (tested March 1995)									
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air:cloth ratio (ft/min)	Melt rate (tph)	Cupola information	Baghouse information
1	0.0058	0.72	14,580	20,403	227	2.7	4.3	3.5 tph capacity, no afterburner, nonnonrecuperative, above charge takeoff	Installed 1994, negative pressure, pulse jet, 16 oz Nomex fabric, air:cloth = 3.96 ft/min, design for 400°F and 30,000 acfm, controls melting and charging
2	0.0035	0.48	16,008	21,992	216	2.9	4.3		
3	0.0047	0.62	15,336	21,567	231	2.9	6.4		
Avg	0.0046	0.61	15,308	21,321	225	2.8	5.0		

Foundry WI-49/50 (tested September 1995)									
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air:cloth ratio (ft/min)	Melt rate (tph)	Cupola information	Baghouse information
1	0.0044	1.2	30,852	59,684	338	3.0	29.7	2 cupolas, 30 tph capacity, afterburner, recuperative, above charge takeoff	Installed 1994, negative pressure, pulse jet, woven fiberglas fabric, air:cloth = 2.4 to 3.7 ft/min, design for 450°F and 50,000 to 70,000 acfm, controls melting
2	0.0047	1.2	30,826	59,347	332	3.0	28.4		
3	0.0060	1.5	29,750	60,281	339	3.0	24.4		
Avg	0.0050	1.3	30,476	59,771	336	3.0	27.5		

APPENDIX E

SOURCE TEST PARTICULATE MATTER DATA FOR ELECTRIC INDUCTION FURNACE FILTERS

E.1 INTRODUCTION

This appendix presents the individual sampling run data for the source tests available to characterize the control performance for fabric and cartridge filters applied to EIF (Chapter 4). Summary test data are given in Table E-1 along with information on furnace melting rates and capacities and a description of the filters and the processes they serve.

The data in Table E-1 represent a range of furnace sizes and types of filters. The design furnace melting rates range from 0.8 to 15 tons per hour, and ventilation rates range from 6,500 to 225,000 acfm. All of the foundries produce iron in the furnaces tested. The filters include both negative and positive pressure operating modes and employ both shaker and pulse jet cleaning systems. Some were installed about 20 to 25 years ago, and some are relatively new (rebuilt). The design air-to-cloth ratios cover a range of 1.7 to 11.8 ft/min. No information is available on the ages of the bags in service when the tests were conducted.

The reported results were checked to ensure the weights of PM from the filter and the probe catch were above detection limits. When the reported catch was less than 3 mg, a detection limit value of 3 mg and the sample volume were used to estimate the detection limit in gr/dscf. Values calculated in this manner are reported as "less than" (<).

TABLE E-1. PM TEST RESULTS FOR FILTERS SERVING EIF AND SCRAP PREHEATERS

Foundry MI-04 (tested August 1994)								
Run	PM* (gr/dscf)	PM* (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	<0.0006	<0.027					4.1	Negative pressure, pulse jet cleaning Fabric: polyester Design gas flow rate: 50,000 acfm Design operating temperature: 80°F Design air-to-cloth ratio: 6 ft/min Serves 3 EIF, 1.5 tons/hr design melt rate for each
2	<0.0006	<0.027						
3	<0.0006	<0.027						
Avg	<0.0006	<0.027						
* The results were reported as <0.0002 gr/dscf and were adjusted to <0.0006 gr.dscf based on the best estimate of the detection limit.								
Foundry CA-01 (tested March 1996)								
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	<0.0002	<0.05	41,000	43,110	90	2.56	1.3	Positive pressure, shaker cleaning; in series with 2 prefilters and a HEPA filter Fabric: polyester Design gas flow rate: 49,600 acfm Design operating temperature: 81°F Design air-to-cloth ratio: 2.95 ft/min Serves 8 EIF, (0.5 to 1.75 tons/hr design melt rate), 4 casting stations, 4 mold spray/coating stations, 1 Hawley system

Foundry IN-13 (tested October 1996)								
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	<0.0006	<0.34	66,943	71,590	95	2.91	33.8	Negative pressure, pulse jet cleaning Fabric: polyester Design gas flow rate: 72,500 acfm Design operating temperature: 150°F Design air-to-cloth ratio: 2.95 ft/min Installed 1995 Serves 3 EIF, 10.7 tons/hr design melt rate for each; controls charging, melting, holding furnaces, ladle metallurgy
2	<0.0006	<0.34	66,453	72,190	102	2.94		
3	<0.0006	<0.34	67,590	73,100	100	2.97		
Avg	<0.0006	<0.34	66,995	72,290	99	2.94		

Foundry WI-43 (tested November 1997)								
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	<0.0010	<0.6	60,236	66,964	111	4.0	112	Negative pressure, pulse jet cleaning Fabric: polyester Design gas flow rate: 110,000 acfm Design operating temperature: 100°F Design air-to-cloth ratio: 6.5 ft/min Installed 1995 Serves 10 EIF, 11 tons/hr design melt rate each; controls charging, melting, magnesium treatment
2	<0.0011	<0.6	59,491	66,543	115	3.9	114	
3	<0.0011	<0.6	58,117	65,870	122	3.9	137	
Avg	<0.0011	<0.6	59,281	66,459	116	3.9	121	

Foundry WI-43: scrap preheater only (tested November 1997)								
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Preheat rate (tph)	Baghouse design and service data
1	<0.0007	<0.4	71,594	88,045	169	7.8	56	Negative pressure, pulse jet cleaning Fabric: fiberglass Design gas flow rate: 80,000 acfm Design operating temperature: 310°F Design air-to-cloth ratio: 7.1 ft/min Installed 1995 Serves 3 scrap preheaters, 33 tons/hr design rate each
2	<0.0007	<0.4	72,303	88,649	167	7.9	69	
3	<0.0007	<0.4	73,230	87,282	149	7.7	58	
Avg	<0.0007	<0.4	72,376	87,992	162	7.8	61	

Foundry MN-7 (tested August 1996)								
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	<0.0010	<1.0	110,900	118,500	99	3.9	7.55	Negative pressure, pulse jet cleaning Fabric: polyester (Dacron) felt (16 oz) singed finish Design gas flow rate: 119,300 acfm Design operating temperature: 103°F Design air-to-cloth ratio: 3.9 ft/min Installed 1991; Serves one EIF, 15.2 tons/hr design melt rate; controls charging, melting, tapping, holding furnaces, ladle metallurgy, pouring/cooling
2	<0.0013	<1.2	111,900	120,600	103	3.9		
3	0.0014	1.3	109,600	118,800	107	3.9		
Avg	<0.0012	<1.2	110,800	119,300	103	3.9		

Foundry WI-47 (tests of 3 systems)								
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Melt rate (tph)	Design and service data
Avg	0.0011	0.4	44,052				3.0	Negative pressure, pulse jet cleaning Fabric: polyester Design gas flow rate: 50,000 acfm Design air-to-cloth ratio: 7 ft/min Installed 1991 Serves preheater and one EIF, 3.5 tons/hr design melt rate; controls charging, melting
Avg	0.0006	0.22	46,032				2.8	Negative pressure, pulse jet cartridge cleaning Fabric: cartridge collector Design gas flow rate: 40,000 acfm Design air-to-cloth ratio: 1.3 ft/min Installed 1991 Serves two EIFs, 5 tons/hr design melt rate for each; controls charging, melting; also controls inoculation and cast cooling
Avg	0.0052	2.92	65,132				4.4	Venturi scrubber with <13 in water pressure drop; 73,500 acfm Serves two EIF for melting (5 tph each); also pouring and cooling

Foundry IN-24 (tested December 1996)								
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Melt rate (tph)	Cartridge filter design and service data
1	0.0017	0.34	23,050	23,111	62	1.55	4.4	Negative pressure, pulse jet cartridge cleaning Fabric: cellulose cartridge Design gas flow rate: 25,000 acfm Design operating temperature: 180°F Design air-to-cloth ratio: 1.68 ft/min Installed 1996 Serves two EIF, 4.5 tons/hr design melt rate controls charging, melting, tapping
2	0.0014	0.28	23,171	23,074	59	1.55		
3	0.0026	0.50	22,909	22,842	60	1.53		
Avg	0.0019	0.37	23,043	23,009	61	1.55		

Foundry CA-09 (tested October 1987)								
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	0.0015	0.076	5,906	6,503	102	1.4	0.8	Negative pressure, shaker cleaning Fabric: polyester Design gas flow rate: 9,600 acfm Design operating temperature: 130°F Design air-to-cloth ratio: 2 ft/min Installed 1997 Serves three EIFs, two at 0.8 tph and one at 1.5 tph design melt rate each; controls melting, charging, preheater, and sand reclaimer
2	0.0023	0.113	5,727	6,427	113	1.3		
3	0.003	0.145	5,630	6,426	121	1.3		
Avg	0.0023	0.11	5,754	6,452	112	1.3		

Foundry MN-12 (tested March 1995 and May 1996)								
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	0.0034	0.38	13,200	13,500	86	2.54	5.8	Positive pressure, shaker cleaning Fabric: felt Design gas flow rate: 29,800 acfm Design operating temperature: 100°F Design air-to-cloth ratio: 2.8 ft/min Installed 1980 Serves two EIF, 4.7 tons/hr design melt rate each; controls charging, melting, tapping, ladle metallurgy; two stacks on baghouse
2	0.0014	0.14	11,700	12,200	90	2.29	6.0	
3	0.0024	0.21	10,300	11,000	78	2.07	6.3	
4	0.0022	0.24	12,700	13,100	86	2.46	5.8	
5	0.0026	0.31	13,700	14,100	82	2.65	6.4	
6	0.0012	0.14	13,800	14,200	84	2.67	6.4	
Avg	0.0022	0.47*	25,100*	26,000*	84	2.45	6.1	
1	0.0009	0.11	14,700	15,600	105	2.93	5.2	
2	0.0016	0.19	14,000	14,900	104	2.80	5.3	
3	0.0028	0.35	14,400	15,500	111	2.91	5.3	
4	0.0005	0.06	13,800	14,700	105	2.76	5.1	
5	0.0006	0.07	14,200	14,700	89	2.76	5.3	
6	0.0019	0.22	13,500	14,200	95	2.67	5.3	
Avg	0.0014	0.33*	28,200*	29,900*	102	2.80	5.2	

* The baghouse has two stacks; Runs 1-3 are for one stack and Runs 4-6 are for the other stack.

Foundry PA-06 (tested July 1995; one of two baghouses in parallel)								
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	0.0022	0.71	37,936	41,151	106		8.0	Negative pressure, reverse pulse cleaning (two baghouses in parallel) Fabric: polyester Design gas flow rate: 95,094acfm for two baghouses Design operating temperature: 120°F Design air-to-cloth ratio: 4.38 ft/min Installed 1996 Serves one EIF at10 tons/hr design melt rate each; also controls inoculation and carbon/silicon adjustment
2	0.00124	0.39	36,578	40,150	108			
3	0.00064	0.2	36,267	39,414	104			
Avg	0.0014	0.43	36,927	40,238	106			

Foundry PA-06 (tested July 1995; one of two stacks; doubled flow and emission rate to estimate for both stacks)								
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	0.00225	1.32	68,464	75,040	97		8.0	Negative pressure, reverse pulse cleaning (two baghouses in parallel) Fabric: polyester Design gas flow rate: 95,094acfm for two baghouses Design operating temperature: 120°F Design air-to-cloth ratio: 4.57 ft/min Installed 1996 Serves one EIF at10 tons/hr design melt rate each; also controls inoculation and carbon/silicon adjustment
2	0.00116	0.68	68,402	75,204	95			
3	0.00117	0.68	68,094	74,434	93			
Avg	0.0015	0.89	68,320	74,893	95			

Foundry OH-43 (tested October 1997)								
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Melt rate (tph)[2]	Baghouse design and service data
1	0.0038	2.25	69,695	74,979	83	6.04	9.4	Negative pressure, pulse jet cleaning Fabric: polyester Design gas flow rate: 65,000 acfm Design operating temperature: 90-110°F Design air-to-cloth ratio: 5.24 ft/min Installed 1996 Serves two EIF, 15 tons/hr design melt rate each; controls melting, grinding, shot blasting, pouring
2	0.0013	0.81	71,174	76,590	83	6.17	5.9	
3	0.0018	1.09	71,568	78,190	93	6.30	12.2	
Avg	0.0023	1.38	70,812	76,586	86	6.34	9.2	

[2] Tons per hour transferred; both furnaces were operating, but there was only one charge during the test. Test includes both melting and holding.

Foundry TX-11 (tested October 1993)								
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	0.0030	2.29	81,362	93,159	95	3.11	3.85	Negative pressure, shaker cleaning Fabric: Nomex Design gas flow rate: 90,000 acfm Design operating temperature: 100°F Design air-to-cloth ratio: 3 ft/min Installed 1977 Serves one EIF, 3.75 tons/hr design melt rate; controls charging, melting, tapping, ladle metallurgy
2	0.0021	1.74	77,351	90,950	111	3.03		
3	0.0020	1.71	76,379	90,057	112	3.00		
Avg	0.0024	1.91	78,364	91,389	106	3.05		

Foundry MI-28 (tested March 1996)								
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	0.0031	1.03	38,480			2.10	5.20	Negative pressure, pulse jet cleaning Fabric: Polyester Design gas flow rate: 70,000 acfm Design operating temperature: 135°F Design air-to-cloth ratio: 3.9 ft/min Installed 1995 Serves 3 EIFs, 9 tons/hr design melt rate and 2 scrap preheaters; controls charging, melting, tapping
2	0.0028	0.94	39,512			2.20		
3	0.0027	0.96	41,190			2.30		
Avg	0.0029	1.03	39,728			2.20		

Foundry IN-11 (tested September 1990)								
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	0.0032	1.435	52,383	61,842	143	2.14	Unknown	Negative pressure, pulse jet cleaning Fabric: polyester (Dacron) Design gas flow rate: 100,000 acfm Design operating temperature: unknown Design air-to-cloth ratio: 3.46 ft/min Installed 1990 Two identical baghouses serving three EIF each, 10 tons/hr design melt rate each; controls preheater, charging, melting, tapping
2	0.0050	2.217	52,200	62,017	143	2.15		
3	0.0026	1.140	52,100	61,534	142	2.13		
Avg	0.0036	1.597	52,228	61,798	143	2.14		
1	0.0019	1.456	89,280	103,143	135	3.57		
2	0.0037	2.827	88,683	102,427	136	3.54		
3	0.0017	1.303	89,633	104,083	139	3.60		
Avg	0.0024	1.862	89,199	103,218	137	3.57		

Foundry IN-29 (tested February 1997)								
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	0.0025	0.85	40,367	42,354	86	12.5	24	Positive pressure, pulse jet cleaning Fabric: polyester felt Design gas flow rate: 40,000 acfm Design operating temperature: 175°F Design air-to-cloth ratio: 11.8 ft/min Installed 1996 Serves two EIF, 10.5 tons/hr design melt rate; controls preheating, melting
2	0.0017	0.59	39,694	41,609	85	12.3	20	
3	0.0076	2.56	39,033	41,037	86	12.1	23	
Avg	0.0039	1.33	39,698	41,667	86	12.3	23	

Foundry IN-12 (tested March 1990)								
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	0.0056	2.38	49,122	51,817	99		15	Uncontrolled induction furnaces (3 at 5 tph)
2	0.0068	2.86	49,247	51,865	99			
Avg	0.0062	2.62	49,185	51,841	99			

Foundry PA-46 (tested October 1995)								
Run	PM (gr/dscf)	PM (lb/hr)	Flow (dscfm)	Flow (acfm)	Temp (°F)	Air-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	0.008	10.76	155,000				15	Negative pressure, pulse jet cleaning Fabric: polyester Design gas flow rate: 225,000 acfm Design operating temperature: 100°F Design air-to-cloth ratio: 6.8 ft/min Installed 1995 Serves five EIF, 3.3, 3.3, 4.1, 6.8, and 12.7 tons/hr design melt rate; controls charging, melting, tapping
2	0.009	11.25	150,000					
3	0.008	10.55	155,000					
Avg	0.008	10.85	153,000					

APPENDIX F

SOURCE TEST PARTICULATE MATTER DATA FOR ELECTRIC ARC FURNACE BAGHOUSES

F.1 INTRODUCTION

This appendix presents the individual sampling run data for the source tests available to characterize the control performance for baghouses applied to EAF (Chapter 4). Summary test data are given in Table F-1 along with information on furnace melting rates and capacities and a description of the control systems and the processes they serve.

The data in Table F-1 represent a range of furnace sizes and types of baghouses. The design furnace melting rates range from 2.5 to 15 tons per hour, and ventilation rates range from 31,000 to 225,000 acfm. The baghouses include both negative and positive pressure operating modes and employ both shaker and pulse jet cleaning systems. Some were installed about 30 years ago, and some are relatively new (rebuilt). The design air-to-cloth ratios cover a range of 2.3 to 5.7 ft/min. No information is available on the ages of the bags in service when the tests were conducted.

The reported results were checked to ensure the weights of PM from the filter and the probe catch were above detection limits. When the reported catch was less than 3 mg, a detection limit value of 3 mg and the sample volume were used to estimate the detection limit in gr/dscf. Values calculated in this manner are reported as "less than" (<).

TABLE F-1. PM TEST RESULTS FOR BAGHOUSES SERVING EAF

Foundry IN-7 (tested December 1997)								
Run	PM loading (gr/dscf)	PM mass flow rate (lb/hr)	Flow rate (dscfm)	Flow rate (acfm)	Temp, (°F)	Air-to-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	0.0006	0.15	29,200				3.7	Negative pressure; shaker cleaning. Fabric: Dacron/cotton. Design gas flow rate: 31,200 acfm. Design operating temperature: 100 °F. Design air-to-cloth ratio: 2.51 ft/min. Rebuilt 1985. Serves one EAF, 3.6 tons/hr design melt rate.
2	0.0004	0.11	32,100				3.7	
3	0.0005	0.13	30,300				3.1	
Average	0.0005	0.13	30,500				3.5	
Foundry IA-09 (tested August 1996)								
Run	PM loading (gr/dscf)	PM mass flow rate (lb/hr)	Flow rate (dscfm)	Flow rate (acfm)	Temp, (°F)	Air-to-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	0.00083	0.62	85,099	87,520	127	2.4	5.65	Positive pressure; shaker cleaning. Fabric: 10.5 oz. polyester. Design gas flow rate: 85,000 acfm Design operating temperature: 90 °F. Design air-to-cloth ratio: 2.36 ft/min. Installed 1974. Serves two EAFs, 6.0 tons/hr design melt rate each, one holding furnace with 61 tons capacity, and one holding furnace with 40 tons capacity.
2	0.00063	0.47	85,200	87,030	129	2.4		
3	0.00041	0.29	79,414	81,406	126	2.3		
Average	0.00062	0.46	83,238	85,319	127	2.4		

Foundry IA-09 (tested July 2002)								
Run	PM loading (gr/dscf)	PM mass flow rate (lb/hr)	Flow rate (dscfm)	Flow rate (acfm)	Temp, (°F)	Air-to-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	0.0007	0.51	85,927	93,624	127	2.6	5.65	Positive pressure; shaker cleaning. Fabric: 10.5 oz. polyester. Design gas flow rate: 85,000 acfm Design operating temperature: 90 °F. Design air-to-cloth ratio: 2.36 ft/min. Installed 1974. Serves two EAFs, 6.0 tons/hr design melt rate each, one holding furnace with 61 tons capacity, and one holding furnace with 40 tons capacity.
2	0.0007	0.50	83,992	89,854	117	2.5		
3	0.0006	0.42	80,727	86,978	121	2.4		
Average	0.00067	0.48	83,549	90,152	122	2.5		

Foundry IA-09 (tested May 1995)								
Run	PM loading, gr/dscf	PM mass flow rate, lb/hr	Flow rate, dscfm	Flow rate, acfm	Temp, °F	Air-to-cloth ratio, ft/min	Melt rate (tph)	Baghouse design and service data
1	0.0013	1.0	87,520				---	Positive pressure; shaker cleaning. Fabric: 10.5 oz. polyester. Design gas flow rate: 85,000 acfm Design operating temperature: 90 °F. Design air-to-cloth ratio: 2.36 ft/min. Installed 1974. Serves two EAFs, 6.0 tons/hr design melt rate each, one holding furnace with 61 tons capacity, and one holding furnace with 40 tons capacity.
2	0.001	0.63	87,030				---	
3	0.00072	0.50	81,406				---	
Average	0.0010	0.71	85,319				5.65 total	

Foundry TX-19 (January 1995)								
Run	PM loading, gr/dscf	PM mass flow rate, lb/hr	Flow rate, dscfm	Flow rate, acfm	Temp, °F	Air-to-cloth ratio, ft/min	Melt rate (tph)	Baghouse design and service data
1	0.0030	1.18	46,100	51,000	114	2.34		Negative pressure; shaker cleaning. Fabric: 10.5 oz. seamless polyester. Design gas flow rate: 50,000 acfm. Design operating temperature: 250 °F. Design air-to-cloth ratio: 2.30 ft/min. Serves two EAFs, 5 tons/hr design melt rate each.
2	<0.0013	<0.5	47,700	52,500	114	2.41		
3	<0.0013	<0.5	46,700	51,600	118	2.37		
Average	<0.002	<0.7	46,800	51,700	115	2.37		
Foundry AL-11 (tested September 1995)								
Run	PM loading, gr/dscf	PM mass flow rate, lb/hr	Flow rate, dscfm	Flow rate, acfm	Temp, °F	Air-to-cloth ratio, ft/min	Melt rate (tph)	Baghouse design and service data
1	0.0019	1.77	109,000	122,000	121	3.05	9.1, 9.4	Negative pressure; pulse jet cleaning. Fabric: 18 oz. polyester dual density felt. Design gas flow rate: 140,000 acfm. Design operating temperature: 200 °F. Design air-to-cloth ratio: 3.50 ft/min. Rebuilt 1995. Serves two EAFS, 9.25 tons/hr design melt rate each.
2	0.0017	1.58	108,000	123,000	130	3.08	9.4, 9.5	
3	0.0009	0.87	113,000	127,000	126	3.18	9.1, 9.5	
Average	0.0015	1.41	110,000	124,000	126	3.10	9.2, 9.5	

Foundry MN-3 (tested May 1993)								
Run	PM loading, gr/dscf	PM mass flow rate, lb/hr	Flow rate, dscfm	Flow rate, acfm	Temp, °F	Air-to-cloth ratio, ft/min	Melt rate (tph)	Baghouse design and service data
1	0.0021	2.64	146,200	155,600	84	2.27	4.8, 3.9	Negative pressure; shaker cleaning. Fabric: polyester. Design gas flow rate: 180,000 acfm Design operating temperature: 100°F Design air-to-cloth ratio: 2.4 ft/min Installed 1980. Serves two EAFs, 4.3 tons/hr design melt rate each.
2	0.0019	2.29	142,200	150,000	85	2.19	4.8, 4.4	
3	0.0019	2.45	151,000	157,100	85	2.30	6.3, 4.4	
Average	0.0020	2.46	146,500	154,200	85	2.25	5.3, 4.2	

Foundry MI-09 (tested October 1996)								
Run	PM loading (gr/dscf)	PM mass flow rate (lb/hr)	Flow rate (dscfm)	Flow rate (acfm)	Temp, (°F)	Air-to-cloth ratio (ft/min)	Melt rate (tph)	Baghouse design and service data
1	0.0044	1.03	26,702	31,467	144		12	Positive pressure; shaker cleaning. Fabric: Polyester. Design gas flow rate: 200,000 acfm. Design operating temperature: 170 °F. Design air-to-cloth ratio: 2.33 ft/min. Built 1987. Serves three EAF, 15 tons/hr design melt rate.
2	0.0030	0.69	26,365	31,868	159			
3	0.0017	0.39	26,716	31,447	143			
4	0.0015	0.35	26,544	31,654	151			
Average	0.0027	0.62	26,582	31,609	149			

Foundry OH-1 (tested March 1994)								
Run	PM loading, gr/dscf	PM mass flow rate, lb/hr	Flow rate, dscfm	Flow rate, acfm	Temp, °F	Air-to-cloth ratio, ft/min	Melt rate (tph)	Baghouse design and service data
1	0.0025	4.45	208,000	234,000	96			Design gas flow rate: 225,000 acfm. Design operating temperature: 150 °F. Design air-to-cloth ratio: Serves three EAFs, 13 tons/hr design melt rate each.
2	0.0030	5.26	205,000	230,000	103			
3	0.0025	4.42	206,000	230,000	102			
Average	0.0027	4.71	206,000	231,000	100			

Foundry OH-1 (tested May 1997)								
Run	PM loading, gr/dscf	PM mass flow rate, lb/hr	Flow rate, dscfm	Flow rate, acfm	Temp, °F	Air-to-cloth ratio, ft/min	Melt rate (tph)	Baghouse design and service data
1	0.0063							
2	0.0076							
3	0.0059							
Average	0.0066							

Foundry WI-45 (tested September 1990)								
Run	PM loading, gr/dscf	PM mass flow rate, lb/hr	Flow rate, dscfm	Flow rate, acfm	Temp, °F	Air-to-cloth ratio, ft/min	Melt rate (tph)	Baghouse design and service data
1	0.0033	1.97	33,550				2.07	Positive pressure; shaker cleaning. Fabric: polyester/cotton. Design gas flow rate: 35,000 Design operating temperature: 125 °F. Design air-to-cloth ratio: 5.7 ft/min. Installed 1979. Serves one EAF, 2.5 tons/hr design melt rate and sand mulling.
2	0.0025	1.45	33,800				2.16	
3	0.0035	1.77	33,667				2.46	
Average	0.0031	1.73	33,700				2.23	

Foundry IA-17 (tested January 1995)								
Run	PM loading, gr/dscf	PM mass flow rate, lb/hr	Flow rate, dscfm	Flow rate, acfm	Temp, °F	Air-to-cloth ratio, ft/min	Melt rate (tph)	Baghouse design and service data
1	0.0069	5.35	82,000				8.3, 11.6	Negative pressure; shaker cleaning. Fabric: woven Dacron. Design gas flow rate: 120,383. Design operating temperature: 182 °F. Design air-to-cloth ratio: 2.59 ft/min. Installed 1972. Serves two EAFs, 12 tons/hr design melt rate each.
2	0.0029	2.55	92,100				9.6, 14.1	
3	0.0035	2.68	85,200					
Average	0.0044	3.53	86,400					

Foundry PA-11 (tested November 1994)								
Run	PM loading, gr/dscf	PM mass flow rate, lb/hr	Flow rate, dscfm	Flow rate, acfm	Temp, °F	Air-to-cloth ratio, ft/min	Melt rate (tph)	Baghouse design and service data
1	0.0058	4.9	99,000				15.1	Negative pressure; shaker cleaning. Fabric: polyester. Design gas flow rate: 120,000. Design operating temperature: 130 °F. Design air-to-cloth ratio: 3.2 ft/min. Installed 1977. Serves one EAF, 15 tons/hr design melt rate.
2	0.0080	6.3	92,000				15.1	
3	0.0103	7.6	86,000				8.2	
Average	0.0080	6.3	92,000				12.8	

APPENDIX G

SOURCE TEST PARTICULATE MATTER DATA FOR POURING, COOLING AND SHAKEOUT

G.1 INTRODUCTION

This appendix presents the individual sampling run data for the source tests available to characterize the control performance for baghouses and wet scrubbers applied to pouring, cooling, and shakeout at iron foundries (Chapter 4). Summary test data are given in Table G-1 along with descriptions of the control systems and the processes they serve. The test data and control device information were compiled from EPA's comprehensive 1998 survey of the industry. Some respondents provided information on each test run, and other respondents only provided the average for the test. Individual run information is presented when available.

There are many common features of the baghouses listed in the table. Almost all are negative pressure baghouses with pulse jet cleaning, and most of the air-to-cloth ratios are in the range of 5 to 7.4 ft/min. The table includes one shaker baghouse and four cartridge filters. The design flow rates for baghouses range 10,000 to 375,000 acfm. It is common for a single control system to serve multiple operations, such as different combinations of pouring, cooling, shakeout, and sand handling.

The wet scrubbers are low pressure drop devices with a range of 3.2 to 13.5 inches of water. The types include venturi, cyclonic, and centrifugal scrubbers. The design flow rates for the scrubbers range from 32,000 to 104,000 acfm, and liquid-to-gas ratios range from 2 to 8 gallons per 1,000 actual cubic feet. The scrubbers are applied to various combinations of pouring, cooling, and shakeout, and one also serves as the control device for an induction furnace.

TABLE G-1. PM SOURCE TEST RESULTS FOR BAGHOUSES AND SCRUBBERS SERVING POURING, COOLING, AND SHAKEOUT

Foundry ID	Date	Run no.	PM (lb/hr)	PM (gr/dscf)	Flow (dscfm)	Design information for fabric filters				Operations served
						Flow (acfm)	Air:cloth (ft/min)	Material	Cleaning type	
IN-13	Oct-96	1	0.51	0.00043	138,000	150,000	4.5	polyester	pulse jet	shakeout Lines 1 & 2; return sand s
		2	0.28	0.00024	136,000					
		3	0.23	0.00020	134,000					
		Average	0.34	0.00029	137,000					
WI-43	Oct-93	Average	0.56	0.0005	135,000	143,000	5.6	polyester felt	pulse jet	cooling and grinding (C22)
WI-43	Oct-93	Average	0.24	0.0005	55,000	60,000	7.1	polyester felt	pulse jet	shakeout and grinding (C33)
WI-43	Oct-93	Average	0.44	0.0005	94,000	101,000	7.1	polyester felt	pulse jet	cooling and sand handling (C31)
IN-13	Oct-96	1	0.57	0.00085	78,000	85,500	4.4	polyester	pulse jet	shakeout Lines 3 & 4
		2	0.35	0.00054	76,000					
		3	0.17	0.00026	76,000					
		Average	0.36	0.00055	76,000					
WI-43	Oct-93	Average	0.39	0.0008	56,000	60,000	7.1	polyester felt	pulse jet	cooling, shakeout, grinding (C32)
WI-43	Oct-93	Average	0.42	0.0009	55,000	60,000	7.1	polyester felt	pulse jet	cooling, shakeout, grinding (C34)
WI-43	Aug-95	Average		0.0009	-	60,000	7.1	polyester felt	pulse jet	cooling, shakeout, grinding (C32)
WI-42	Jan-00	Average	0.87	0.001	102,000	150,000	6.6	polyester felt	pulse jet	2 pouring/cooling lines; 2 cast cooling lines
WI-42	Jan-00	Average	1.10	0.001	128,000	150,000	6.5	polyester felt	pulse jet	shakeout
WI-01	Jun-94	Average	0.80	0.001	93,000	198,000	NR	NR	NR	5 shakeout/cast cooling lines
WI-43	Aug-95	Average	1.89	0.0012	184,000	180,000	7.1	polyester felt	pulse jet	cooling, shakeout, grinding (C35)
IA-17	Feb-96	1	0.67	0.0018	43,000	50,000	1.4	cellulose	pulse jet	shakeout and sand transfer with Line 802
		2	0.40	0.0011	42,000		(cartridge)			
		3	0.42	0.0011	45,000					
		Average	0.50	0.0013	43,000					
WI-01	Jun-94	Average	0.50	0.0015	39,000	51,000	NR	NR	NR	pouring/cooling Lines 1 & 5; sand mullor
MN-12	Mar-95	1	0.10	0.0009	12,400	12,400	9.4	polyester	shaker	pouring
		2	0.20	0.0020	11,600					
		3	0.16	0.0016	11,700					
		Average	0.15	0.0015	11,900					

Foundry ID	Date	Run no.	PM (lb/hr)	PM (gr/dscf)	Flow (dscfm)	Design information for fabric filters				Operations served
						Flow (acfm)	Air:cloth (ft/min)	Material	Cleaning type	
SC-07		1	0.62	0.0013	55,000	60,000	NR (cartridge)	NR	pulse jet	pouring/cooling
		2	0.86	0.0018	56,000					
		3	1.08	0.0024	52,000					
		Average	0.85	0.0019	54,000					
IN-29		Average	0.75	0.0019	46,000	51,000	5.5	polyester felt	pulse jet	shakeout
OH-48	Nov-96	1	0.30	0.0034	10,306	10,000	9.1	polyester	pulse jet	shakeout
		2	0.06	0.0007	10,655					
		3	0.16	0.0017	10,802					
		Average	0.17	0.0019	10,588					
WI-43	Oct-93	Average	1.66	0.0022	89,000	96,000	8.9	acrylic coated polyester	pulse jet	cooling and shakeout (C19)
WI-15		Average	1.49	0.0024	73,000	75,000	7	polyester	pulse jet	pouring, cooling, shakeout
MN-12	Mar-95	1	0.25	0.0029	10,100	10,000	5.8	felt	pulse jet	cooling
		2	0.19	0.0023	9,800					
		3	0.24	0.0029	9,800					
		Average	0.23	0.0027	9,900					
OH-13	Feb-96	1	1.76	0.0033	63,000	65,000	6.5	polyester	pulse jet	pouring, cooling, shakeout, miscellaneous (DS23)
		2	1.22	0.0023	63,000					
		3	1.58	0.0030	63,000					
		Average	1.52	0.0028	63,000					
TX-19	Jan-95	1	1.1	0.005	21,259	30,000	6.5	polyester	pulse jet	shakeout
		2	0.29	0.0015	22,481					
		3	0.54	0.002	21,002					
		Average	0.64	0.003	21,581					
IA-17	Feb-96	1	4.43	0.0038	136,000	140,000	7.4	singed polyester	pulse jet	shakeout and sand transfer with Line 803
		2	3.79	0.0033	134,000					
		3	2.60	0.0023	132,000					
		Average	3.61	0.0031	134,000					
WI-01	Jun-94	Average	1.18	0.0032	43,000	198,000	NR	NR	NR	pouring/cooling Lines 2 & 4; sand handling

Foundry ID	Date	Run no.	PM (lb/hr)	PM (gr/dscf)	Flow (dscfm)	Design information for fabric filters				Operations served
						Flow (acfm)	Air:cloth (ft/min)	Material	Cleaning type	
SC-07		1	0.70	0.0035	23,000	20,000	NR (cartridge)	NR	pulse jet	shakeout
		2	0.67	0.0037	21,000					
		3	0.70	0.0041	20,000					
		Average	0.69	0.0038	21,000					
IA-17	Nov-97	1	15.17	0.0047	377,000	375,000	5	polyester	pulse jet	shakeout and sand transfer with Line 801
		2	11.60	0.0038	356,000					
		3	9.11	0.0029	366,000					
		Average	11.96	0.0038	367,000					
OH-43	Oct-97	1	1.79	0.0045	46,000	50,000	5.2	polyester	pulse jet	cooling; bond and sand storage
		2	0.91	0.0023	46,000					
		3	2.06	0.0049	49,000					
		Average	1.59	0.0039	47,000					
IN-11		Average		0.0041	-	174,000	3.6	polyester	pulse jet	shakeout
IA-17	Feb-96	1	4.91	0.0054	106,000	110,000	5.9	polyester	pulse jet	shakeout and sand transfer with Line 802
		2	3.65	0.0040	106,000					
		3	3.21	0.0036	104,000					
		Average	3.92	0.0043	106,000					
IA-17	Feb-96	1	2.96	0.0022	157,000	110,000	5.9	polyester	pulse jet	shakeout and sand transfer with Line 802
		4	7.03	0.0052	158,000					
		5	7.48	0.0056	156,000					
		Average	5.82	0.0043	157,000					
WI-01	Jun-94	Average	1.46	0.0044	39,000	101,000	NR	NR	NR	pouring/cooling Lines 2 & 4; sand handling
MI-04		Average	1.30	0.0047	32,000	75,000	5.1	polyester	pulse jet	shakeout
OH-13	Mar-98	1	1.05	0.0020	63,000	65,000	6.5	polyester	pulse jet	pouring, cooling, shakeout; miscellaneous (DS23)
		2	0.94	0.0018	63,000					
		3	6.56	0.0122	63,000					
		Average	2.85	0.0053	63,000					
TX-11		1	1.83	0.0089	24,000	170,300	2	polyester	shaker	pouring, cooling, shakeout
		2	0.69	0.0033	24,000					
		3	0.95	0.0047	24,000					
		Average	1.16	0.0056	24,000					

Foundry ID	Date	Run no.	PM (lb/hr)	PM (gr/dscf)	Flow (dscfm)	Design information for fabric filters				Operations served
						Flow (acfm)	Air:cloth (ft/min)	Material	Cleaning type	
IA-17	Feb-96	1	2.02	0.0074	32,000	35,600	7.4	singed polyester	pulse jet	shakeout and sand transfer with Line 803
		2	1.92	0.0073	31,000					
		3	1.25	0.0048	30,000					
		Average	1.73	0.0065	31,000					
OH-43	Oct-97	1	2.50	0.0063	46,000	50,000	5.2	polyester	pulse jet	shakeout and sand cooling
		2	3.21	0.0075	50,000					
		3	2.57	0.0059	51,000					
		Average	2.76	0.0066	49,000					
IN-11		Average		0.0076	-	180,000	7.4	polyester	pulse jet	shakeout
AZ-04		Average	6.3	0.0109		45,000	6.1	polyester	pulse jet	shakeout
OH-22	May-93	1	11.2	0.019	67,911	80,000	6.4	polyproplene	pulse jet	shakeout
		2	24.6	0.042	67,863					
		3	15.7	0.027	68,314					
		Average	17.2	0.029	68,029					

Foundry ID	Date	Run no.	PM (lb/hr)	PM (gr/dscf)	Flow (dscfm)	Design information for wet scrubbers				Operations served
						Flow (acfm)	Type	Δp (in water)	L:G (1,000 gal/acf)	
TN-09	Mar-86	1	0.49	0.0011	39,000	75,000	cyclonic	13.5	8	shakeout
		2	0.50	0.0011	34,000					
		Average	0.50	0.0011	36,000					
TN-09	Sep-90	Average	1.06	0.0023	54,000	75,000	cyclonic	13.5	8	shakeout
TN-09	Mar-87	1	0.66	0.0021		45,000	centrifugal	6.0	2.5	shakeout
		2	1.12	0.0033						
		3	0.63	0.0019						
		Average	0.80	0.0024						
TN-09	Mar-87	1	1.40	0.0032	51,000	54,000	centrifugal	5.8	2.5	pouring and cooling
		2	2.00	0.0046	51,000					
		3	2.20	0.0050	51,000					
		Average	1.90	0.0043	52,000					
WI-28	Oct-90	1	1.50	0.0051	34,000	60,000	venturi	6	5	cooling, shakeout
		2	1.25	0.0043	34,000					
		Average	1.38	0.0047	34,000					
WI-47		Average	2.92	0.0052	65,000	73,500	venturi	13	2	induction furnace, pouring, cooling
TN-09	Mar-86	1	2.90	0.0091	37,000	75,000	cyclonic	13.5	8	shakeout
		2	0.80	0.0021	44,000					
		3	2.30	0.0052	52,000					
		Average	2.00	0.0055	42,000					
OH-22	May-93	1	7.3	0.0085	99,871	99,000	venturi	3.5	NR	shakeout
		2	3.3	0.0039	98,072					
		3	3.5	0.0042	98,931					
		Average	4.7	0.0055	98,958					
WI-47		Average	1.18	0.0064	21,000	32,000	venturi	13	2	shakeout
OH-22	Oct-94	1	8.52	0.01	102,769	104,000	venturi	3.2	NR	shakeout
		2	14.2	0.016	101,986					
		3	8.73	0.01	106,224					
		Average	10.5	0.012	103,660					

NR = not reported

TECHNICAL REPORT DATA

(Please read Instructions on reverse before completing)

1. REPORT NO. EPA-453/R-02-013	2.	3. RECIPIENTS ACCESSION NO.
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16. ABSTRACT

This report provides the background information for the proposed NESHAP to control metallic and organic emissions of hazardous air pollutants (HAP) from iron and steel foundries. The emission control techniques, estimates of emissions, control costs, and environmental impacts are presented.

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