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

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

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
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LIST OF ACRONYMS

acfm	Actual cubic feet per minute
BOPF	Basic oxygen process furnace
CAA	Clean Air Act
cfm	Cubic feet per minute
CO	Carbon monoxide
D/F	Dioxin and furan
dscfm	Dry standard cubic feet per minute
EAF	Electric arc furnace(s)
ESP	Electrostatic precipitator
g/scm	Gram(s) per standard cubic meter
gr/dscf	Grain(s) per dry standard cubic foot
HAP	Hazardous air pollutant
HCN	Hydrogen cyanide
lb/hr	Pound per hour
lb/ton	Pound per ton
MACT	Maximum achievable control technology
Mn	Managanese
NESHAP	National emission standard for hazardous air pollutants
NSPS	New source performance standard
PAH	Polynuclear aromatic hydrocarbon(s)
Pb	Lead
PM	Particulate matter
Q-BOP	Quelle basic oxygen process
scfm	Standard cubic feet per minute
tpd	Tons per day
tpy	Tons per year
VOC	Volatile organic compound(s)

1.0 INTRODUCTION

This document summarizes the basic background information used in the development of MACT standards for the integrated iron and steel manufacturing source category. All references cited in this document are available in Docket No. A-2000-44. In addition, this document is supplemented by technical memoranda to the docket to document those steps in the standards development process not covered within this compilation of background information.

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 the processes in detail and provides estimates of baseline emissions for each process. Emission control technologies and their performance are summarized in Chapter 4. Chapter 5 presents the determination of the MACT floor. Model plants are developed in Chapter 6 (for use in estimating potential impacts), and options for emission control and monitoring are discussed. Environmental and energy impacts are estimated for the model plants and for all plants nationwide in Chapter 7. The estimated costs for emission control and monitoring are given in Chapter 8. Appendix A summarizes the emissions data and Appendix B documents the information used to develop the MACT floor.

1.1 STATUTORY BASIS

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

Emission reductions may be accomplished through application of measures, processes, methods, systems or techniques including, but not limited to: (1) reducing the volume of, or eliminating emissions of, such pollutants through process changes, substitution of materials, or other modifications, (2) enclosing systems or processes to eliminate emissions, (3) collecting, capturing, or treating such pollutants when released from a process, stack, storage or fugitive emissions point, (4) design, equipment, work practice, or operational standards (including requirements for operator training or certification) as provided in subsection (h), or (5) 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 as appropriate emitting one or more of the HAP 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. A schedule for promulgation of standards for each source category was published on December 3, 1993 (58 FR 63941).

Integrated iron and steel manufacturing is one of the 174 categories of sources listed. As defined in the EPA report, "Documentation for Developing the Initial Source Category List" (EPA-450/3-91-030), the category consists of plants engaged in producing steel. The source category includes, but is not limited to, the following process units: (1) sinter production, (2) iron production, (3) iron preparation (hot metal desulfurization), (4) steel production, (5) semi-finished product preparation, (6) finished product preparation, and (7) handling and treatment of raw, intermediate, and waste materials. The iron production process includes the production of iron in blast furnaces by the reduction of iron-bearing materials with a hot gas. The steel production process includes BOPF.

The listing was based on the Administrator's determination that integrated iron and steel plants may reasonably be anticipated to emit several of the listed HAP in sufficient quantity to be designated as major sources. The EPA schedule for promulgation of the section 112 emission standards requires MACT rules for the integrated iron and steel source category to be promulgated by November 15, 2000. If MACT standards for this source category are not promulgated by May 15, 2002 (18 months following the promulgation deadline), section 112(j) requires 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.

2.0 INDUSTRY OVERVIEW

The steel industry is composed of two distinct types of facilities: integrated plants and non-integrated plants ("minimills"). A fully integrated facility produces steel from raw materials of coal, iron ore, and scrap. Non-integrated plants do not have all of the equipment to produce steel from coal, iron ore, and scrap on-site. Instead, they purchase their raw materials in a processed form (primarily scrap). This rulemaking includes only the integrated iron and steel industry, which has sinter plants, blast furnaces, and BOPF (see Table 2-1).

2.1 BACKGROUND[1]

In the past 15 years, the U.S. steel industry has lost over 61 percent of its employees and 58 percent of its facilities. Slow growth in demand for steel, markets lost to other materials, increased imports, and older, less efficient production facilities are largely responsible for the industry's decline. While the integrated steel industry was contracting, minimills more than doubled their capacity in the same period and they continue to expand into new markets. Minimills use EAF to melt scrap and other materials to make steel products. In addition to fundamentally different production technologies, other differences between the integrated steel mills and minimill are also significant. Minimills have narrow product lines and often have small, non-unionized work forces that may receive higher hourly wages than a comparable unionized work force, but without union benefits. Additionally, minimills typically produce much less product per facility (less than 1 million tons of steel per year). Lower scrap prices in the 1960s and 1970s created opportunities for the minimill segment of the market to grow rapidly.

Initially, the EAF technology could only be used in the production of low quality long products, such as concrete reinforcing bar. However, minimill products have improved in quality over the years and overcome technological limitations to diversify their product lines. Recently, minimills have entered new markets, such as flat-rolled products; however, more than half of the market for quality steel products still remains beyond minimill capability and is supplied by integrated producers.

TABLE 2-1. INTEGRATED IRON AND STEEL PLANTS

No.	Company	City & State	BOPF Shops		Blast Furnaces	Sinter Plants
			Vessels	Shops		
1	Acme Steel	Riverdale, IL	2	1	1	
2	AK Steel	Ashland, KY	2	1	1	
3	AK Steel	Middletown, OH	2	1	1	1
4	Bethlehem Steel	Burns Harbor, IN	3	1	2	1
5	Bethlehem Steel	Sparrows Pt., MD	2	1	1	1
6	Geneva Steel	Orem, UT	2	1	3	1
7	Gulf States Steel	Gadsden, AL	2	1	1	
8	Inland Steel	East Chicago, IN	4	2	3	1
9	LTV Steel	Cleveland, OH	4	2	3	
10	LTV Steel	East Chicago, IN	2	1	2	1
11	National Steel	Granite City, IL	2	1	2	
12	National Steel	Ecorse, MI	2	1	3	
13	Rouge Steel	Dearborn, MI	2	1	2	
14	USX	Braddock, PA	2	1	2	
15	USX	Fairfield, AL	3	1	1	
16	USX	Gary, IN	6	2	4	1
17	USS/Kobe Steel	Lorain, OH	2	1	2	
18	WCI Steel	Warren, OH	2	1	1	
		Youngstown, OH				1
19	Weirton Steel	Weirton, WV	2	1	2	
20	Wheeling-Pittsburgh Steel	Mingo Junction, OH	2	1	2	
		Follansbee, WV				1
Totals			50	23	39	9

2.2 GEOGRAPHIC DISTRIBUTION[1]

Figure 2-1 shows the locations of integrated plants that produce iron and steel. The highest geographic concentration of mills is in the Great Lakes region, where most integrated plants are based. According to the *Census of Manufactures*, 46 percent of steel mills are located in six Great Lakes States: New York, Pennsylvania, Ohio, Indiana, Illinois, and Michigan, with a heavy concentration of steel manufacturing in the Chicago area. Approximately 80 percent of the U.S. steelmaking capacity is in these States. The South is the next largest steel-producing region, although there are only two integrated steel plants. Steel production in the western U.S. is limited to one integrated plant and several minimills.

Historically, the mill sites were selected for their proximity to water (tremendous amounts are used for cooling and processing, and for transportation) and the sources of their raw materials, iron ore and coal. Traditional steelmaking regions included the Monongahela River valley near Pittsburgh and along the Mahoning River near Youngstown, Ohio.

2.3 SIZE DISTRIBUTION[1]

Large, fully-integrated steel mills have declined considerably in the last 15 years, largely due to loss of market share to other materials, competition, and the high cost of pension liabilities. In comparing the *1992 Census of Manufacture* data with the data from 1977, these changes are clear. While the number of establishments under SIC 3312 fell by 58 percent from 504 facilities in 1977 to 247 in 1992, the absolute number of integrated mills has always been small, and the reduction is largely due to a drop in the number of small establishments. A more relevant statistic is the reduction in employees during the same time period. The work force for these facilities was dramatically reduced as plants closed or were reorganized by bankruptcy courts. Those that remained open automated and streamlined operations resulting in a 61 percent reduction in the number of production employees over the same 15 year period. Approximately 172,000 were still employed in SIC 3312 establishments in 1992.

2.4 PRODUCT CHARACTERIZATION[1]

The iron and steel industry produces iron and steel mill products, such as bars, strips, and sheets, as well as formed products such as steel nails, spikes, wire, rods, pipes, and non-steel electrometallurgical products such as ferroalloys. Under SIC 3312, Blast Furnaces and Steel

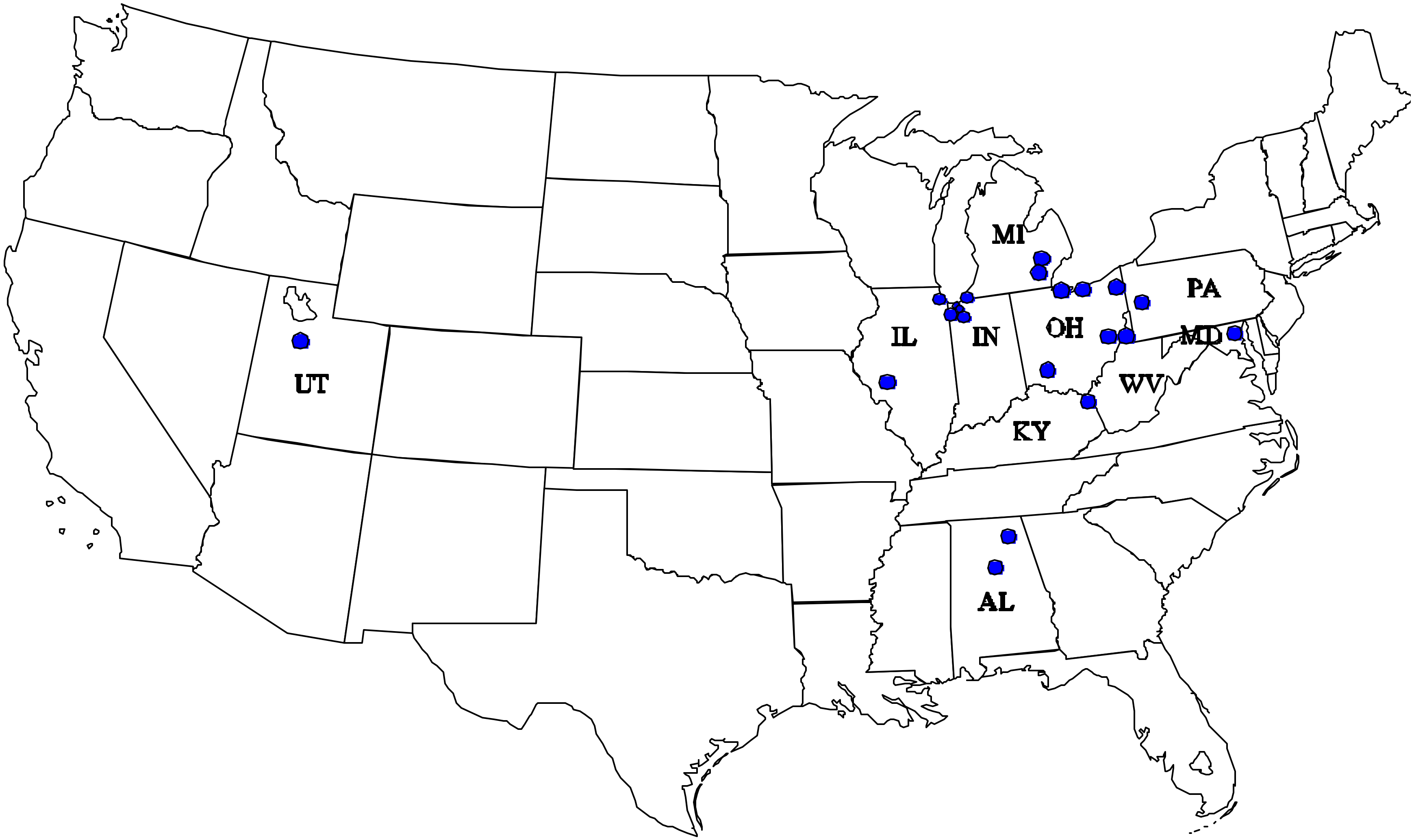

FIGURE 2-1. LOCATIONS OF INTEGRATED IRON AND STEEL PLANTS

Mills, products also include coke and products derived from chemical recovery in the coking process, such as coal tar and distillates.

Historically, the automotive and construction sectors have been the two largest steel consuming industries. Consequently, fluctuations in sales and choice of materials in these industries have a significant impact on the iron and steel industry. Over the last two decades, the structure of the steelmaking industry has changed dramatically due to new technologies, foreign competition, and loss of market share to other materials. Many of the large, fully-integrated facilities have closed, and those that are still operating have reduced their workforce, increased automation, and invested in new technologies to remain competitive.

2.5 REFERENCES

1. U.S. Environmental Protection Agency. Profile of the Iron and Steel Industry. EPA Office of Compliance Sector Notebook Project. EPA/310-R-95-005. September 1995.

3.0 PROCESS DESCRIPTION AND BASELINE EMISSIONS

This chapter provides a brief description of the sintering, ironmaking, and steelmaking processes used at integrated iron and steel plants. Detailed descriptions of these processes are available in "The Making, Shaping, and Treating of Steel[1]." Emission points, factors affecting emissions, HAP, and the baseline level of emissions are also presented. Emission estimates are based on data submitted by individual companies, tests of sinter plants conducted by EPA, and AP-42 emission factors.

3.1 SINTER PLANTS

Sintering is a process that recovers the raw material value of many waste materials generated at iron and steel plants that would otherwise be landfilled or stockpiled. An important function of the sinter plant is to return waste iron-bearing materials to the blast furnace to produce iron. Another function is to provide part or all of the flux material (e.g., limestone, dolomite) for the ironmaking process.[1, 2]

Feed material to the sintering process includes ore fines, reverts (including blast furnace dust, mill scale, and other byproducts of steelmaking), recycled hot and cold fines from the sintering process, and trim materials (calcite fines, and other supplemental materials needed to produce a sinter product with prescribed chemistry and tonnage).

The materials are proportioned and mixed to prepare a chemically uniform feed to the sinter strand, so that the sinter will have qualities desired for satisfactory operation of the blast furnace. The chemical quality of the sinter is often assessed in terms of its basicity, which is the percent total basic oxides divided by the percent total acid oxides $((CaO+MgO)/(SiO_2+Al_2O_3))$; sinter basicity is generally 1.0 to 3.0. The relative amounts of each material are determined based on the desired basicity, the rate of consumption of material at the sinter strand, the amount of sinter fines that must be recycled, and the total carbon content needed for proper ignition of the feed material.[2]

The sintering machine accepts feed material and conveys it down the length of the moving strand. Near the feed end of the grate, the bed is ignited on the surface by gas burners and, as the mixture moves along on the traveling grate, air is pulled down through the mixture to burn the fuel by downdraft combustion; either coke oven gas or natural gas may be used for fuel to ignite the undersize coke or coal in the feed. As the grates move continuously over a series of windboxes toward the discharge end of the strand, the combustion front in the bed moves progressively downward. This creates sufficient heat and temperature to agglomerates the fine particles, forming a cake of porous clinker, and providing the strength and other properties needed for use in the blast furnace.

The sinter machine strand is composed of pallets which ride on rails over the windboxes. Each pallet has a grated bottom, open ends where the cars come together, and sideboards of maximum height for the sinter bed. The windboxes provide for a controlled distribution of combustion air as it is drawn through the sinter bed. Air is drawn down through the burden, into the windboxes and through an initial separator to a large fan. Very coarse particles are recovered in the windboxes. Other somewhat less coarse particles are removed by the separator. After the fan, the gases are further cleaned before discharge to the atmosphere.[2] Each sinter strand generally has 12 to 22 windboxes. The height of the sinter bed varies between 9 and 24 inches.

The cake of porous clinker is discharged from the sinter strand to a breaker which reduces the sinter to smaller pieces, generally less than 6 inches in diameter. The crushed product is screened before and/or after cooling; in older plants one or both steps of screening may be absent. Fines and other pieces similar for use as a hearth layer are returned to the feed system.[2] The sinter is cooled to below 300°F so that it can be handled on conveyor belts. The sinter product is then transferred to feed areas for the blast furnace. Sinter coolers are often used in conjunction with a water quench and circular or straight line moving beds with forced or induced draft, or they may be quiescent. A portion of the cooling air may be fed to the windbox system to utilize its heat content. The finished product is then ready to be used in the blast furnace feed (burden), along with iron ore pellets, coke, and fluxing agents.[1, 2]

The amount of return fines may fluctuate if the quality of the sinter changes or if the efficiency of screening changes. Some facilities may use a hearth layer, although some older plants do not have the necessary equipment for creating the hearth layer. The amount of flux material varies depending on the percentage of sinter used in the blast furnace burden, the flux requirement of the blast furnace, and other production factors in the ironmaking process. Economics generally favor a high, or super flux sinter.[2]

There are currently nine sinter plants in operation in the United States. Four of the plants are located in Indiana, with two in Ohio, and one each in Utah, Maryland, and West Virginia. The plants range in capacity from 0.5 to 4.4 million tpy with a total nationwide capacity of 17.6 million tpy.

3.1.1 Emission Points

The emission points associated with the sinter plant are shown in Figure 3-1. The figure also indicates the typical emission control devices, if any, that have been installed for each emission point. The most significant source of emissions is the windbox, which is controlled either by a baghouse or wet scrubber at each of the nine plants. This emission point is a potential source of organic HAP as well as metal HAP because oil and other organics may be present in the sinter feed material.

The other emission points shown in the figure are primarily sources of PM emissions. Emissions from the discharge end of the sintering operation are also controlled at each of the plants (the discharge end emissions points include discharge, crusher, hot screen, cold screen, and the cooler at some plants). Emissions from material storage and handling, mixing, and sinter storage are generally uncontrolled.

3.1.2 Factors Affecting Emissions

Several factors can affect the PM emissions, and consequently, the emissions of HAP metals in the PM. For example, PM emissions from the windbox are affected by the amount of fines (e.g., pollution control dust from the steelmaking process) and their particle size distribution; an increase in fines can result in a larger quantity of PM being emitted as well as lower particle sizes in the emissions. The composition of the feed material, such as the amount of manganese and lead, also affects the quantity of these HAP that comprise the PM. Operating parameters, such as the bed air flow rate, bed depth, proper proportioning and mixing of the feed materials, and condition of the grate and machine seals affect the generation of PM from the windboxes.[2]

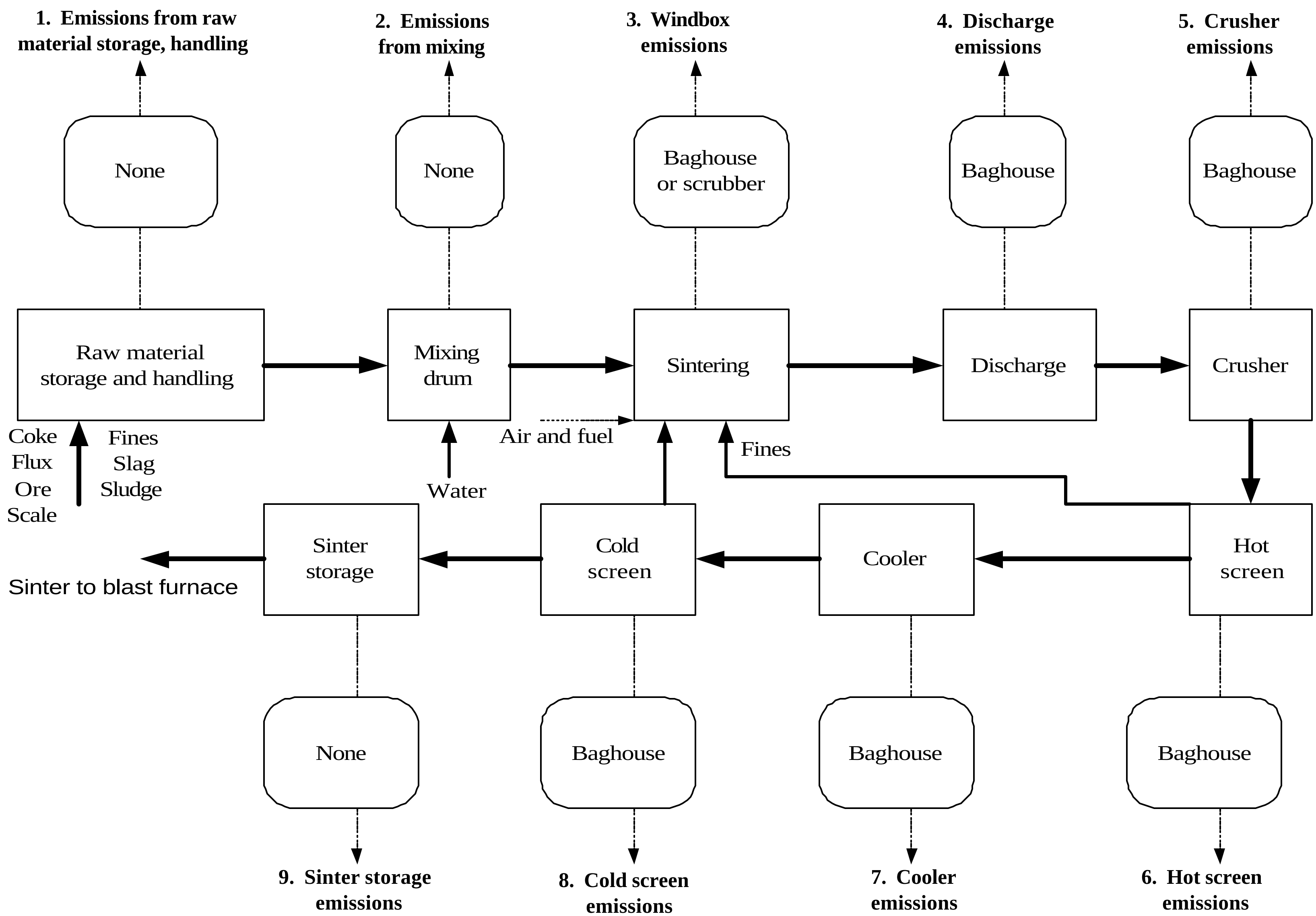

FIGURE 3-1. SCHEMATIC OF SINTER PLANT EMISSION POINTS AND TYPICAL CONTROLS

Emissions of hydrocarbons, pyrolysis products, and products of incomplete combustion are also affected by the feed composition, especially the amount of oily material in the feed, as well as by the combustion conditions. Hydrocarbon vapors, identified by a bluish plume, originate from oil in the feed when it is vaporized on the sinter strand ahead of the flame front and is evaporated or pyrolized. The oil in the feed originates from oily mill scale, blast furnace sludge, and coke breeze, which may contain tarry material and oil absorbed from the sump in which it is recovered.[2]

Emissions from the discharge end, including screening and crushing, are primarily PM and are affected by the amount of fines generated and their composition (i.e., the amount of metal HAP that comprise the PM) and by the ventilation rate that is used. The capture efficiency of the hoods used on the discharge end is a major factor affecting the fugitive emissions from the process. Emissions from the sinter cooler are affected by the quantity of fines in the sinter product being cooled and the type of cooler, whether quiescent, circular, or straight line moving beds, and whether they use forced or induced draft.[2]

3.1.3 Estimates of Baseline Emissions

The major emission points of interest for the sinter plant and those for which data are available are the windbox stack, the discharge end (includes the discharge, crushing, screening, and transfer points, which are usually ducted to a common control device), and the cooler stack. At a few plants, emissions from the cooler are also ducted to the control device used to control emissions from the discharge end.

3.1.3.1 HAP Metal Emissions from the Windbox. Emission test data were obtained from several plants to characterize typical PM emissions from the control device that treats the combustion air and offgases from the sinter plant windboxes. The PM data, when combined with dust analyses for HAP metals, provide one means to estimate potential HAP metal emissions. The PM data summarized in Table 3-1 for the windbox were taken from References 3 through 18. Most of the data were obtained from responses to a survey of the industry (section 114 information collection request) and from test reports provided by individual companies. In addition, EPA conducted tests at two sinter plants in 1997 and measured HAP metal emissions from a plant with a baghouse and one with a scrubber.[17, 18]

TABLE 3-1. ESTIMATES OF PM EMISSIONS FROM SINTER PLANTS[a]

Plant	Capacity (million tpy)	Control device			PM Emissions (tpy)			
		Windbox	Discharge	Cooler	Windbox	Discharge	Cooler	Total
AK Steel, Middletown, OH[3, 4]	0.9	Scrubber	Baghouse	Baghouse	148	172	c	320
Bethlehem Steel, Burns Harbor, IN[5, 6]	2.9	Scrubber	Baghouse	None	247	87[b]	1,450[d]	1,784
Bethlehem Steel, Sparrows Point, MD[7]	4.0	Scrubber	Baghouse	Cyclone	507	196	245	948
Geneva Steel, Provo, UT[8, 9]	0.8	Baghouse	Cyclone	No cooler	22	8.0	--	30
Inland Steel, East Chicago, IN[10,11]	1.4	Baghouse	Baghouse	None	60	41	700[d]	801
LTV Steel, East Chicago, IN	1.9	Scrubber	Scrubber	None	142[17]	70[12,13]	950[d]	716,380
USX, Gary, IN[14]	4.4	Baghouse	Baghouse	None	200[e]	132[b]	2,200[d]	2,532
WCI Steel, Warren, OH[15]	0.8	Baghouse	Baghouse	Baghouse	5.4[18]	1.8[18]	c	7
Wheeling-Pittsburgh, Follansbee, WV[16]	0.5	Scrubber	Baghouse	None	116	8.8	250[d]	375
Totals	**17.6**	**--**	**--**	**--**	**1,447**	**717**	**5,795**	**7,959**

[a] Emission estimates without footnotes are as reported in the reference under "Plant."
[b] Based on an emission factor of 0.06 lb/ton (see text).
[c] Included with discharge emissions (common control device).
[d] Based on an emission factor of 1 lb/ton (see text).
[e] No emissions data because the plant recently upgraded control to a baghouse; used emission factor of 0.09 lb/ton based on average factor from Geneva and Inland Steel.

HAP metals that have been reported in the PM include antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, and selenium.[17, 18] However, manganese (Mn) and lead (Pb) have been the most prevalent by far of the metal HAP; all other metal HAP combined represent less than 1 percent of the quantity of Pb and Mn. Consequently, the focus of the baseline emission estimates will be on Mn and Pb as the HAP metals of interest.

The emission estimates for lead and manganese in Table 3-2 that are referenced are the values that were measured and reported by the companies and also include the results of two tests conducted by EPA in 1997. These data were used to develop estimates of Mn and Pb as a percent of PM that could be applied to the other plants to estimate emissions. For example, Bethlehem Steel reported manganese as 0.3 percent of PM[7], Inland reported it as 0.8 percent[10, 11], and the two EPA tests showed a wide range of 0.05 to 3.5 percent.[17, 18] To estimate Mn emissions from other plants, an average value of **1.2 percent** of PM was used.

For Pb, Bethlehem reported a value of 2 percent of the PM,[5, 6] Inland reported 0.3 percent,[10, 11] AK Steel reported 1.3 percent[3, 4], and EPA measured 2.2 percent at WCI.[18] For the estimates in Table 3-2, an average value of **1.5 percent** of PM was used to estimate Pb emissions.

3.1.3.2 PAH Emissions from the Windbox. In the two sinter plant tests conducted by EPA in 1997, PAH known as the "7-PAH" and "16-PAH" were analyzed. The 7 PAH include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene. The 16-PAH add to this list naphthalene, phenanthrene, pyrene. acenaphthene, acenapthylene, anthracene, benzo(ghi)perylene, fluoranthene, and fluorene. Based on the test results, the emission factors given below were developed for plants with baghouses and scrubbers:[17, 18]

Control device	7-PAH (lb/ton)	16-PAH (lb/ton)
Baghouse	6.5×10^{-4}	1.0×10^{-2}
Scrubber	2.4×10^{-5}	9.7×10^{-4}

TABLE 3-2. ESTIMATES OF HAP EMISSIONS FROM SINTER PLANTS

Plant	HAP emissions (tpy)							
	Windbox					Discharge	Cooler	Total
	Mn[a]	Pb[b]	Volatiles[c]	7-PAH[d]	16-PAH[e]	Mn[f]	Mn[f]	
AK Steel, Middletown, OH	0.13[3, 4]	2.6[3, 4]	9.9	0.01	0.4	0.53[3, 4]	g	**14**
Bethlehem Steel, Burns Harbor, IN	3.0	4.9[5, 6]	32	0.03	1.4	0.7	11	**53**
Bethlehem Steel, Sparrows Point, MD	1.5[7]	7.6	44	0.05	1.9	0.6[7]	0.7[7]	**56**
Geneva Steel, Provo, UT	0.03[8]	0.03[8]	8.8	0.3	4.0	0.00[8]	h	**13**
Inland Steel, East Chicago, IN	0.5[10, 11]	0.2[10,11]	15	0.5	7.0	0.5[10, 11]	5.3	**29**
LTV Steel, East Chicago, IN	0.06[17]	14[17]	21	0.01[17]	0.6[17]	0.7[12, 13]	7.1	**43**
USX, Gary, IN	2.4	3.0	48	1.4	22	1.0	16.5	**94**
WCI Steel, Warren, OH	0.1[18]	0.08[18]	8.8	0.3	4.2[18]	0.07[18]	g	**14**
Wheeling-Pittsburgh, Follansbee, WV	1.4	1.7	5.5	0.006	0.2	0.07	1.9	**11**
Totals	**9.12**	**34.1**	**194**	**2.6**	**42**	**4.2**	**42**	**327**

[a] Based on 1.2 percent of PM emissions in Table 3-1 unless specific reference is given.
[b] Based on 1.5 percent of PM emissions in Table 3-1 unless specific reference is given.
[c] Based on an emission factor of 0.022 lb/t (see text).
[d] Based on emission factors of 6.5×10^{-4} and 2.4×10^{-5} lb/t for baghouses and scrubbers, respectively.
[e] Based on emission factors of 1.0×10^{-2} and 9.7×10^{-4} lb/t for baghouses and scrubbers, respectively.
[f] Based on 0.75 percent of PM emissions in Table 3-1 unless specific reference is given.
[g] Combined with discharge emissions (common control device).
[h] No cooler.

3.1.3.3 Volatile Organic HAP Emissions from the Windbox. Several plants reported emissions of VOC from the windbox, some of which are HAP. For example, a test report provided by Inland Steel reported 0.39 lb/ton of non-methane hydrocarbons (expressed as propane)[20], and another test report provided by LTV Steel reported 167 lb/hr of VOC (expressed as carbon).[21] For a typical production rate of 416 ton/hr of sinter[12, 13], the emission factor would be 0.40 lb/ton. Based on an emission factor of 0.39 to 0.40 lb VOC/ton, VOC emissions from the windbox for the individual plants would range from 100 to 880 tpy with a nationwide total of 3,800 tpy.

Speciated data for volatile HAP were provided by Bethlehem Steel[22]:

Compound	lb/yr
Benzene	25,283
Carbon disulfide	21,507
Toluene	10,015
Xylene	4,186
Total	**64,971**

Chloromethane, ethyl benzene, and styrene were also reported at much lower levels, about 10 percent of the quantity of toluene that was measured. For an annual production rate of 2.92 million tons of sinter in 1992[5, 6], these HAP compounds were emitted at a rate of **0.022 lb/ton**. This emission factor was applied to the other plants to estimate volatile HAP emissions.

3.1.3.4 Emissions of D/F from the Windbox. Testing was conducted for D/F by EPA at two sinter plants.[17, 18] The results expressed as TEQ (total equivalent to 2,3,7,8-TCDD) were 0.7 g/yr (5.5×10^{-7} g/ton of sinter) for the plant with a wet scrubber and 2.8 g/yr (3.4×10^{-6} g/ton of sinter) for the plant with a baghouse. Based on a nationwide capacity of 10.2 million tpy for plants with scrubbers and 7 million tpy for plants with baghouses, the nationwide estimate of TEQ from sinter plants is 29 g/yr.

3.1.3.5 Emissions from the Discharge End. The only significant HAP reported by the companies in emissions from the discharge end were metals, and Mn was by far the most prevalent. Test data for PM were obtained from several plants (those not marked with a footnote in Table 3-1). The data from the reporting plants were used to derive a PM emission factor for the other plants:

Plant	Control	PM (lb/ton)
LTV[12, 13]	scrubber	0.074
Weirton[19]	scrubber	0.041
WCI[18]	baghouse	0.0044
Inland[10, 11]	baghouse	0.082
Bethlehem[7]	baghouse	0.098
Wheeling-Pittsburgh[16]	baghouse	0.035
Average		**0.06**

Other than the very low results for WCI, there are no obvious differences in the emission factors for scrubbers and baghouses; consequently, the average value of **0.06 lb/ton** was used to estimate PM emissions from the discharge end for the other plants.

Dust analyses provided by Bethlehem Steel showed Mn to be 0.3 percent of PM for discharge emissions,[7] and similar data from Inland revealed a value of 1.2 percent.[10, 11] A midrange value of **0.75 percent** of PM was used to estimate Mn emissions for the other plants.

3.1.3.6 Emissions from the Cooler. Test data were available for 2 tests conducted at USS Gary Works for an uncontrolled cooler in October 1979 and December 1987. The results showed a concentration of 0.033 gr/dscf, 147 lb/hr, and 518,700 dscfm. The resulting emission factor is about 1 lb/ton. Test data were also available from Bethlehem's Sparrows Point plant for a cooler controlled by a cyclone with a rated efficiency of 90 percent. The cyclone achieves an outlet concentration of 0.02 gr/dscf with a flow of 640,000 acfm at 600EF with a resulting emission factor of about 0.12 lb/ton.[7] Assuming 90 percent control, the uncontrolled emission factor would be 1.2 lb/ton. For the estimates presented in this section, an uncontrolled emission factor of **1 lb/ton** is used. This emission factor likely represents coolers with very high flow rates of air through the bed of hot sinter. If other plants use lower flow rates or quiescent coolers, the uncontrolled emissions may be much lower than 1 lb/ton. This factor was coupled with the concentration derived for Mn from the discharge end (0.75 percent of PM) because the composition of the sinter dust from the discharge end and cooler should be about the same. Consequently, the estimates of Mn emissions from the cooler for the plants without controls are based on PM emissions of 1 lb/ton and 0.75 percent Mn in the PM.

3.1.4 Uncertainties in the Emission Estimates

A major uncertainty in the emission estimates is the quantity of emissions that are not captured and escape as fugitive emissions with the ventilation air. The plants reported measured emissions from point sources, which were the stacks from which emissions from the control device were discharged. However, the capture efficiency of hoods used on several emission points associated with the discharge end was reported as about 95 percent,[7] which means that the quantity that was not captured was far more than the quantity emitted from control devices that were generally rated as 99 to 99.9 percent efficient in the control of PM. Some of the larger particles may settle out in the building, and other PM that escapes capture is emitted with the ventilation air to the atmosphere.

Uncertainty is also introduced by differences in the composition of the feed materials used by the plants. The percent of Pb and Mn in the dust may be directly related to the amount of these metals in the feed materials. In addition, some of the more volatile metal compounds may be more concentrated in fine particles (i.e., the concentration of HAP metals may vary as a function of particle size). The quantity and type of organics in the feed material (such as oily scale), may also affect the type and quantity of organic compounds that are emitted.

3.2 BLAST FURNACES

The blast furnace converts iron oxide into molten iron for subsequent refining in the BOPF shop to produce steel. A typical burden (feed) may consist of iron ore, pellets, sinter, limestone, coke, mill scale, BOPF slag, and other iron bearing materials. The burden material is charged into the top of the furnace and slowly descends through the furnace. The coke provides the thermal energy required for the process and provides carbon to reduce the iron oxide and to remove oxygen in the form of CO.

The blast furnace is a vertical shaft furnace. Raw materials are charged into the top of the furnace and fall to the top of the burden of raw materials already in the furnace. As they descend in the furnace, they are heated by a countercurrent flow of gas. Heated air is injected through the tuyeres, located near the bottom of the furnace just above the hearth. The air moves countercurrent to the burden, consuming the coke (carbon). Raw materials are introduced at the top of the blast furnace; the hottest temperature zone in the furnace is at the hearth level, where the burden is molten.

The furnace filling is controlled by the level of burden in the furnace. When the level is below a preset point, the stockhouse functions continuously, filling the skips with predetermined weights of materials in the ordered sequence. The top of the blast furnace is enclosed so that blast furnace gas can be drawn off above the stock level and a bell and hopper arrangement can be used for charging the furnace. Most installations use a combination of two bells so that a gas tight space can be provided between the two bells to prevent gas from escaping while the lower bell is opened. Raw materials are taken to the furnace top by a skip hoist or a conveyor belt and dropped into the upper hopper. With the large bell closed, the small bell is lowered and the charge material is dropped into the large-bell hopper. When the large-bell hopper is full, the small bell is held closed, the large bell is lowered, and the material is dumped into the blast furnace without allowing any of the gas to escape.

A more recent innovation, used on several blast furnaces in the industry, is the *Paul Wurth* bell-less top, in which the charge materials are deposited into hoppers located at the top of the furnace. The hoppers can be depressurized for loading and repressurized for discharging the material into the furnace. There are at least two hoppers so that while one is being loaded, the other can be discharged into the furnace. As the charge material enters the furnace, it is directed by a rotating chute to various locations on top of the stockline.[1]

With this design, the furnace burns fuel more efficiently, leaks less, and can hold pressure. There is also not a problem with wearing a hole in the bell or sealing bell rods.[1]

In the blast furnace process, the heated raw materials react chemically with one another. The principal set of reactions are the complex ones between coke, air, and iron ore. Part of the coke is consumed by the oxygen in the air to produce heat for the process. Another part of the coke combines with the oxygen in the iron ore and releases free iron, which melts, drips to the bottom of the furnace, and collects in the hearth. A final portion of the carbon dissolves in the iron. The heat of the blast furnace serves to calcine the limestone. The resulting calcium oxide reacts with the impurities in the ore, principally sulfur, and, in molten form, descends to the hearth. The slag, being about one-third the density of the iron, floats in a separate layer on the iron bath.

Ironmaking is a continuous process within the blast furnace; however, it is a semi-continuous process with respect to periodic charging of materials into the top of the furnace and periodic tapping of molten iron and slag from the bottom of the furnace. Periodically, the hearth becomes full of molten iron and slag. Because there is a limit to the amount that can be tolerated before it interferes with the furnace operation, they must be removed from the furnace at regular intervals. The iron notch, which is used for tapping the hot metal, is located just above the floor of the hearth; each furnace has one or more iron notches When the furnace is in operation, the iron notch is completely filled with a refractory material, called taphole clay. To cast the hot metal from the furnace, a tapping hole is drilled through this material.

The hot metal flows through this hole and is discharged into a trough, which is a long narrow basin typically 3 to 5 feet wide and 26 to 40 feet long; the trough generally has a slightly sloping bottom away from the furnace. At the far end of the trough, there is a dam to hold back the hot metal until the depth of the metal in the trough is sufficient to contact the bottom of a refractory skimmer block. The skimmer holds back the slag and diverts it into the slag runners. The hot metal flows over the dam and down the iron runner, where it is directed in sequence to a train of ladles positioned under stationary spouts along the runner. At several large blast furnaces, a tilting spout is used, positioned between two hot metal tracks. The spout is first tilted to fill the ladle on one track and then to fill the one on the other track. While the second ladle is being filled, the first one can be replaced with an empty one so that the cast can be continued uninterrupted while several ladles are filled.

After the flows of iron and slag cease, the tap hole is plugged with fresh clay by a device called a "mud gun", and the ironmaking process resumes. The hot metal is transported from the blast furnace to the BOPF shop in refractory-lined ladles that have a course of insulating material between the lining and the steel shell.[23]

Blast furnace gas (primarily CO) is collected from offtakes at the top of the furnace; this gas is cleaned of PM and is used to fire the blast furnace stoves that heat the furnace air. Excess blast furnace gas is used as a fuel in other processes at the plant.

There are currently a total of 39 blast furnaces at 20 plants that are owned by 14 companies in the U.S. The plants are located in 10 different States, with the largest number in Ohio and Indiana. Each furnace has the capacity to produce 700,000 to 3,440,000 tpy of hot metal.

3.2.1 Blast Furnace Auxiliaries

3.2.1.1 Stoves. About 30 percent of the blast furnace gas is utilized to heat the hot air blast by means of the blast furnace stoves; there are generally 3 to 4 stoves per blast furnace. The remainder is used for other heating purposes throughout the facility.

Before the blast air is delivered to the blast furnace tuyeres, it is preheated by passing it through regenerative stoves that are heated primarily by combustion of the blast furnace off-gas. In this way, some of the energy of the off-gas that would otherwise have been lost from the process is returned to the process. The additional thermal energy returned to the blast furnace as heat decreases the amount of fuel that has to be burned for each unit of hot metal and thus improves the efficiency of the process. In many furnaces, the off-gas is enriched by the addition of a fuel with much higher calorific value, such as natural gas or coke oven gas, to obtain even higher hot blast temperatures. This decreases the fuel requirement and increases the hot metal production rate to a greater extent than is possible when burning off gas alone to heat the stoves.

3.2.1.2 Blast Furnace Gas Cleaning. As the blast furnace gas leaves the top of the furnace, it contains dust particles varying in size from about 6 millimeters to a few microns. The dust that is carried out of the top, referred to as flue dust, is made up of fine particles of coke and burden material and extremely fine particles of chemical compounds formed from reactions within the blast furnace. Before the blast furnace gas can be burned in either the hot blast stoves or the boiler house, it must be cleaned to remove most of the flue dust and prevent plugging and damaging of the checkers or burners and to keep the dust from being discharged into the atmosphere with the products of combustion. The gas normally passes through a dry dustcatcher, where the coarser particles are removed, and then through a wet-cleaning system, where the very fine particles are scrubbed from the gas with water.

3.2.1.3 Pulverized Coal Injection. At least six facilities in the industry have installed pulverized coal injection systems to replace some of the coke required for the blast furnace. Coal injection systems are much less costly than building new coke batteries and have fewer environmental problems, as temperatures are not high enough to liberate any problem elements in the coal. As much as 40 percent of the furnace coke can be replaced on a one-for-one basis with coal. The quantity of coal that can be used is affected by quality of the coke and is also limited by the amount of oxygen available at the tuyeres.

In preparing coal for injection, the first step is a grinding or pulverizing operation; most systems take the coal down to 80 percent-200 mesh. The coal is stored under a controlled atmosphere, brought up to furnace pressure in feed tanks, and pneumatically conveyed in a single pipe to the blast furnace area. The coal-air mixture is then divided in a static distributor for delivery to each pipe by way of individual pipes.[24]

Uniform distribution to the furnace tuyeres is critical. At the tuyeres, fine coal meets the hot blast at around 2,000 EF. The object of coal injection is to get the particles broken down to atoms of carbon and combusted with oxygen before the end of the raceway, the combustion zone in front of the tuyeres. Coal injection has a positive effect on blast furnace operations. The flame temperature can be more effectively controlled and there is an indication that slips occur less frequently.[25]

3.2.2 Emission Points and Factors Affecting Emissions

A schematic of the emission points is given in Figure 3-2 and described in this section. The major emissions of interest occur from the **casthouse during tapping** when molten iron and slag are removed from the furnace.

Emissions occur at the taphole, from the trough, from the runners that transport the iron and slag, and from the ladle that receives the molten iron. These emissions include flakes of graphite (carbon) called "kish" that is released as the metal cools (because the solubility of carbon in the metal decreases as it cools) and metal oxides that form when the reduced metal (e.g., iron, manganese) reacts with oxygen in the air.[23] Factors affecting these emissions include the duration of tapping, exposed surface area of metal and slag, length of runners, and the presence/absence of runner covers and flame suppression, which reduce contact with air.

Gaseous and particulate emissions occur from **slag handling** as the slag is discharged and allowed to cool. Particulate emissions also occur when the solidified slag is later broken up and removed. These emissions are generally uncontrolled.

Emissions from **raw material handling** occur from the storage, sizing, screening, mixing, and transport of the feed materials that comprise the blast furnace burden. These raw materials that generate dust include iron ore, pellets, sinter, coke, and flux materials such as limestone and silica.[23] Emissions are affected by the extent to which fine particles are generated, use of enclosures and extent of exposure to the atmosphere, use of water sprays or other materials for suppression, etc.

The gas leaving the blast furnace is primarily CO and nitrogen and is heavily laden with PM. The gas is cleaned and is used as fuel in the blast furnace stoves and other operations at the plant. Emissions occur from the **stove stack** when this gas is burned. The quantity and composition of these emissions are affected by the amount and type of particles remaining after cleaning and the combustion conditions when the fuel is burned.

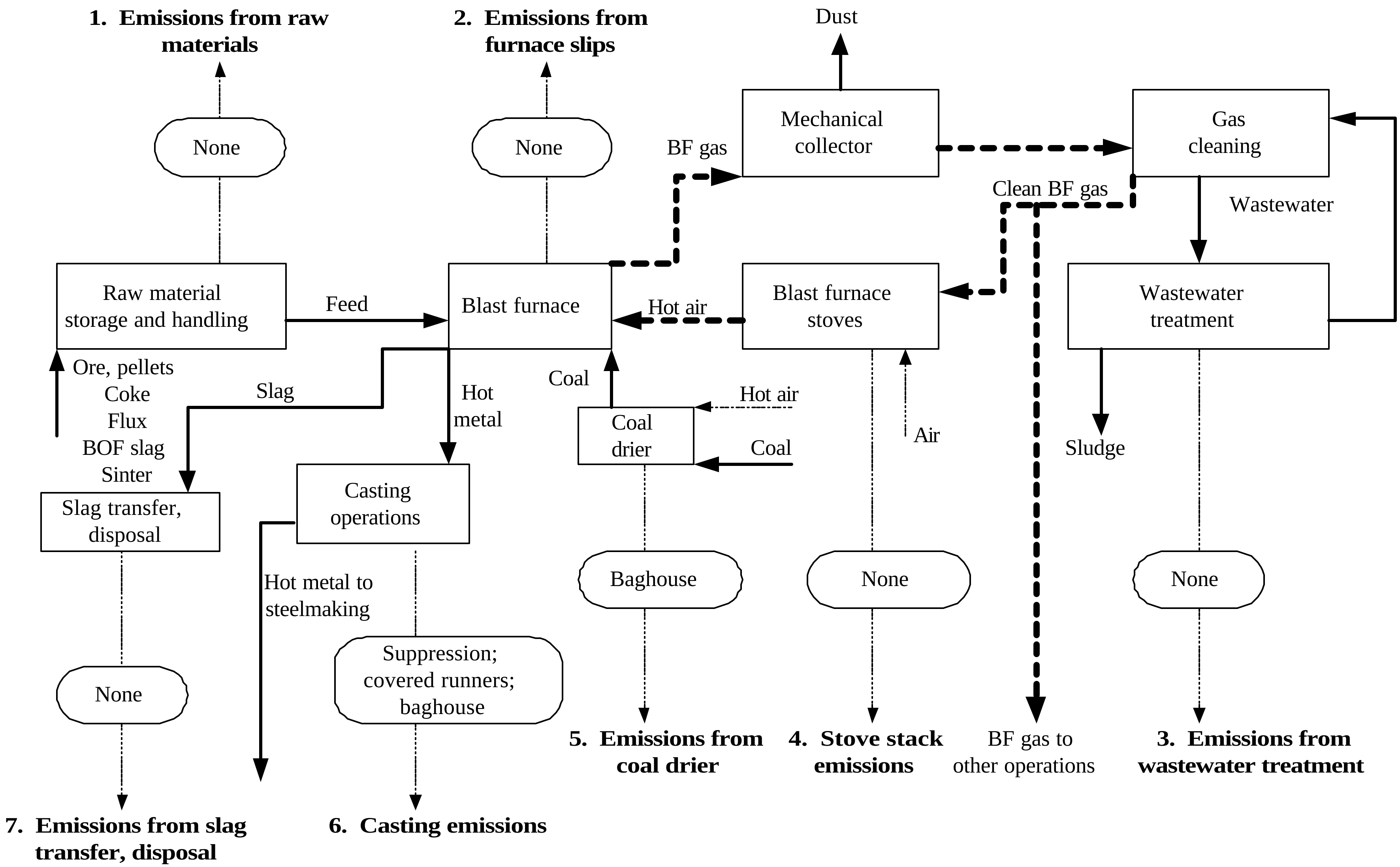

FIGURE 3-2. SCHEMATIC OF BLAST FURNACE EMISSION POINTS AND TYPICAL CONTROLS

Emissions also occur from **furnace "slips."** A slip occurs when the burden material hangs or bridges in the furnace rather than continuing its downward movement. When this happens, the solid material below the "hang" continues to move downward and form a void below the hang that is filled with hot gas at very high pressure. When the hang finally collapses, the sudden downward thrust of the burden material forces the hot gas upward with the force of an explosion. To prevent damage to the furnace, the pressure is relieved through bleeder stacks on top of the furnace that discharge the particle-laden gas directly to the atmosphere.[1] Factors that are believed to contribute to blast furnace slips include re-solidification of previously fused slag and molten iron, an excessive quantity of fines in the coke, alkalis such as oxides of sodium and potassium, and overblowing of the furnace (excess air).[23] One plant reported that slips were very infrequent now because they used pellets rather than iron ore.[19] Older blast furnaces are reported to experience more slips than are newer furnaces.[23] The quantity of emissions from slips is related to the duration of the slips, their frequency, how fast the pressure rises, and how quickly it is relieved.

Emissions are also discharged uncontrolled to the atmosphere during a practice known as **"back drafting."** Back drafting occurs when it is necessary to take the furnace out of blast for a short period of time (generally less than 2 hours) to perform maintenance. The blast air is stopped, the bleeders are opened to pull some of the furnace gas out of the top, and gas is also drawn back through the tuyeres to a hot stove where it is burned and discharged through the stove stack. Some plants use a back-draft stack to discharge the gas rather than drawing the gas back through a stove.[1, 23] Only one plant reported their level of emissions from back drafting (200 tpy of PM).[8] No other information was available on the frequency of back drafting or the level of emissions.

Emissions also occur from the **wastewater collection and treatment system**. The blast furnace gas is heavily laden with particles (on the order of 30 g/scm) as it leaves the furnace. The gas is cleaned by passing it through a cyclone (called a dust catcher) and then directing it to venturi scrubbers for final cleaning. The direct contact water used in the scrubber dissolves HCN from the gas, and the HCN is subsequently stripped from the water when it passes through the cooling tower.

3.2.3 Estimates of Baseline Emissions

The approach used in this section to estimate baseline emissions relies on estimates submitted by the individual companies and emission factors in EPA's AP-42 emission factor document.[26] For metal HAP, Mn was the only HAP metal reported by most companies. Estimates of PM emissions are used with analyses of the dust for metals (expressed as percent Mn) to estimate Mn emissions. The only other HAP identified from blast furnace operations was HCN. HCN was measured and reported by two plants as being emitted from the blast furnace water.[7, 27] The estimates of HCN emissions from these two plants are applied to other plants to estimate HCN emissions.

3.2.3.1 Casthouse PM Emissions. The emission estimates for PM submitted by the companies are summarized in Table 3-3. The table indicates there was considerable variability in the emission factors used by the different plants even though similar controls are in place. For example, five plants that use flame suppression and covered runners used an emission factor of 0.3 to 0.6 lb/ton, while other plants used lower values. The AP-42 emission factor for the casthouse roof monitor is 0.6 lb/ton or 0.3 lb/ton for the taphole and trough only. If local evacuation is used, an emission factor (prior to any control device) of 1.3 lb/ton is recommended.[26] Because 5 of the 11 plants in Table 3-4 that use suppression controls (e.g., flame suppression, covered runners) used the factor of 0.3 to 0.6 lb/ton to estimate their emissions and it is consistent with the AP-42 number, a value of 0.6 lb/ton (from AP-42) is used in this section to estimate emissions for plants without hoods and baghouses.

The emission factors used by seven plants with hoods to capture the emissions and a control device (baghouse or a scrubber) to remove PM are also shown in Table 3-4. These factors range from 0.01 to 0.1 lb/ton and average about 0.05 lb/ton. Consequently, emissions from casthouse operations that use hoods to capture emissions and direct them to a control device will be estimated as 0.05 lb/ton.

3.2.3.2 Miscellaneous Emission Points. The PM emission estimates provided for **raw material handling** are given in Table 3-4 and show a range of 0.0086 to 0.1 lb/ton with an average of 0.04 lb/ton, which will be used in this section to estimate baseline emissions.

TABLE 3-3. CASTHOUSE PM EMISSION ESTIMATES SUBMITTED BY THE COMPANIES

Plant (State)	Control	Production (10^6 tpy)	PM emissions (tpy)	Emission factor (lb/ton)
Acme Steel (IN)[28, 29]	FS, CR	0.8	53	0.1
AK Steel (KY)[30, 31]	FS, CR	1.92	288	0.3
AK Steel (OH)[3, 4]	FS, CR	2.2	330	0.3
Bethlehem Steel (IN)[5, 6]	FS, CR	5.5	1,250	0.5
Geneva Steel (UT)[8]	FS, CR	2.7	189	0.1
LTV Steel(OH)[32]	FS, CR	4.1	147	0.07
USX (AL)[33, 34]	FS, CR	1.9	570	0.6
Rouge Steel (MI)[35]	FS, CR	2.7	122	0.09
USS/Kobe No. 4[36]	FS, CR	1.0	300	0.6
LTV Steel H3 (IN)[12, 13]	FS, CR	1.6	48	0.06
Weirton Steel (WV)[19]	FS, CR	2.1	80	0.08
Wheeling-Pitt No.1 (WV)[16]	FS, CR	0.7	14	0.04
Plants with local hoods vented to a control device				
Bethlehem Steel (MD)[7]	FS, ECR, Hood, BH	3.5	208	0.1
Inland Steel No.7 (IN)[10, 11]	ECR, Hood, BH	4.0	146	0.07
Inland Steel Nos. 5,6 (IN)[10, 11]	ECR, Hood, Scrubber	2.5	48	0.04
National Steel (IL)[37, 38]	CR, Hood, BH	2.4	94	0.08
USS/Kobe No. 3[36]	ECR, Hood, BH	1.3	57	0.087
USX (PA)[33, 34]	FS, AC, BH	2.2	29	0.03
Wheeling-Pitt 5,6 (OH)[16]	FS, CR, AC, Hood, BH	1.6	8.7	0.01

FS = flame suppression, usually for covered runners and sometimes at the taphole.
CR = covered runners.
ECR = evacuated covered runners (vented to a control device).
Hood = local hoods used to capture emissions at the tap hole and trough, and sometimes from the torpedo car, and subsequently ducted to a control device.
BH = baghouse.
AC = an air curtain that is used to contain emissions within a limited area of the casthouse where they are captured by a hood and sent to a control device.

TABLE 3-4. RAW MATERIAL HANDLING, SLAG HANDLING,AND FURNACE SLIP PM EMISSION ESTIMATES SUBMITTED BY THE COMPANIES

Plant	Production (10^6 tpy)	PM emissions (tpy)	Emission factor (lb/ton)
Raw material handling			
Acme Steel[28, 29]	0.8	30	0.075
Geneva Steel[8]	2.7	39	0.029
Inland No. 7[10, 11]	4.0	45	0.023
USX (AL)[33, 34]	1.9	71	0.075
USS Kobe[36]	2.3	118	0.1
Weirton Steel[19]	2.1	16	0.015
Wheeling-Pitt No. 1[16]	0.7	3	0.0086
Wheeling-Pitt No. 5,6[16]	1.6	15	0.019
Average			0.04
Slag handling			
Acme Steel[28, 29]	0.8	1.6	0.0040
AK Steel (KY)[30, 31]	1.92	53	0.056
National (IL)[37, 38]	2.4	4.7	0.004
USX (AL)[33, 34]	1.9	3.2	0.0034
USS Kobe[36]	2.3	80.9	0.07
Weirton Steel[19]	2.1	3.4	0.0032
Slips			
Acme Steel[28, 29]	0.8	1	0.0025
AK Steel (KY)[30, 31]	1.92	295	0.31
Geneva Steel[8]	2.7	69	0.051
USX (AL)[33, 34]	1.9	20	0.021

The emission estimates for **slag handling** are also shown in Table 3-4 and range from 0.003 to 0.07 lb/ton. The AP-42 estimate for emissions from slag handling (using a front-end loader) is 0.026 lb/ton.[26] This value is used to provide a highly uncertain estimate of fugitive emissions from slag handling.

Three plants provided estimates of PM emissions from **furnace slips** that were in the range of 0.0025 to 0.31 lb/ton (see Table 3-4), which spans a range of 2 orders of magnitude. Emissions from slips are highly variable and difficult to estimate. A median value between the extremes of 0.03 lb/ton is used to provide a highly uncertain estimate of emissions from slips.

The emissions of PM from the **blast furnace stoves** were provided by several plants and are summarized in Table 3-5. The average value of 0.056 lb/ton will be used to estimate PM emissions from the blast furnace stove.

These emission factors are applied to each emission point at each plant in Table 3-6 to estimate total PM emissions from blast furnace operations. The use of consistent emission factors for plants with similar controls should provide a better relative comparison among plants than the use of site-specific emission factors of unknown origin.

TABLE 3-5. BLAST FURNACE STOVE PM EMISSION ESTIMATES SUBMITTED BY THE COMPANIES

Plant (State)	Production (10^6 tpy)	PM emissions (tpy)	Emission factor (lb/ton)
Acme Steel (IN)[28, 29]	0.8	26.1	0.052
AK Steel (KY)[30, 31]	1.9	50	0.05
Geneva Steel (UT)[8]	2.7	30	0.022
LTV Steel(OH)[32]	4.1	152	0.074
LTV Steel H3 (IN)[12, 13]	1.6	36	0.045
LTV Steel H4 (IN)[12, 13]	2.0	48	0.048
National (IL)[37, 38]	2.4	13	0.011
Rouge Steel (MI)[35]	2.7	5.8	0.0043
USX (PA)[33, 34]	2.2	20	0.018
USX (AL)[33, 34]	1.9	161	0.17
USS Kobe (OH)[36]	2.3	18.7	0.016
Weirton Steel (WV)[19]	2.1	61	0.058
Wheeling-Pitt No. 1 (WV)[16]	0.7	21	0.060
Wheeling-Pitt No. 5,6 (WV)[16]	1.6	84	0.11
Average			0.05

TABLE 3-6. ESTIMATES OF PM EMISSIONS FROM BLAST FURNACE OPERATIONS

Plant	Furnace	Capacity (million tpy)	Casthouse control	Particulate matter emissions (tpy)					
				Casthouse	Raw materials	Slips	Stoves	Slag	Total
Acme Steel, Riverdale, IL[28, 29]	1	1.0	Flame suppression and covered runners	300	20	15	25	13	373
AK Steel, Ashland, KY[30, 31]	A	1.9	Covered runners with flame suppression	570	38	29	48	25	709
AK Steel, Middletown, OH[3, 4]	3	2.2	Flame suppression at taphole, torpedo car	660	44	33	55	29	821
Bethlehem Steel, Burns Harbor, IN	C,D	5.5	Flame suppression at taphole, covered runners, N2 over torpedo car	1,650	110	83	138	72	2,052
Bethlehem Steel, Sparrows Point, MD	L*	3.5	Hood over tapping, evacuated runner covers, both to baghouse; flame suppression at torpedo car	88	70	53	88	46	343
Geneva Steel, Orem, UT	1,2,3	2.7	Partially covered runners with flame suppression	810	54	41	68	35	1,007
Gulf States Steel, Gadsden, AL	2	1.2	No controls	360	24	18	30	16	448
Inland Steel, East Chicago, IN	7	4.0	Hood over tapping, evacuated runner covers, both to baghouse	100	80	60	100	52	392
	5, 6	2.5	Hood over tapping, evacuated runner covers, both to scrubber	63	50	38	63	33	245
LTV Steel, Cleveland, OH	C1,C5	2.7	Covered runners with flame suppression	810	54	41	68	35	1,007
	C6	1.4	Covered runners with flame suppression; fume suppression hoods for tapping	420	28	21	35	18	522
LTV Steel, East Chicago, IN	H3	1.6	Covered runners with flame suppression	480	32	24	40	21	597

TABLE 3-6. ESTIMATES OF PM EMISSIONS FROM BLAST FURNACE OPERATIONS

Plant	Furnace	Capacity (million tpy)	Casthouse control	Particulate matter emissions (tpy)					
				Casthouse	Raw materials	Slips	Stoves	Slag	Total
	H4	2.0	Covered runners with flame suppression; hood over tapping and tilting spout to baghouse	50	40	30	50	26	196
National Steel, Granite City, IL	A,B	2.4	Hoods over tapping and torpedo car to baghouse; covered runners	60	48	36	60	31	235
National Steel, Ecorse MI	A,B,D	4.9	Hoods over tapping and tilting spout to baghouse	123	98	74	137	64	495
Rouge Steel, Dearborn, MI	B, C	2.7	Flame suppression at taphole & at covered runners	810	54	41	76	35	1,015
USX, Braddock, PA	1, 3	2.3	Air curtain at tapping to baghouse, flame suppression	57	46	35	64	30	232
USX, Fairfield, AL	8	2.0	Covered runners with flame suppression	600	40	30	56	26	752
USX, Gary, IN	4,6,8	3.4	Flame suppression	1,020	68	51	95	44	1,278
USX, Gary, IN	13	2.7	Hood and evacuated covered runners to baghouse	68	54	41	76	35	273
USS/Kobe Steel, Lorain, OH	3	1.3	Hood over tapping to baghouse, covered runners	33	26	20	36	17	131
	4	1.0	Flame suppression	300	20	15	28	13	376
WCI Steel, Warren, OH	1	1.6	Hoods over tapping and pouring station to baghouse	40	32	24	45	21	162
Weirton Steel, Weirton, WV	1,3	2.1	Covered runners with flame suppression for iron & slag	630	42	32	59	27	790
Wheeling Pittsburgh Steel, Mingo Junction, OH	1N	0.7	Partially covered runners with flame suppression	210	14	11	20	9	263

TABLE 3-6. ESTIMATES OF PM EMISSIONS FROM BLAST FURNACE OPERATIONS

Plant	Furnace	Capacity (million tpy)	Casthouse control	Particulate matter emissions (tpy)					
				Casthouse	Raw materials	Slips	Stoves	Slag	Total
	5S	1.6	Hood in roof (with air curtain) for tapping, hood over torpedo car, both to baghouse; covered runners with flame suppression	40	32	24	45	21	162
Totals		60.9		10,350	1,218	914	1,601	792	14,875

* H and J are operated only when L is down for a re-line.

3.2.3.3 Estimates of Mn Emissions. Several plants provided data from dust analyses to estimate Mg emissions from the blast furnace casthouse. A few plants reported the percent Mn in the dust from other operations. These data are summarized in Table 3-7. The table indicates that Mn was reported to range from 0.1 to 1.7 percent of PM with an average of 0.6 percent, which is the value used in Table 3-8 to estimate Mn emissions from the casthouse. This same value (0.6 percent) was also used to estimate Mn emissions from raw material handling, slag, and slips because the few data points for these sources are relatively consistent with the range seen for casthouse dust. A value of 0.2 percent Mn was used to estimate Mn emissions from blast furnace stoves (Table 3-8). Total Mn emissions from blast furnace operations are given in Table 3-8.

3.2.3.4 Estimates of HCN Emissions. Emissions of HCN were reported for the cooling tower used for the blast furnace scrubber water. Two plants calculated the amount of HCN stripped from the water in the cooling tower by analyzing the water for HCN concentration before and after cooling and measuring the wastewater flow rate. The decrease in HCN concentration times the water flow rate provides a measure of the HCN that was emitted. One plant reported the average value from several measurements as resulting in 51 tpy of HCN emissions and an emission factor based on iron production of 0.035 lb/ton.[7] Another plant reported a range of 40 to 70 tpy of HCN emissions based on their measurements.[27] For a typical production rate of 1.15 million tpy, this range results in an HCN emission factor of 0.07 to 0.12 lb/ton. The emission estimates for HCN presented in Table 3-9 are based on a midrange value 0.08 lb/ton.

The Bethlehem Burns Harbor plant reported that there was essentially no HCN in their scrubber water and provided data from samples taken and analyzed by EPA. Differences in the furnace design and operation such as furnace top temperatures and pressures may explain why HCN is generated in some blast furnace operations and not in others. The Burns Harbor plant has indicated that HCN can be produced at certain times during the startup or shutdown of the blast furnace for a reline. No HCN emissions were estimated for the Burns Harbor plant to reflect the normal steady-state operation.

If HCN is produced in the blast furnace operation, it will remain in the scrubber water under alkaline conditions because it will be in an ionized form. Under acidic conditions, HCN is in an un-ionized form and is stripped from the scrubber water as it goes through a cooling tower. The pH of blast furnace water systems is controlled at different levels depending on the corrosiveness and fouling potential of the system. A system that is either too basic or too acidic can result in damage to equipment or piping.

3.2.4 Uncertainties in the Emission Estimates

There is inherent uncertainty in the estimates of emissions from blast furnace operations because of their fugitive nature. The limited data on casthouse emissions apparently were developed from tests in other countries for casthouses that were entirely evacuated to a control device. In addition, there are few data available on the effectiveness of covers and flame suppression or on the capture efficiency of local hoods that are used at some plants. Another uncertainty is the variation in the Mn content in the iron, which may be affected by the Mn content of the iron ore or other materials. One plant reported a significant decrease in Mn content, which would mean the Mn emitted with the PM may be less than the estimates provided here. Uncertainty is also introduced for the HCN emission estimates because data were available for only three plants. Data on the HCN concentration in the wastewater entering and leaving the scrubber for other plants would improve the HCN emission estimates.

TABLE 3-7. Mn DATA PROVIDED BY THE COMPANIES

Source	Plant	Percent Mn in PM
Casthouse	Acme Steel[28, 29]	0.81
	AK Steel (KY)[30, 31]	1.7
	BSC (MD)[7]	0.29
	Geneva Steel[8]	0.25
	Inland No. 7[10, 11]	0.43
	Inland Nos. 5, 6[10, 11]	1.2
	LTV H3[12, 13]	0.55
	LTV H4[12, 13]	0.52
	National[37, 38]	0.14
	Rouge Steel[35]	0.13
	USX (PA)[33, 34]	0.52
	USX (AL)[33, 34]	0.11
	USS Kobe (OH)[36]	0.3
	Average	0.6
Raw material handling	Acme Steel[28, 29]	0.60
	Weirton Steel[19]	1.2
Slag	National Steel[37, 38]	0.64
Stove	National Steel[37, 38]	0.25
	USX (AL)[33, 34]	0.20
Slips	Geneva Steel[8]	0.25

TABLE 3-8. ESTIMATES OF Mn EMISSIONS FROM BLAST FURNACE OPERATIONS

Plant	Furnace	Capacity (million tpy)	Mn emissions (tpy)					
			Casthouse	Raw materials	Slips	Stoves	Slag	Total
Acme Steel, Riverdale, IL	1	1.0	1.8	0.12	0.090	0.056	0.078	2.1
AK Steel, Ashland, KY[30, 31]	A	1.9	3.4	0.23	0.171	0.106	0.148	4.1
AK Steel, Middletown, OH[3, 4]	3	2.2	4.0	0.26	0.198	0.123	0.172	4.7
Bethlehem Steel, Burns Harbor, IN	C,D	5.5	9.9	0.66	0.495	0.308	0.429	11.8
Bethlehem Steel, Sparrows Point, MD	L	3.5	0.5	0.42	0.315	0.196	0.273	1.7
Geneva Steel, Orem, UT	1,2,3	2.7	4.9	0.32	0.243	0.151	0.211	5.8
Gulf States Steel, Gadsden, AL	2	1.2	2.2	0.14	0.108	0.067	0.094	2.6
Inland Steel, East Chicago, IN	7	4.0	0.6	0.48	0.360	0.224	0.312	2.0
	5, 6	2.5	0.4	0.30	0.225	0.140	0.195	1.2
LTV Steel, Cleveland, OH	C1,C5	2.7	4.9	0.32	0.243	0.151	0.211	5.8
	C6	1.4	2.5	0.17	0.126	0.078	0.109	3.0
LTV Steel, East Chicago, IN	H3	1.6	2.9	0.19	0.144	0.090	0.125	3.4
	H4	2.0	0.3	0.24	0.180	0.112	0.156	1.0
National Steel, Granite City, IL	A,B	2.4	0.4	0.29	0.216	0.134	0.187	1.2
National Steel, Ecorse MI	A,B,D	4.9	0.7	0.59	0.441	0.274	0.382	2.4
Rouge Steel, Dearborn, MI	B, C	2.7	4.9	0.32	0.243	0.151	0.211	5.8
USX, Braddock, PA	1, 3	2.3	0.3	0.28	0.207	0.129	0.179	1.1

TABLE 3-8. ESTIMATES OF Mn EMISSIONS FROM BLAST FURNACE OPERATIONS

Plant	Furnace	Capacity (million tpy)	Mn emissions (tpy)					
			Casthouse	Raw materials	Slips	Stoves	Slag	Total
USX, Fairfield, AL	8	2.0	3.6	0.24	0.180	0.112	0.156	4.3
USX, Gary, IN	4,6,8	3.4	6.1	0.41	0.306	0.190	0.265	7.3
USX, Gary, IN	13	2.7	0.4	0.32	0.243	0.151	0.211	1.3
USS/Kobe Steel, Lorain, OH	3	1.3	0.2	0.16	0.117	0.073	0.101	0.6
	4	1.0	1.8	0.12	0.090	0.056	0.078	2.1
WCI Steel, Warren, OH	1	1.6	0.2	0.19	0.144	0.090	0.125	0.8
Weirton Steel, Weirton, WV	1,3	2.1	3.8	0.25	0.189	0.118	0.164	4.5
Wheeling Pittsburgh Steel, Mingo Junction, OH	1N	0.7	1.3	0.08	0.063	0.039	0.055	1.5
	5S	1.6	0.2	0.19	0.144	0.090	0.125	0.8
Totals		60.9	62.1	7.3	5.5	3.4	4.8	83.1

TABLE 3-9. ESTIMATES OF HCN EMISSIONS FROM BLAST FURNACE WASTEWATER TREATMENT (COOLING TOWER)

Plant	Furnace	Capacity (million tpy)	HCN emissions (tpy)
Acme Steel, Riverdale, IL	1	1.0	40
AK Steel, Ashland, KY[30, 31]	A	1.9	76
AK Steel, Middletown, OH[3, 4]	3	2.2	88
Bethlehem Steel, Burns Harbor, IN	C,D	5.5	*
Bethlehem Steel, Sparrows Point, MD	L	3.5	140
Geneva Steel, Orem, UT	1,2,3	2.7	108
Gulf States Steel, Gadsden, AL	2	1.2	48
Inland Steel, East Chicago, IN	7	4.0	160
	5, 6	2.5	100
LTV Steel, Cleveland, OH	C1,C5	2.7	108
	C6	1.4	56
LTV Steel, East Chicago, IN	H3	1.6	64
	H4	2.0	80
National Steel, Granite City, IL**	A, B	2.4	96
National Steel, Ecorse, MI	A,B,D	4.9	196
Rouge Steel, Dearborn, MI	B, C	2.8	112

TABLE 3-9. ESTIMATES OF HCN EMISSIONS FROM BLAST FURNACE WASTEWATER TREATMENT (COOLING TOWER)

Plant	Furnace	Capacity (million tpy)	HCN emissions (tpy)
USX, Braddock, PA	1, 3	2.3	92
USX, Fairfield, AL	8	2.0	80
USX, Gary, IN	4,6,8,13	6.1	244
USS/Kobe Steel, Lorain, OH	3	1.3	52
	4	1.0	40
WCI Steel, Warren, OH	1	1.6	64
Weirton Steel, Weirton, WV	1,3	2.1	84
Wheeling Pittsburgh Steel, Mingo Junction, OH	1N	0.7	28
	5S	1.6	64
Total		61	2,220

* This plant provided data showing essentially no HCN in the scrubber water.
** This plant does not have a cooling tower. HCN emissions are likely to occur at other steps in the wastewater treatment process.

3.3 BASIC OXYGEN PROCESS FURNACE [1, 39]

This section provides a brief description of the BOPF process; additional details on the process can be found in References 1 and 39. The BOPF shop is a cyclical batch operation, beginning when the molten iron is brought from the blast furnace in torpedo cars and transferred to a ladle. Each shop is comprised of several distinct operations including: (1) hot metal transfer of the molten iron received from the blast furnace; (2) deslagging of the hot metal; (3) desulfurization; (4) charging of hot metal and steel scrap to the BOPF vessel; (5) refining the hot metal into steel; (6) tapping the furnace; (7) deslagging; (8) ladle metallurgy, where additional alloy additions and final changes to the chemistry of the steel may be made; and (9) transfer of the steel to a continuous caster.

The plants and their production capacities, process flow rates, and control devices for primary and secondary emissions are listed in Tables 3-10 and 3-11. Information on controls used for ancillary processes is given in Table 3-12. This information was obtained from survey responses listed in References 3 through 8, 10 through 13, 15 through17, and 27 through 38. There are a total of 23 BOPF shops at 20 plants that are owned by 14 companies with a nationwide capacity of about 68 million tpy. The plants are located in 10 different States, with the largest number in Ohio and Indiana with 6 shops each.

3.3.1 Reladling, Desulfurization, and Slag Skimming

After the hot metal is produced in the blast furnace, it is transferred to the BOPF shop. Brick lined torpedo cars are preferred because of their insulating qualities and consequent lower heat loss from the iron. The hot metal is then **reladled** from the torpedo cars to the BOPF shop ladle. This transfer is accompanied by the emissions of kish, a mixture of fine iron oxide particles together with larger graphite particles. The reladling generally takes place under a hood to capture these emissions.

Desulfurization of the hot metal is accomplished by means of various reagents such as oda ash, lime, and magnesium. Injection of the reagents is accomplished pneumatically with either dry air or nitrogen. Desulfurization may take place at various locations within the iron and steel making facility; however, if the location is the BOPF shop, then it is most often

TABLE 3-10. BOPF SHOP EMISSION CONTROL SYSTEMS -- CLOSED HOOD BOPF SHOPS

Closed Hood BOPF Shops						
Plant	**Location**	**Capacity (tpy)**	**Flow (dscfm)**	**Top/bottom blown**	**Primary control**	**Secondary control**
AK Steel[30, 31]	Ashland, KY	2,167,545	78,000	Top	Scrubber	Baghouse
AK Steel[3, 4]	Middletown, OH	2,716,000	40,000 (#15) 51,000 (#16)	Top	Scrubber	None
Geneva Steel	Provo, UT	2,500,000	77,800	Bottom	Scrubber	Baghouse
Inland Steel No. 2 Shop	East Chicago, IN	2,500,000	50-60,000	Top	Scrubber	Scrubber
LTV Steel No. 2 Shop	Cleveland, OH	4,380,000	138,000	Top	Scrubber	Baghouse
USS/Kobe Steel	Lorain, OH	2,600,000	58,000 (L) 59,000 (N)	Top	Scrubber	Baghouse
USS Fairfield Works	Fairfield, AL	2,200,000	81,000	Bottom	Scrubber	Baghouse

TABLE 3-11. BOPF SHOP EMISSION CONTROL SYSTEMS -- OPEN HOOD BOPF SHOPS

Open Hood BOPF Shops						
Plant	**Location**	**Capacity (tpy)**	**Flow (dscfm)**	**Top/bottom blown**	**Primary control**	**Secondary control[a]**
Acme Steel[28, 29]	Riverdale, IL	1,290,000	288,000	Top	ESP	None
Bethlehem Steel	Burns Harbor, IN	5,353,500	339,600[b]	Top	Scrubber	None[b]
Bethlehem Steel	Sparrows Point, MD	4,000,000	600,000[c]	Top	Scrubber	None
Gulf States Steel	Gadsden, AL	1,300,000	327,000	Top	ESP	None
Inland Steel No. 4	East Chicago, IN	2,740,000	310-380,000	Top	Scrubber	Baghouse
LTV Steel	East Chicago, IN	4,161,000	458,100	Top	ESP	None
LTV Steel No. 1 Shop	Cleveland, OH	3,340,000	550,000	Top	ESP	None
National Steel	Granite City, IL	2,575,440	330,000	Top	ESP	Enclosure to primary system
National Steel	Ecorse, MI	4,100,000	500,000	Top	ESP	Baghouse
Rouge Steel	Dearborn, MI	3,309,000	500,000	Top	ESP	None
USS Edgar Thomson Works	Braddock, PA	2,760,000	174,000	Top	Scrubber	Baghouse
USS Gary Works	Gary, IN	2,933,935	267,858[c]	Top	Scrubber	None
USS Gary Works	Gary, IN	3,992,812	267,227[c]	Bottom	Scrubber	Baghouse
WCI Steel	Warren, OH	1,728,000	480,000[c]	Top	ESP	None
Weirton Steel	Weirton, WV	3,200,000	280,000	Top	Scrubber	None
Wheeling Pittsburgh Steel	Mingo Junction, OH	2,600,000	210,000	Top	Scrubber	None

[a] Only systems with separate capture and control devices for fugitive emissions are listed; several plants use the primary control system for partial capture of charging and tapping emissions.
[b] acfm total for 3; this shop has 1 closed hood and 2 open hood vessels. The closed hood vessel has a scrubber for secondary control.
[c] acfm.

TABLE 3-12. SUMMARY OF CONTROLS FOR ANCILLARY PROCESSES

Plant		Other controls				
		Hot Metal Reladle	**Hot Metal desulfurization**	**Hot Metal deslagging**	**Slag transfer**	**Ladle metallurgy**
Acme Steel, Riverdale, IL[28, 29]		Baghouse	Baghouse	Baghouse	None	Baghouse
AK Steel, Ashland, KY		Baghouse-1	Baghouse-1	Baghouse-1	None	Baghouse-2
AK Steel, Middletown, OH		Baghouse-1	Baghouse-1	Baghouse-2	None	Baghouse-3, Scrubber
Bethlehem, Burns Harbor, IN (3 vessels in 1 shop) -- 3 stations		Baghouse-1	Baghouse-1	Baghouse-1	None	Baghouse-3
Bethlehem, Sparrows Pt., MD		Baghouse-1	Baghouse-2	Baghouse-3	None	Baghouse-4
Geneva Steel, Orem, UT		None	Baghouse-1	None	None	None
Gulf States Steel, Gadsden, AL		Baghouse-1	Baghouse-1	Baghouse-1	None	Baghouse-2
Inland Steel, East Chicago, IN (2 shops)	(o) (c)	Baghouse-1 Baghouse-1	Baghouse-1 Baghouse-1	None Baghouse-1	None None	 Baghouse-2
LTV Steel, East Chicago, IN		Baghouse-1	Baghouse-1	Baghouse-1	None	Baghouse-2
LTV Steel, Cleveland, OH (2 shops)	(o) (c)	Baghouse-1 Baghouse-1	Baghouse-1 Baghouse-1	Baghouse-1 Baghouse-1	None None	Baghouse-2 Baghouse-2 & scrubber
National Steel, Granite City, IL		Baghouse-1	Baghouse-1	Baghouse-2	None	Baghouse-3
National Steel, Ecorse, MI		Baghouse-1	Baghouse-1	Baghouse-1	None	Baghouse-2
Rouge Steel, Dearborn, MI		Baghouse-1	Baghouse-2	Baghouse-2	None	Baghouse-3,4
USX, Fairfield, AL		Baghouse-1,2	Baghouse-1,2	None	None	Baghouse-3,4
USX, Gary, IN (2 shops)	(o) (o)	Baghouse Baghouse	Baghouse Baghouse	None None	None None	 Baghouse
USX, Braddock, PA		Baghouse-1	Baghouse-1	None	None	
USS/Kobe Steel, Lorain, OH		Flame suppression	Baghouse-1	None	None	Baghouse-1 Cyclone/ Baghouse-2
WCI Steel, Warren, OH		Flame supp.	Baghouse-1	Baghouse-1	None	Baghouse-2
Weirton Steel, Weirton, WV		Baghouse-1	Baghouse-2	Baghouse-2	None	Baghouse-3
Wheeling Pittsburgh Steel, Mingo Junction, OH		Baghouse-1	Unknown	Baghouse-1	Water spray	None

o = open; c = closed

* One ladle met station has no controls; a steam injector and condenser are used for vacuum degassing operations.

accomplished at the reladling station to take advantage of the fume collection system at that location.

Skimming of slag from the ladle of molten iron keeps this source of high sulfur out of the steelmaking process. Skimming results in the emissions of kish, and is therefore normally done under a hood.[40]

3.3.2 BOPF Shop

The BOPF receives a charge composed of molten iron and scrap and converts it to molten steel. Each BOPF shop contains at least two BOPF vessels that may be operated alternately; in some shops, both vessels may be in use at different stages of the cycle. The distinct operations in the BOPF process are:

(1) **charging** -- the addition of molten iron and metal scrap to the furnace,

(2) **oxygen blow** -- introducing oxygen into the furnace to refine the iron,

(3) **turndown** -- tilting the vessel to obtain a sample and check temperature,

(4) **reblow** -- introducing additional oxygen, if needed,

(5) **tapping** -- pouring the molten steel into a ladle, and

(6) **deslagging** - pouring residual slag into a slag pot.

A jet of high purity oxygen oxidizes the carbon and the silicon in the molten iron in order to remove these products and to provide heat for melting the scrap. After the oxygen jet is started, lime is added to the top of the bath to provide a slag of the desired basicity. Fluorspar and mill scale are also added in order to achieve the desired slag fluidity. The oxygen combines with the unwanted elements (with the exception of sulfur) to form oxides, which leave the bath as gases or enter the slag. As refining continues and the carbon content decreases, the melting point of the bath increases. Sufficient heat must be generated from the oxidation reactions to keep the bath molten.[1]

The furnace is a large, open-mouthed vessel lined with a basic refractory material (the term "basic" refers to the chemical characteristic of the lining). There are currently three methods that are used to supply the oxidizing gas: (1) top blown, (2) bottom blown, and (3) combination blowing. These processes are described in detail below.

The basic oxygen steelmaking process is a thermochemical process; computations are made to determine the necessary percentage of molten iron, scrap, flux materials, and alloy additions. Various steelmaking fluxes are added during the refining process to reduce the sulfur and phosphorus content of the metal to the proscribed level. The oxidation of silicon, carbon, manganese, phosphorus, and iron provide the energy required to melt the scrap, form the slag, and raise the temperature of the bath to the desired temperature.

After the steel is refined, alloy or other additions are made in the vessel as necessary, and the vessel is then turned down and tapped. If the analysis is correct, the heat is tapped; however, if the analysis is off, then it may be necessary to either blow with additional oxygen to elevate the temperature and/or cool the steel by coolant additions to the bath. In most shops, the steel is transferred to a ladle metallurgy station for further alloy additions and then to a continuous caster. A few facilities may still teem some of their steel, pouring the molten steel into ingot molds, but most facilities have switched to the more modern and efficient process of continuous casting.

The BOPF shop is generally arranged with three parallel aisles. The first aisle, the charging aisle, has one or more cranes for handling charge materials to the furnace as well as handling ladles of molten slag away from the furnace. The second aisle, the furnace aisle, contains the furnaces, collection hood for the fumes, lances for injecting oxygen into the bath, and overhead bins for storing and metering out the various flux materials and alloy additions. The third aisle, the pouring aisle, handles the finished heats of steel. This aisle has one or more overhead cranes and facilities for receiving heats of steel into ingot molds or continuous casting machines.

During the oxygen blow in the top blown process, the oxygen lance is lowered through a special hole in the top wall of the hood, is stopped a short distance above the bath of steel, and the oxygen flow is initiated. The vessel is upright during the blow and the fumes have a direct access from the mouth of the furnace into the mouth of the hood. At other times in the process, the vessel may be tilted so that the mouth of the vessel does not align with the opening in the hood and capture of the fumes becomes more difficult. The vessel is tilted toward the charging aisle for charging with scrap, charging with molten iron, sampling the heat for analysis, and dumping the slag. The vessel is tilted toward the pouring aisle when pouring the finished heat of steel from the furnace into the steel ladles. These operations are controlled by a secondary capture system at some facilities in the industry. The desired specifications of the end product are usually accomplished by the additions of suitable alloying materials to the ladle of finished steel as it is filled. The gases which evolve from the steelmaking operation are captured by the hood and then enter a gas cleaning system consisting of a electrostatic precipitator or a wet scrubber.[40]

3.3.2.1 Bottom Blown Furnace. An alternative to the use of an oxygen lance is found in the Q-BOP process. In this process, oxygen and natural gas are injected through tuyeres in the bottom of the vessel. The metallurgy of the process, the ancillary equipment, and the fume suppression system are generally the same as for the BOPF. The principal advantage of the Q-BOP is that it requires less headroom in the furnace aisle than the BOPF. This has allowed the Q-BOP to be installed in an existing open hearth building, saving cost in construction. The Q-BOP is also capable of producing steel at a somewhat faster rate than does the BOPF.

When the Q-BOP is tilted to receive scrap and molten iron, or to sample the steel for analysis, it is necessary to maintain a flow through the tuyeres so that they do not become blocked. In normal practice, the oxygen and natural gas are turned off when the vessel is tilted and these gases are replaced by a flow of nitrogen. Because of this, there is an unrestrained flow of emissions of fumes from the mouth of the vessel due to the gas flow from the tuyeres. For this reason, the Q-BOP is more fully enclosed at the level of the charging floor than many BOPF vessels. In order to direct the gases back into the collection system, a pair of large horizontally sliding doors are provided; these doors are opened to permit the addition of scrap and molten iron but are closed at all other times.[40]

3.3.2.2 Combination Blowing. Combination blowing processes utilize oxygen through a top lance and an inert gas through tuyeres or permeable elements in the furnace bottom to stir the bath. A second class of combination blowing processes uses some of the oxygen through a top lance or tuyeres mounted in the top cone of the vessel, and the balance of the oxygen through Q-BOP type tuyeres in the vessel bottom. These processes can usually switch the bottom gas from oxygen to argon or nitrogen for stirring purposes.[1]

3.3.3 Ladle Metallurgy

The purpose of ladle metallurgy (also referred to as secondary steelmaking) is to produce steel which satisfies stringent requirements of surface, internal, and microcleanliness quality and mechanical properties. Ladle metallurgy is a secondary step of the steelmaking process often performed in a ladle after the initial refining process in the primary BOPF is completed. This secondary step enables plants to exercise control over many processing conditions contributing to a higher quality of steel including:

1. Teeming temperature, especially for continuous casting operations;
2. Deoxidation;
3. Decarburization (ease of producing steels to low carbon levels of less than 0.03 percent);

4. Additional adjustment for chemical composition;
5. Increasing production rates by decreasing refining times in the furnace.[1]

Nearly all of the integrated iron and steel facilities have ladle metallurgy operations. Several ladle metallurgy processes are commonly used, including vacuum degassing, ladle refining, argon/oxygen decarburization, and lance powder injection.

3.3.4 Emission Points and Factors Affecting Emissions

The emission points associated with the BOPF shop are shown in Figure 3-3. The most significant sources of emissions are from charging, tapping, and the oxygen blow portions of the furnace cycle. Auxiliary processes including hot metal transfer, desulfurization, slag skimming, and ladle treatment also contribute to the total emissions. Emissions from desulfurization and ladle metallurgy are captured and controlled by a series of one or more control devices at most plants. Emissions from slag removal, slag transfer and disposal, and from transfer to the continuous caster or ingot molds are generally uncontrolled.

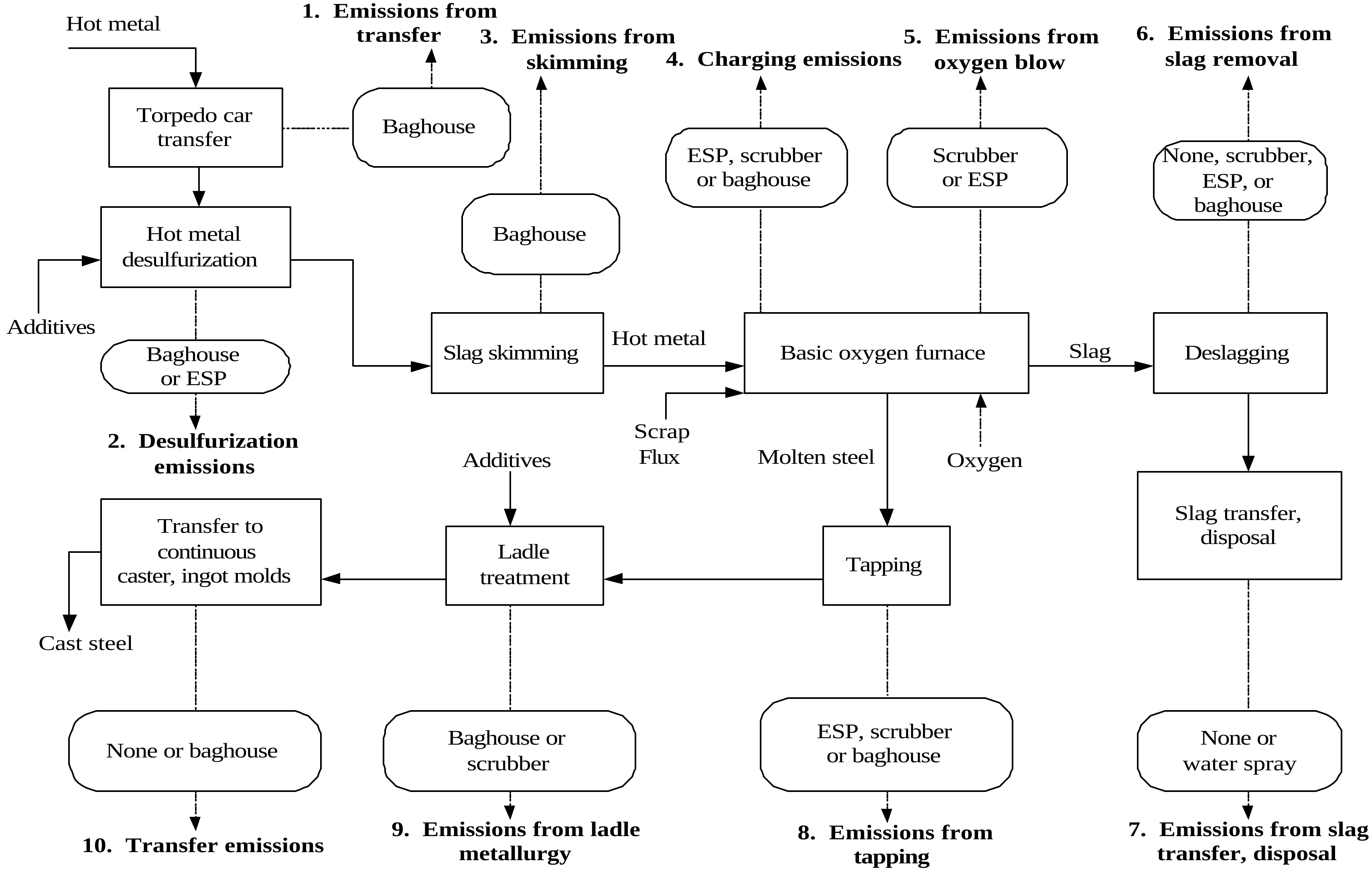

FIGURE 3-3. SCHEMATIC OF BOPF SHOP EMISSION POINTS AND TYPICAL CONTROLS

The major HAP reported to be emitted from the BOPF process is Mn; some Pb has also been reported, as have very small quantities of chromium, copper, mercury, nickel, and selenium.[7, 8,37, 38] Emission control performance for this operation has been determined traditionally based on PM emissions.

There are differences in BOPF and types of control devices among the various shops. The primary emission capture and control system for the BOPF vessel is either an **open hood** directed to an ESP or wet scrubber, or a **closed hood** ducted to a wet scrubber. In the closed hood system, the diameter of the hood is approximately the same as the diameter of the vessel, and the lower portion of the hood is a skirt that can be lowered onto the mouth of the vessel. This seals off the space between the hood and the vessel, limiting the amount of air that can enter the system.

In contrast, the open hood is loose-fitting and draws in dilution air with the emissions captured from the BOPF. The volume of gas collected in the closed hood system is reduced by 80 to 85 percent as compared to the open hood system. Because there is less danger from explosion in the open hood system, the vessels may be connected to a common gas cleaning system. In an closed hood system, each vessel has a separate scrubber system because of the potential explosion hazard from leakage of air into the system from an idle furnace. There are currently **7 closed hood** BOPF shops and **16 open hood** BOPF shops in operation in the U.S.

BOPF vessels are also differentiated as either **"top blown"** or **"bottom blown."** There are currently **3 bottom-blown** shops and **20 top-blown** shops in the U.S.

As discussed above, differences in process design and operation affect the quantity and concentration of pollutants that escape capture and are emitted as fugitive emissions. In addition, charging emissions are affected by the quality, quantity, and composition of scrap charged to the furnace as well as the pour rate and pouring technique used to charge the hot metal.

After refining in the BOPF vessel, the steel may be sent to a ladle metallurgy station for further refining or alloy additions before subsequent transfer to the continuous caster. All of the BOPF shops in the U.S. have a ladle metallurgy station, although the actual process varies from plant to plant. Emissions from these operations are affected by the type of capture device used and the surface area of molten metal that is exposed to the atmosphere.

3.3.5 Estimates of Baseline Emissions

The approach used in this section to estimate baseline emissions relies on estimates submitted by the individual companies and emission factors in EPA's AP-42 emission factor document.[26] For metal HAP, Mn was the HAP metal most reported by the facilities. Estimates of PM are used with analyses of the dust for metals (expressed as percent Mn) to estimate Mn emissions.

3.3.5.1 BOPF Charging, Oxygen Blow, and Tapping PM Emissions. Emission estimates for PM from BOPF charging, oxygen blow, and tapping, are provided in Table 3-13 from estimates provided by each company in response to survey questionnaires. Many companies apparently reported only emissions from the discharge stacks of emission control devices, and only a few attempted to estimate fugitive emissions that escape through the roof monitor. To put the estimates on a common basis, the AP-42 emission factors[26] were used in an attempt to account for both primary system emissions and fugitive emissions from certain processes that escape through the roof monitor. Several plants submitted emission measurements for the primary control system; consequently, when measurements were available, the measurements were used instead of the AP-42 emission factors.

3.3.5.2 Miscellaneous Emission Points. The PM emission estimate factors used for hot metal transfer, desulfurization, charging, oxygen blow, and tapping, are summarized in Table 3-14. The PM emission measurements for ladle metallurgy shown in Table 3-13 are very low relative to emissions from other points because this process is controlled by baghouses at almost all plants. Consequently, ladle metallurgy operations contribute very little to HAP metal emissions (i.e., Mn) from the BOPF shop. All of the emission factors except that for the primary control system for closed hood BOPFs are from AP-42. For closed hood shops, the emission factor of 0.0068 lb/ton was not consistent with the test measurements submitted by three plants with closed hood shops. Their measurements given below were used to derive an emission factor of 0.035 lb/ton.

Plant	Capacity (tpy)	Emissions (lb/yr)
1	1,700,000	64,000
2	2,500,000	134,000
3	4,400,000	102,000
Total	8,600,000	300,000

Emission factor (closed hood BOPFs) = 300,000/8,600,000 = 0.035 lb/ton

3.3.5.3 Estimates of Mn Emissions. More than half of the plants provided data on Mn emissions from the BOPF shop, and they typically estimated these emissions from the percent of PM that was Mn. Emissions of Mn far exceeded all other HAP metals combined; consequently, estimates of HAP emissions from this process will focus on Mn as the HAP of interest. The data from various companies ranged from 0.14 to 10.7 percent of PM; however, the vast majority was in the range of about 0.5 to 1.5 percent. Neglecting the two outliers on the extreme end of the range, the overall average of the data indicated that Mn was 0.95 percent of PM. This value of 0.95 percent should be accurate within a factor of two or less for most plants and was used to estimate Mn emissions from charging, oxygen blow, and tapping operations for the BOPF shop. The emission estimates for PM and Mn are provided in Tables 3-15 and 3-16.

TABLE 3-13. PM EMISSIONS FROM THE BOPF SHOP REPORTED BY THE COMPANIES

Plant	Capacity (million tpy)	Reported PM Emissions (tpy)				
		Desulfurization	Charge	O_2 Blow	Tap	Ladle Met.
Acme Steel (IL)	1.3	24	29	51	64	0
AK Steel (KY)	2.2			9	220[a]	13
AK Steel (OH)	2.7		193	58	394	0.3[b]
Bethlehem Steel (IN)	5.3			51[c]		
Bethlehem Steel (MD)	4.0	7	93	226	119	0.6
Geneva Steel (UT)	2.5	19	22	28	32	
Gulf States Steel (AL)	1.3					
Inland Steel #2	2.5	119[d]	50[e]	67[f]		8.4
Inland Steel #4	2.7	33[g]	89[e]	400		
LTV Steel (IN)	4.2	6[d]		307[h]		
LTV Steel (OH) #1	3.3	5[d]		158[3, 4]		5
LTV Steel (OH) #2	4.4	41[i]				
National Steel (IL)	2.6	2[g]		230[c]		2
National Steel (MI)	4.1	76[d]	159[e]			10
Rouge Steel (MI)	3.3	31[k]	16[l]	208[c]	30[l]	39[b]
USS/Kobe Steel (OH)	2.6	9.8	5.5	17.4	4.2	10.3
USX (AL)	2.2	1	496[e]	23		5.6
USX BOPF (IN)	2.9					
USX Q-BOP (IN)	4.0					
USX (PA)	2.8	2.5[d]				
WCI Steel (OH)	1.7					
Weirton Steel (WV)	3.2	12[j]	149[e]	203		2
Wheeling-Pitt (OH)	2.6	11	18	96	52	9

[a]includes transfer, desulfurization, skimming, charging
[b]from control device only
[c]includes charging, tapping; from control device only
[G]includes hot metal transfer
[h]includes charging; 354 tpy from roof
[i]includes transfer, skim, tap, charge

[d]includes transfer, slag skimming
[e]includes tapping
[f]reported 84 tpy from roof monitor
[j]includes slag skimming
[k]includes roof monitor
[l]roof monitor only

TABLE 3-14. EMISSION FACTORS USED FOR THE BOPF SHOP

Emission point	PM in lb/ton	Source
Open hood with ESP	0.13	AP-42
Open hood with scrubber	0.09	AP-42
Closed hood with scrubber	0.035	Derived (see text)
Q-BOP with scrubber	0.056	AP-42
Charging fugitives with baghouse	0.0006	AP-42
Tapping fugitives with baghouse	0.0026	AP-42
Uncontrolled charging fugitives	0.142	AP-42
Uncontrolled tapping fugitives	0.29	AP-42
Hot metal transfer at roof monitor	0.056	AP-42
Desulfurization with baghouse	0.009	AP-42

TABLE 3-15. ESTIMATES OF PM EMISSIONS FROM THE BOPF SHOP

Plant	Capacity (10^6 tpy)	Estimates of PM emissions (tpy) from AP-42 factors[a]				
		Transfer, desulfurization	Charge	O_2 blow	Tap	Total
Open hood shops with no secondary controls[b]						
Acme Steel (IL)	1.3	42	92	85	189	408
Bethlehem Steel (IN)	5.3	174	380	51[c]	776	1,381
Bethlehem Steel (MD)	4.0	130	284	180	580	1,174
Gulf States Steel (AL)	1.3	42	92	85	189	408
LTV Steel (IN)	4.2	135	295	270	603	1,303
LTV Steel (OH) #1	3.3	109	237	158[c]	484	988
National Steel (IL)	2.6	84	1	168	3	256
Rouge Steel (MI)	3.3	107	234	215	479	1,035
USX Gary (IN)	2.9	95	208	132	425	860
WCI Steel (OH)	1.7	56	123	113	251	543
Weirton Steel (WV)	3.2	104	227	203[c]	464	998
Wheeling-Pitt (OH)	2.6	85	185	96[c]	377	743
Open hood shops with secondary controls						
Inland Steel #4	2.7	89	1	400[c]	4	494
National Steel (MI)	3.5	114	1	159[c]	5	279
USX (PA)	2.8	90	1	124	4	218
Closed hood shops with secondary controls						
AK Steel (KY)[30, 31]	2.2	71	1	9[c]	3	83
Inland Steel #2	2.5	81	1	67[c]	3	152
LTV Steel (OH) #2	4.4	142	1	51[c]	6	200
USS/Kobe Steel (OH)	2.6	48	0	26	2	76

TABLE 3-15. ESTIMATES OF PM EMISSIONS FROM THE BOPF SHOP

Plant	Capacity (10^6 tpy)	Estimates of PM emissions (tpy) from AP-42 factors[a]				
		Transfer, desulfurization	Charge	O_2 blow	Tap	Total
Closed hood shops with no secondary controls						
AK Steel (OH)[3, 4]	2.7	88	192	230[c]	392	902
Q-BOPs with secondary controls						
Geneva Q-BOP (UT)	2.5	81	0.8	28[c]	3.3	113
USX Q-BOP (AL)	2.2	72	0.7	62	2.9	138
USX Q-BOP (IN)	4.0	130	1.2	112	5.2	248
Total	**68**	**2,169**	**2,558**	**3,024**	**5,249**	**13,001**

[a] Estimated from the emission factors in Table 3-14 unless otherwise noted.
[b] Assumes no capture and control by the primary system; most open hood shops control some of the fugitive emissions by the primary capture and control system.
[c] These are based on emission measurements submitted by the companies.

TABLE 3-16. ESTIMATES OF Mn EMISSIONS FROM THE BOPF SHOP

Plant	Capacity (10^6 tpy)	Estimates of Mn emissions (tpy) [a]				
		Transfer, desulfurization	Charge	O_2 blow	Tap	Total
Open hood shops with no secondary controls						
Acme Steel (IL)	1.3	0.4	0.9	0.8	1.8	3.9
Bethlehem Steel (IN)	5.3	2	4	0	7	13
Bethlehem Steel (MD)	4.0	1	3	2	6	11
Gulf States Steel (AL)	1.3	0.4	0.9	0.8	1.8	3.9
LTV Steel (IN)	4.2	1	3	3	6	12
LTV Steel (OH) #1	3.3	1.0	2.3	1.5	4.6	9.4
National Steel (IL)	2.6	0.8	0.0	1.6	0.0	2.4
Rouge Steel (MI)	3.3	1	2	2	5	10
USX Gary (IN)	2.9	0.9	2.0	1.3	4.0	8.2
WCI Steel (OH)	1.7	0.5	1.2	1.1	2.4	5.2
Weirton Steel (WV)	3.2	1.0	2.2	1.9	4.4	9.5
Wheeling-Pitt (OH)	2.6	0.8	1.8	0.9	3.6	7.1
Open hood shops with secondary controls						
Inland Steel #4	2.7	0.8	0.0	3.8	0.0	4.7
National Steel (MI)	3.5	1.1	0.0	1.5	0.0	2.6
USX (PA)	2.8	0.9	0.0	1.2	0.0	2.1
Closed hood shops with secondary controls						
AK Steel (KY)	2.2	0.7	0.0	0.1	0.0	0.8
Inland Steel #2	2.5	0.8	0.0	0.6	0.0	1.4
LTV Steel (OH) #2	4.4	1.3	0.0	0.5	0.1	1.9
USS/Kobe Steel (OH)	2.6	0.5	0.0	0.2	0.0	0.7

TABLE 3-16. ESTIMATES OF Mn EMISSIONS FROM THE BOPF SHOP

Plant	Capacity (10^6 tpy)	Estimates of Mn emissions (tpy) [a]				
		Transfer, desulfurization	Charge	O_2 blow	Tap	Total
Closed hood shops with no secondary controls						
AK Steel (OH)	2.7	0.8	1.8	2.2	3.7	8.6
Q-BOPs with secondary controls						
Geneva Q-BOP (UT)	2.5	0.8	0.0	0.3	0.0	1.1
USX Q-BOP (AL)	2.2	0.7	0.0	0.6	0.0	1.3
USX Q-BOP (IN)	4.0	1.2	0.0	1.1	0.0	2.4
Total	**95**	**21**	**24**	**29**	**50**	**124**

* Based on 0.95 percent Mn in the PM (Table 3-15).

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4.0 EMISSION CONTROL TECHNIQUES AND EQUIPMENT

This chapter presents an overview of the techniques typically used to capture and control PM emissions from integrated iron and steel processes, including sinter plants, blast furnaces, and BOPF shops. This overview describes equipment design parameters, operating conditions, application of these control techniques in the industry, and factors that determine the effectiveness of these techniques in reducing emissions. Each section includes a discussion of the various capture systems and control techniques, performance of controls, and pollution prevention opportunities. Detailed descriptions of a few systems in place at actual plants are given to provide more insight into operation and design considerations.

4.1 SINTER PLANT

4.1.1 Windbox

The sinter plant windbox serves as the capture system for the sintering machine and is the most critical source of emissions in the sinter plant because of the number and variety of pollutants to be controlled and the high volume flowrate of the exhaust air. After sinter materials are mixed, they are ignited on the surface by gas burners. As the materials move through the sinter bed, air is pulled down through the mixture to burn the fuel by downdraft combustion through a series of windboxes, and evacuated to a control device.[1]

Baghouses and wet scrubbers are the principal means for controlling emission from the sinter plant windbox. Four plants use a baghouse and five plants use a wet scrubber to control windbox emissions. The final control unit may be preceded by a mechanical collector to remove large, heavy, and abrasive particles.[2]

The control of emissions from the windbox is made more difficult by factors such as the high volume rate of gas, the sometimes high resistivity of the dust, and the presence of hydrocarbon vapors. Table 4-1 presents various operating parameters for the windbox control systems.

TABLE 4-1. EMISSION CONTROLS FOR SINTER PLANT WINDBOXES

Plants with baghouses

Plant	State	Capacity (tpy)	Flow (dscfm)	Air/cloth ratio (acfm/ft^2)	) p (in. water)	Cleaning	Filter Material	Location
Geneva Steel[3]	UT	803,000	306,800	4.0	6	Pulse jet	Polyester	Windbox
Inland Steel[4, 5]	IN	1,000,000	400,000	1.4	4.9	Reverse air	Polyester	Windbox
USS Gary Works[6, 7]	IN	4,400,000	675,000 (estimate)					
WCI Steel[8]	OH	840,000	400,000	3.9	--	Pulse jet	Nomex	Windbox

Plants with wet scrubbers

Plant	State	Capacity (tpy)	Flow (dscfm)	L/G (gal/1000 acf)	) p (in. water)	Scrubber Type	Demister	Location
AK Steel[9, 10]	OH	895,000	219,000	8.2	50 - 55	Venturi	Mist eliminator	Windbox
Bethlehem[11, 12]	IN	2,922,000	485,000	12	60 - 70	Venturi	Chevrons	Windbox
Bethlehem[13, 14]	MD	4,000,000	600,000	12	35	Venturi	Chevrons	Windbox
LTV Steel[15, 16]	IN	1,927,000	265,000	9	40-55	Venturi	Chevrons	Windbox
Wheeling Pittsburgh[17]	WV	500,000	141,000	9.4	80	Venturi	--	Windbox

air/cloth ratio = ratio of air flow to cloth area in actual cubic feet per minute per square foot of cloth
) p = pressure drop in inches of water
L/G = liquid to gas ratio in gallons of water per 1,000 actual cubic feet of gas.

4.1.1.1 Baghouses. In a baghouse, the particle-laden gas flows through a number of filter bags placed in parallel, leaving the dust retained by the fabric. The type of filter material used in a baghouse depends on the specific application in terms of chemical composition of the gas, operating temperature, dust loading, and the physical and chemical characteristics of the particulate. The type of filter material used will limit the maximum operating gas temperature for the baghouse.

Extended operation of a baghouse requires that the dust be periodically cleaned off the cloth surface and removed from the baghouse; this is commonly accomplished in the sinter plant by reverse air or pulse jet cleaning; shaker cleaning may also used in certain circumstances, and is used for several baghouses on the discharge end of the sinter plant. After a new fabric goes through a few cycles of use and cleaning, it retains a residual layer of dust that becomes the filter medium; this phenomenon is responsible for highly efficient filtering of small particles.

In reverse air cleaning, gas flow to the bags is stopped in the compartment being cleaned, and a reverse flow of air is directed through the bags. This reversal of air gently collapses the bags and the shear forces developed remove dust from the surface of the bags. The reverse air for cleaning comes from a separate fan capable of supplying clean, dry air for one or two compartments at an air-to-cloth ratio similar to that of the forward air flow.[18]

In pulse jet cleaning, a burst of air is forced down through the bag expanding it violently. The fabric reaches its extension limit, and the dust separates from the bag. The filtering flows are opposite in direction when compared with reverse air designs. Bags are mounted on wire cages to prevent collapse while the dusty gas flows through them. The top of the bag and cage assembly is attached to the baghouse structure, whereas the bottom end is loose and tends to move in the turbulent gas flow.

Pulse jet baghouses may be compartmented; the bags are cleaned by compartment, with one compartment off-line at a time. Where they are not compartmented, bags are cleaned by rows when a timer initiates the burst of cleaning air through a quick-opening valve. A pipe above each row of bags carries the compressed air. The pipe is pierced above each bag so that cleaning air exits directly downward into the bag.

In shaker cleaning, inside-to-outside air flow is used and cleaning is accomplished by suspending the bag from a motor-driven hook or framework that oscillates. The motion creates a sine wave along the fabric, which dislodges the previously collected dust. Chunks of agglomerated dust fall into a hopper below the compartment. The compartments operate in sequence so that one compartment at a time is cleaned. Parameters that affect cleaning include the amplitude and frequency of the shaking motion and the tension of the mounted bag. The vigorous oscillations tend to stress the bags and require heavier and more durable fabrics.[18]

Baghouses have been installed on the sinter plant windbox at four plants. Two of the baghouses are pulsejet and one is a reverse air cleaning system; the remaining baghouse is a dry injection baghouse. One of these systems is described in greater detail below. The baghouses generally have an air flowrate of 300,000 to 400,000 scfm, an air-to-cloth ratio of 1.0 to 4.0 acfm/ft^2, and a pressure drop of 4 to 9 inches of water. Two of the windbox baghouses have polyester bags and one has Nomex® bags; information is not currently available on the fourth baghouse since it was only recently brought on-line.

The plants with baghouses have strict limits on the amount of oil in the sinter feed or the amount of oily mill scale that can be used because organic condensibles from the process can foul ("blind") the fabric used to filter PM. The oil content of the sinter is measured so that it does not exceed a level of approximately 0.1 to 0.2 percent oil in the mill scale feed material. Plants with wet scrubbers can use more oily mill scale in their mix because the hydrocarbon vapors do not interfere with the scrubber's control of PM.

Baghouse Installation at WCI Steel.[8] A system of four baghouses is used to control emissions from the sinter plant at WCI Steel, known as the strand, A, C, and cooler baghouses. The system was modified from an ESP system that was previously used to control emissions. No new building or major structural changes were required to modify the system. A new instrument/control room was built for the new control device system.

The baghouse on the strand was manufactured by Environmental Elements. It is a pulse jet baghouse with 14 compartments, utilizing Nomex® bags. Air is pulled down through 21 windboxes and evacuated to the baghouse. The flow to the baghouse is approximately 400,000 cfm. The baghouse has an air to cloth ratio of 3.90 acfm/ft^2. A preheat burner is used to minimize condensation and to bring the gas up to the desired inlet temperature of 275 EF. The dust is removed from the baghouse by rotary screw to bins where it is stored on the ground to gather moisture and is blended back into the sinter feed.

When the strand baghouse system was first brought online, there were problems with sparks and burning bags in the baghouse. In order to decrease the likelihood of fires occurring in the baghouse, a few changes were made to the system. Spark deflectors were added to the baghouse inlet, and the inlet temperature to the baghouse was decreased from 325EF to 275EF. The molecular size of the hydrocarbons was increased by lowering the inlet temperature so that the bags would not ignite as easily. Additional deflector plates were also added to the baghouse.

Based on the present performance of the system, several changes would have been made if the system was redesigned from the beginning: (1) baffles would be added to the baghouse; (2) the baghouse would be set further away and would have a longer system of duct work and an expansion chamber to drop out sparks before they reach the baghouse; (3) the air-to-cloth ratio would be lowered from 3.9 to 2.5 acfm/ft^2; and (4) spark deflectors would have been added to the system from the beginning.

The C baghouse was manufactured by Bahnson-Hawley and is a pulse jet baghouse that utilizes polyester bags. It serves the material handling bins and the conveyors that transfer the sinter mix to the sinter machine.

The A baghouse was also manufactured by Bahnson-Hawley. It is a pulse jet baghouse with four compartments, utilizing polyester bags. The system serves the discharge end, including the sinter production bins, sinter breaker, hot and cold screens, and 30-40 transfer points.

The cooler baghouse was manufactured by Ohio Ferroalloy. It is a shaker baghouse with 9 compartments, utilizing Nomex® bags. Eight of the compartments are used for the cooler and one compartment is used for the truck loadout station. There are four 200 horsepower fans on the sinter cooler. The first fan is the dirtiest fan and is directed back to hoods on the sinter machine and sent back through as preheat air. The other 3 fans are ducted to the baghouse. The truck loadout station has a 70,000 cfm fan.

4.1.1.2 Scrubbers. High energy scrubbers are used to control emissions from the sinter plant windbox at five plants. Four of the units are high energy venturi scrubbers and one is an impingment scrubber. The impingment scrubber and three of the venturi scrubbers are preceded by a cyclone to remove the heavy particles.

The wet scrubbers generally have an air flowrate of 140,000 to 600,000 scfm, a liquid to gas ratio of 2.0 to 12.0 gallons per thousand actual cubic feet, and a pressure drop of 35 to 80 inches of water.

In general, the wet scrubbers do not have the same limitations as the baghouse systems in the amount of oily mill scale that they can handle. While the use of larger quantities of mill scale will not foul up the scrubber systems, the level of control achievable for hydrocarbons and organic compounds depends on a number of factors.

High energy scrubbers offer good control of particulate condensible hydrocarbons, and, in addition, offer control of the fluorides and sulfur dioxide contained in sinter plant windbox gases. Control of hydrocarbons has been shown to depend on three factors: the concentration of the hydrocarbons in the inlet gas; the particle size of the hydrocarbon mist; and the pressure drop across the venturi throat. The most critical factor in controlling oil emissions when using a high energy scrubber is the control of oily emissions from the sinter strand itself. The efficiency of the oil removal from the scrubber system has rarely been shown to exceed 80 percent.[2]

4.1.2 Discharge End

Emission points on the discharge end include sinter discharge, crusher, hot screen, sinter cooler, and cold screen. These emission points are generally hooded individually with an enclosed hood or a suspended hood and evacuated to one or more control devices; the majority of facilities use a series of one or more baghouses. Scrubbers and rotoclones are also used by several plants to control emissions from these sources. The sinter product is generally cooled by air, although water sprays are occasionally used.

The baghouse is the best demonstrated emission control device for discharge end emission control. In designing a suitable baghouse, the high abrasion characteristics and temperature of the dust require special consideration. Approximately ten baghouses are in use to control emissions from the various discharge emission points, handling one or more emission points. The most common cleaning mechanism is pulse jet, although shaker and reverse air systems are also used. Most of the baghouses use polyester bags, but Nomex® and fiberglass baghouses are also used at some facilities. The baghouses generally have an air flowrate of 32,000 to 350,000 scfm, an air-to-cloth ratio of 1.5 to 6.0 acfm/ft^2, and a pressure drop of 4 to 12 inches of water.

Venturi scrubbers and cyclones are also used to control discharge end emission points at several plants. The venturi scrubbers generally have an air flowrate of approximately 100,000 scfm and a pressure drop of 35 inches of water. The cyclones generally have an air flowrate of 5,000 to 33,000 scfm and a pressure drop of approximately 5 inches of water.

Emissions from the discharge end consist mainly of PM and metals. Table 4-2 shows the various control technologies used for sinter discharge emission points at each plant in the industry.

TABLE 4-2. SINTER DISCHARGE AND COOLER CONTROL TECHNOLOGIES

Plant	Discharge	Crusher	Hot Screen	Cooler	Cold Screen
Bethlehem, IN	Baghouse	Baghouse	Baghouse	None	N/A
Inland Steel, IN	Baghouse	Baghouse	Baghouse	Baghouse	None
LTV Steel, IN	Scrubber	Scrubber	Scrubber	None	None
U.S. Steel, IN	Baghouse	Baghouse	Baghouse	None	Baghouse
Bethlehem, MD	Baghouse	Baghouse	Baghouse	Cyclone	Baghouse
AK Steel, OH	Baghouse	Baghouse	Baghouse	Baghouse	Water sprays
WCI Steel, OH	Baghouse	Baghouse	Baghouse	Baghouse	Baghouse
Wheeling-Pitt, OH	Baghouse	N/A	N/A	Water sprays	Water sprays
Geneva Steel, UT	Rotoclone	N/A	Rotoclone	N/A	N/A

* Certain transfer points are controlled by the discharge baghouse.

4.1.3 Materials Handling

Emissions from material handling are generally fugitive emissions and are usually uncontrolled. These emissions result from material storage, materials mixing, and sinter storage. Fugitive emissions escaping the raw material handling equipment are normally confined within the building in which they are processed, and primarily affect the worker environment. Only one sinter plant in the country uses a baghouse to control emissions from material storage and handling; the remaining plants use no control. Emissions from mixing are also generally uncontrolled, although they are also normally contained within the building. One plant, however, uses water sprays to wet the materials at the various transfer points. While water sprays by themselves may be effective on materials such as dry ore, they are not effective in controlling hot fines. Emissions from sinter storage are generally uncontrolled, although one plant uses chemical dust suppression on the product.

4.1.4 Capture and Control System Performance.

Windbox capture efficiencies were reported by six companies in a 1993 industry survey and by one company in a 1991 screening survey response. These efficiencies range from 93 to 99.9 percent based on engineering estimates. Control device efficiencies varied considerably, ranging from 96.2 to 99.5 percent for a baghouse and from 70 to 99+ percent for a wet scrubber.

4.1.5 Pollution Prevention

Pollution from sinter plants is generated by particulate emissions from various emission points and by organic emissions from the windbox. Sinter plants serve as a means of recycling waste iron-bearing materials that would otherwise be landfilled from other processes at an integrated iron and steel facility and within the sinter plant itself. The use of sinter plants is an effective pollution prevention measure, but significant quantities of particulate and organic compounds are generated as a result of the recycling process.

One of the major sources of organic emissions in the sinter plant is from oily mill scale blended into the feed materials. One way to reduce organic emissions in the sinter plant would be to set a limit for the oil content of the sinter mixture or for the amount of oily mill scale that a plant may use. Even though a high energy wet scrubber may be able to handle larger quantities of oil than a comparable baghouse system, limiting the amount of oil for all plants may reduce organic emissions. Another option may be to de-oil the mill scale prior to recycling the scale in the sinter plant.

4.2 BLAST FURNACE

4.2.1 Casthouse

Emissions from molten iron and slag occur primarily at the tap hole of the blast furnace and in the iron trough immediately adjacent to it. Emissions also result from the runners that transport the iron and slag and from the ladle that receives the molten iron. These emissions include flakes of graphite (carbon) called "kish" that is released as the metal cools (because the solubility of carbon in the metal decreases as it cools) and metal oxides that form when the reduced metal (e.g., iron, manganese) reacts with oxygen in the air.[19] Factors affecting these emissions include the duration of tapping, exposed surface area of metal and slag, length of runners, and the presence/absence of runner covers and flame suppression, which reduce contact with air.

Table 4-3 presents the capture and control systems in place on each furnace in the industry. Three furnaces at three facilities did not report the presence of capture or control systems for emissions from the casthouse. A combination of flame suppression and covered runners is most commonly used at the remaining furnaces in the industry; in addition, more than one-third of the furnaces evacuate emissions to a control device, most commonly a baghouse.

Flame suppression consists of blowing natural gas over the iron runners and torpedo cars. The combustion of the gas consumes oxygen, which suppresses emissions. In addition to flame suppression, many facilities use covered runners on the iron and slag runners. Most furnaces have a removable cover over the iron trough; the cover is removed during drilling of the furnace and is quickly put back into place when the molten iron starts to flow. The cover is removed again at the end of the tap to plug the taphole with refractory clay.

One method of controlling emissions from the casthouse is to totally enclose the casthouse and evacuate it to a baghouse. Alternatively, there may be localized hooding over the iron trough, iron and slag runners, and hot metal ladles that are evacuated to a baghouse. Two furnaces at one facility use a vertical rod-type scrubber to control casthouse emissions.

TABLE 4-3. CASTHOUSE CAPTURE AND CONTROL SYSTEMS

Plant	Location	Furnace	Casthouse		
			FS[a]	CR[b]	Control
Acme Steel[20, 21]	IL	A	Yes	Yes	None
AK Steel[22, 23]	KY	A	Yes	Yes	None
AK Steel[9, 10]	OH	3	Yes	No	None
Bethlehem Steel[13, 14]	MD	L	No	Yes	Baghouse
Bethlehem Steel[11, 12]	IN	C,D	Yes	Yes	None
Geneva Steel[3]	UT	1,2,3	Yes	Yes	None
Gulf States Steel[24]	AL	2	None	None	None
Inland Steel[4, 5]	IN	5,6	No	Yes	Scrubber
		7	No	Yes	Baghouse
LTV Steel[15, 16]	IN	H3	Yes	Yes	None
		H4	Yes	Yes	Baghouse
LTV Steel[25]	OH	C1,C5,C6	Yes	Yes	None
National Steel[26, 27]	IL	A,B	No	Yes	Baghouse
National Steel[26, 27]	MI	A,B,D	No	Yes	Baghouse
Rouge Steel[28, 29]	MI	B,C	Yes	Yes	None
USX Steel[30, 31]	AL	1	Yes	No	Baghouse
USX Steel[6]	IN	4,6,8	Yes	No	None
		13	No	Yes	Baghouse
USX Steel[32, 33]	PA	1,3	Yes	Yes	Baghouse
USS/Kobe Steel[34, 35]	OH	3	No	Yes	Baghouse
		4	Yes	No	None
WCI Steel[8]	OH	1	Yes	Yes	Baghouse
Weirton Steel[36]	WV	1	Yes	Yes	Baghouse
		3	Yes	Yes	None
Wheeling Pittsburgh Steel[17]	WV	1	Yes	Yes	None
		5	Yes	Yes	Baghouse

[a] Flame suppression
[b] Covered runners

The most common baghouse cleaning mechanism is pulse jet, although shaker and reverse air systems are also used. Most of the casthouse baghouses use polyester or polypropylene bags. The baghouses generally have an air flowrate of 125,000 to 400,000 scfm, an air-to-cloth ratio of 2.0 to 7.0 acfm/ft^2, and a pressure drop of 3 to 14 inches of water. Table 4-4 presents the operating parameters for various control systems used on blast furnaces in the U.S.

Gaseous and particulate emissions occur from slag handling as the slag is discharged and allowed to cool. Particulate emissions also occur when the solidified slag is later broken up and removed. These emissions are generally uncontrolled, although some facilities use covered runners.

No. 7 Blast Furnace at Inland Steel. The No. 7 blast furnace at Inland Steel has four holes for tapping. One taphole is always open and the hot metal is removed continuously. To stop tapping, clay is injected into the taphole under pressure to seal the hole. The molten iron and slag that leave the furnace after tapping are separated in troughs and runners. The slag is diverted outside the casthouse and is sprayed with water to cool. The molten iron is transferred to Pugh ladles to be sent to the BOPF. There are covers over the runners for the molten metal and slag as well as canopies above the tapholes, which are evacuated to route the emissions to the baghouse. The casthouse is controlled by two baghouses, a new baghouse with computerized control that can concentrate on specific sources during the various phases of operating practice, and an older general baghouse that serves as back-up. Dust from the baghouses is currently stored for later recycle.[37]

TABLE 4-4. EMISSIONS CONTROLS FOR BLAST FURNACE CASTHOUSES

Furnaces with baghouses									
Plant	**State**	**Capacity (tpy)**	**Furnace**	**Flow (dscfm)**	**Air/cloth ratio (acfm/ft^2)**	**Δp (in. water)**	**Cleaning**	**Filter material**	**Location**
Bethlehem Steel[13, 14]	MD	3,450,000	1	420,000 acfm @170-200	4.0	8	pulse jet	polyester	
Inland Steel[4, 5]	IN	4,000,000	7	-	-	-	-	-	Runner covers
				250,000-275,000	4.2	7	pulse jet	polyester	Canopies over 4 notches
LTV Steel[15, 16]	IN	1,971,000	H4	220,000	4.4	7	pulse jet	polyester	Iron trough and tilting spout
National Steel[26, 27]	IL	2,372,500	A B	369,000	6.88	14	pulse jet	polyester	“A” & “B” taphole
				100,000 acfm	5.82	10	shaker	polyester	Torpedo cars
National Steel[26, 27]	MI	2,000,000	A	400,000	5.15	3-8	reverse air	polyester needle felt	Iron trough/ tilting spout
		900,000	B	170,000	9.0	4-8	pulse jet	polyester felt	
		2,000,000	D	275,000	5.38	3-6	pulse jet	polyester woven	
USX Steel[32, 33]	PA	1,200,000	1	140,000	-	3-12	-	-	Casthouse
		1,100,000	3	140,000	-	3-12	-	-	
USX Steel[6]	IN	3,440,000	13	600,000 acfm	4.8	<8	pulse jet	polyester felt	Casthouse
USS/Kobe[34, 35]	OH	1,300,000	3	224,000	6.28	3-10	pulse jet	polyester	Casthouse

TABLE 4-4. EMISSIONS CONTROLS FOR BLAST FURNACE CASTHOUSES (continued)

Furnaces with baghouses

Plant	State	Capacity (tpy)	Furnace	Flow (dscfm)	Air/cloth ratio (acfm/ft^2)	)p (in. water)	Cleaning	Filter material	Location
WCI Steel[8]	OH	1,500,000	1	125,000	1.98-2.23	-	shaker	-	Casthouse
Wheeling-Pittsburgh[17]	OH	1,682,000	5	103,200	4.5	4-6	pulse jet	polyester felt	

Furnaces with wet scrubbers

Plant	State	Capacity (tpy)	Furnace	Flow (dscfm)	L/G (gal/1000 acf)	)p (in. water)	Scrubber type	Demister	Location
Inland Steel[4, 5]	IN	1,253,000	5	40,000 acfm @250EF	10.0	24-30	Multi-element fixed throat vertical rod type scrubber (2 scrubbers)	vanes in tank	Local hoods over notch, iron and slag runners, and pugh ladles
		1,253,000	6	40,000 acfm @250EF	10.0	35	Multi-element fixed throat (1 scrubber)		

air/cloth ratio = ratio of air flow to cloth area in actual cubic feet per minute per square foot of cloth
)p = pressure drop in inches of water

4.2.2 Gas Cleaning

Blast furnace gas is primarily CO and is heavily laden with particles (on the order of 30 g/scm) as it leaves the furnace. The gas is cleaned and is used as fuel in the blast furnace stoves and other operations at the plant. Emissions occur from the stove stack when this gas is burned; these emissions are generally uncontrolled at all facilities in the industry.

Most furnaces are equipped with a multistage dust collection consisting of a dry cyclone and a wet collection. The gas is cleaned by passing it through the cyclone (called a dust catcher) and then directing it to venturi scrubbers for final cleaning. The preferred method of cleaning the gas is the venturi scrubber. Gases in the venturi scrubber are accelerated in the convergent section of the venturi throat in order to impact at high velocity with the injected scrubber water. The wetted particles of dust are agglomerated to form droplets in the venturi diffuser due to decreasing velocity and surface tension. The water droplets containing the pollutants are then separated from the gas in the subsequent gas separator. Most modern venturi scrubbers are designed with an adjustable throat section to compensate for varied rates of gas flow from the blast furnace. Wear in the throat of the venturi is minimized by the provision of a hardened lining and by a protecting film of water on the convergent inner wall.

Two of the major consumers of blast furnace gas, blast furnace stoves and the underfiring jets of coke ovens, require that the gas be as free of PM as possible. Any excess PM that might remain in the gas would tend to deposit in the combustion spaces of these units causing premature outages and failures. Because the units are essential to the ironmaking process and require a high investment of capital, the plants find it necessary to maintain and operate the gas cleaning equipment at maximum efficiency.[19] Table 4-5 presents the various gas cleaning systems used at integrated iron and steel facilities.

4.2.3 Wastewater

The direct contact water used in the scrubber dissolves HCN from the gas, and the HCN is subsequently stripped from the water when it passes through the cooling tower. Cooling tower emissions are not controlled.

TABLE 4-5. GAS CLEANING SYSTEMS FOR EACH FURNACE

Plant	State	ID	Gas cleaning system
Acme Steel[20, 21]	IL	A	Dry dust catcher, variable throat venturi scrubber, mist eliminator
AK Steel[22, 23]	KY	A	Dust catcher, Bischoff venturi scrubber
AK Steel[9, 10]	OH	3	Dust catcher, Bischoff venturi scrubber, mist eliminator
Bethlehem Steel[13, 14]	MD	L	Dust catcher, venturi scrubber
Bethlehem Steel[11, 12]	IN	C,D	1) Dust catcher; 2) primary wet scrubber; 3) water separator; 4) 3 cone scrubber; 5) water separator; 6) gas cooler; 7) mist eliminator
Geneva Steel[3]	UT	1,2,3	Dust collector, venturi scrubber, gas washer
Gulf States Steel[24]	AL	2	Dust collector, venturi scrubber
Inland Steel[4, 5]	IN	5,6	Dust catcher, venturi scrubber
		7	Dust catcher, Bischoff scrubber
LTV Steel[15, 16]	IN	H3,H4	Dust catcher, fixed orifice scrubber, variable throat scrubber
LTV Steel[25]	OH	C1,C5, C6	Mechanical dust collector, gas washer and cooler, venturi scrubber, gas recirculation stoves
National Steel[26, 27]	IL	A	Mechanical dust collector, Bischoff variable throat anulus wet scrubber
		B	Dust collector, variable throat venturi scrubber
National Steel[26, 27]	MI	A	Dust catcher, variable throat venturi scrubber
		B	Dust catcher, fixed orifice scrubber, gas washer, cooler tower
		D	Dust catcher, fixed orifice scrubber, variable throat venturi gas cooler/scrubber, demister
Rouge Steel[28]	MI	B,C	Mechanical collector, venturi scrubber
USX Steel[30]	AL	1	Dust catcher, quencher, scrubber
USX Steel[6]	IN	4,6,8,1 3	Mechanical collector, gas cleaning

Plant	State	ID	Gas cleaning system
USX Steel[32]	PA	1,3	Dry scrubber, wet scrubber
USS/Kobe Steel[34]	OH	3,4	Dust catcher, quencher, venturi scrubber
WCI Steel[8]	OH	1	Dust collector, primary orifice scrubber, secondary venturi scrubber, spray chamber-type gas cooler
Weirton Steel[36]	WV	1,3	Mechanical dust collector, venturi scrubber
Wheeling-Pittsburgh[17]	OH	1N,5S	Dust catcher, variable throat venturi scrubber, gas cooler

4.2.4 Capture and Control System Performance

Casthouse capture efficiencies were reported by several companies in a 1993 industry survey. These efficiencies range from 50 to 99 percent based on engineering estimates. Control device efficiencies were on the order of 99 percent.

4.3 BOPF SHOP[38]

4.3.1 Primary Furnace Controls

Primary emissions refer to those emissions leaving the mouth of the furnace vessel during the oxygen blow that are captured by the primary hood. Primary emission control systems are divided into two basic types: open full combustion and closed suppressed combustion; partial combustion systems also exist. Use of high energy venturi scrubbers and ESP have been the traditional, best demonstrated control technologies for controlling BOPF primary emissions. More recently, use of fabric filters has been proven to be effective, although this technology is not currently in use at any facility in the U.S.

CO is emitted from the vessel mouth during the oxygen blow phase of the furnace cycle. The gas temperature is sufficiently hot to promote combustion of CO if air is permitted to mix with the waste gas. A design decision must be made to determine how much air, if any, is allowed to mix with the gas, so that hood cooling capacity can be matched to the needs of the system. Some air must be admitted to obtain sufficient capture velocity necessary to contain fume emissions within the hood. Capture velocities generally run 14 to 58 feet per second.

Many BOPF furnace installations use ESP for controlling PM emissions. Because of the potential for igniting the CO/air mixture by precipitator sparking, it is necessary to use an open hood to admit large quantities of excess combustion air at the hood and to facilitate the complete combustion of CO. This design decision leads to larger gas volumes to be treated for control of particulate emissions than is necessary for closed hood furnaces.

More recent designs have incorporated limited or partial combustion of CO (closed hood design), reducing the heat generated in the hood and the volume of gas to be treated. Careful control of the amount of air entering the hood allows 10 to 50 percent combustion of CO. Gas cleaning in closed hood systems is exclusively venturi scrubbers to reduce explosion hazards. The advantages of suppressed combustion (closed hood systems) are reduced energy consumption for gas cleaning as compared to full combustion and the potential for recovering CO as a low-grade fu el source. Ten BOPF shops and one vessel in an open hood BOPF shop currently operate with suppressed combustion hoods; however, none of the plants are recovering the CO, and the gas is generally flared before discharging it to the atmosphere.

4.3.1.1 Open Hood Designs. Both wet scrubbers and ESP are used to control emissions from open hood systems. In this system, the hood skirt is in a fixed position and no precautions for leakage into the system are necessary. Control systems may be shared between furnaces and multiple fans operating in a parallel flow arrangement may be used.

When an ESP is used, gas cooling down stream from the hood skirt is continued by the use of water sprays located in the upper part of the hood. These sprays are generally controlled by time and temperature to turn on and off at various points in the operating cycle. The intent is to limit the gas temperature reaching the precipitator and to moisture condition the gases for better precipitation. Emissions during the oxygen blow are captured by the open hood, enter a hood cooling section, and pass through a conditioning chamber where the gas is cooled and humidified to the required levels for proper ESP operation. The gas cleaning system commonly consists of precipitators, fans, dust handling equipment, and a stack for carrying away the cleaned gases. ESP can be used with open hoods because the combustible CO generated during the oxygen blow burns at the mouth of the vessel, reducing the risk of explosions which could be set off by sparks in the precipitator. Alternatively, a venturi scrubber may be used to control emissions. Because there is less danger of explosion in the open hood system as compared to the closed hood system (most of the CO has been converted to carbon dioxide), all of the vessels in the shop may be connected to a common gas cleaning system. Control device parameters for open hood BOPF systems are presented for each facility in Table 4-6.

The venturi scrubbers on open hood systems generally have an air flowrate of approximately 210,000 to 600,000 scfm and a pressure drop of 25 to 55 inches of water. The ESP on open hood systems generally have an air flowrate of 230,000 to 720,000 scfm and a plating area of approximately 80,000 to 650,000 ft^2.

TABLE 4-6. OPEN HOOD BOPF SHOP PRIMARY CONTROL SYSTEM

Wet Scrubber Control Technology								
Plant	**State**	**Capacity (million tpy)**	**Flow (dscfm)**	**L/G (gal/1000 acf)**	**) p (in. water)**	**Scrubber type**	**Demister**	**Location**
Bethlehem[11, 12]	IN	5.35	113,200 x 3	20	55	Venturi	Pall rings	3 scrubbers for 2 vessels (#1 & 2)
Bethlehem[13, 14]	MD	4.00	600,000[a]	8	50	Venturi	Chevrons	4 Scrubbers for 2 vessels
Inland (#4)[4, 5]	IN	2.74	310,000-380,000	1.0	25	Venturi	Yes	2 vessels
USX, Gary[6]	IN	2.9	268,000	13.1	70-75	Venturi	Yes	3 vessels
USX, Gary (Q-BOP)[6]	IN	4.0	267,000	34.7	70	Venturi	Yes	3 vessels
USX, Braddock[32]	PA	2.76	174,000	--	68-76	Venturi	Yes	2 vessels
Weirton Steel[36]	WV	3.20	280,000	--	50	Venturi	Wood	1 Scrubber for 2 vessels
Wheeling-Pittsburgh[17]	OH	2.95	210,000	10	50	Venturi	Yes	North & south scrubbers

TABLE 4-6. OPEN HOOD BOPF SHOP PRIMARY CONTROL SYSTEM (continued)

ESP Control Technology									
Plant	**State**	**Capacity (million tpy)**	**Flow (dscfm)**	**ESP type**	**Plate area ft^2**	**# of fields in series**	**Type bottom**	**Cleaning method**	**Conditioning Agents**
Acme Steel[20]	IL	1.29	288,000	Single Stage	92,000	3	Dry	Rapping	Water
Gulf States[24]	AL	1.30	327,000	Single stage	150,000	8	Dry	Rapping	Water/steam
LTV Steel[15]	IN	4.16	458,000	Single stage	650,000	5	Dry	Rapping	Water/steam
LTV (#1)[25]	OH	3.34	550,000	--	255,000	4	Dry	Rapping	Water
National[26]	IL	3.58	410,000	--	--	4	Dry	Rapping	Water/steam
National[26]	MI	4.1	500,000[a]	--	80,200	4	Dry	Rapping	Water/steam
Rouge Steel[28]	MI	3.3	500,000	--	--	4	--	Rapping	Humidification
WCI Steel[8]	OH	1.73	400,000	--	114,000	6	--	--	--

[a]acfm

Gulf States Steel ESP upgrade.[39] Gulf States Steel has an open hood BOPF shop with an 550,000 acfm primary gas cleaning system. Extensive developments were carried out to improve the effectiveness of the system. The system became operational in 1994 and has proven to be effective in reducing stack emissions to within regulatory limits.

Air atomized spray nozzles were used to replace direct pressure nozzles in the spray chamber. The improved atomization reduced moisture and dust build-up in the off-gas ducting, as well as the ESP and dust handling system. These nozzles also improved the moisture content of the off-gas, lowering the dust resistivity and improving collection efficiency. However, during low temperature periods of the blowing cycle, the desired cleaning efficiency was not being achieved. Therefore, the plant decided to install a new precipitator system in parallel with the existing units.

To determine the additional collection plate area, the precipitator performance was predicted during the entire blowing system for the existing system, 50 percent and 100 percent expansion. Based on stack opacity, the 100 percent expansion was required to provide acceptable stack opacity levels (10 percent) throughout the oxygen blowing cycle. The expanded system increased the specific collection area from 285 to 560 ft^2/1,000 acfm. The expanded system increased the collection efficiency from 99 to 99.93 percent, and the outlet particulate concentration was reduced from 0.059 to 0.004 gr/acf (0.14 to 0.01 gr/dscf).

4.3.1.2 Closed Hood Designs.[38] In a closed hood system, the diameter of the hood face is roughly the same as the diameter of the mouth of the vessel. The hood usually fits close to the furnace mouth to restrict the inflow of combustion air. Because a completely closed hood would restrict vessel tilting necessary for charging and tapping the furnace, the hood skirt must be movable. The lower portion of the hood is a skirt that can be lowered onto the mouth of the vessel, sealing off the space between the hood and the vessel, thereby limiting the amount of air that can enter the system. The gas, mainly CO, is collected in an uncombusted state. The volume of gas collected in a closed hood system is reduced by as much as 80 to 85 percent as compared to that of an open hood system. In addition, there is a need to limit the amount of air infiltration downstream of the hood. Normal points of leakage in an open hood system such as the lance port and flux chutes must be sealed and purged of nitrogen before use in the closed hood system.

Gas cleaning is performed by a scrubber to minimize the risk of explosion. The cleaned gas is usually flared at the stack. Because of the potential explosion hazard from leakage of air into the system from an idle furnace, the closed hood system must have a separate scrubber system for each vessel. Control device parameters for closed hood BOPF systems are presented for each facility in Table 4-7.

Initial cooling of the gas leaving the furnace is carried out using a water-cooled hood. Cooling is continued by the use of a spark box or quencher, in which grit and coarse particles resulting from refractory and chunks of slag or metal are separated from the gas stream. From the quencher, the waste stream flows to a high energy scrubbing device where the removal of fine particles occurs. The most common scrubber type is a venturi with an adjustable throat. The venturi is opened or closed to increase or decrease gas velocity, i.e., pressure drop through the throat. A critical part of the scrubbing unit is a moisture-separating device to knock out drops of water carried out of the throat. The device may be a series of baffles or a centrifugal chamber in which the gas rotates, causing the drops to impinge on the chamber walls. An after cooling chamber is occasionally used, in which the used cooling water is sprayed to further reduce the gas temperature. At cooler temperatures, moisture condenses from the gas, reducing the volume of gas to be handled by the fan. The system may have multiple venturi throats, but draft is provided only by a single fan. The gas cleaning facilities are not shared between adjacent furnace vessels; each furnace has an independent gas cleaning system. All closed hood systems in the U.S flare the CO-rich waste gas stream generated during oxygen blowing. The venturi scrubbers on closed hood systems generally have an air flowrate of approximately 40,000 to 268,000 scfm, a pressure drop of 40 to 80 inches of water, and a liquid-to-gas ratio of 2.6 to 34.7 gal/1,000 acf.

TABLE 4-7. OPERATING PARAMETERS OF CLOSED HOOD BOPF SYSTEMS--VENTURI SCRUBBERS

Plant	State	Capacity (million tpy)	Vessel	Flow (dscfm)	L/G (gal/1000 acf)	)p (in. water)	Scrubber type	Demister	Efficiency (%)
AK Steel[22]	KY	2.17	1	78,000	11.5	60	Venturi	Yes	99+ (E)
			2	78,000	11.5	60	Venturi	Yes	99+ (E)
AK Steel[9]	OH	2.71	15	40,000	2.9	45-50	Venturi	No	99+
			16	51,000	2.6	40-50	Venturi	No	99+
Bethlehem Steel[11]	IN	--	3	197,000[a]	21	55	Venturi	--	--
Geneva (Q-BOP)[3]	UT	2.5	1	78,300	--	70-80	Venturi	--	99
			2	77,300	--	70-80	Venturi	--	99
Inland Steel (No. 2)[4]	IN	2.5	1, 2	50,000-60,000	10	55	Venturi	Yes	99.8 (E)
LTV Steel (No. 2)[25]	OH	4.38	1	55,000	--	--	Venturi	--	99.9
			2	55,000	--	--	Venturi	--	99.9
USS/Kobe[34]	OH	2.6	L	58,000	--	--	Venturi	Yes	99+
			N	59,000	--	--	Venturi	Yes	99+
USS Steel[30]	AL	2.2	U	--	--	60-95	Venturi	--	--
			X	76,000	--	51-92	Venturi	--	--
			C	76,000	--	59-96	Venturi	--	--

[a]acfm

4.3.2 Secondary Sources of Emissions

Secondary sources of emissions within a BOPF shop include hot metal transfer, desulfurization, slag skimming, charging, turndown, tapping, deslagging, teeming, ladle maintenance, flux handling, slag handling and disposal, and ladle metallurgy operations. Most facilities use a combination of one or more baghouses or, less frequently, wet scrubbers, to control secondary BOPF shop emissions. Capture and control systems are described in detail in the following sections. Following the general description of the controls, Table 4-8 presents the controls currently used for each emission point at the various facilities and Table 4-9 presents the operating parameters for each control device.

4.3.2.1 Furnace Controls.[38] Emissions that occur during the steps of the furnace cycle that require the vessel to be tipped out from under the hood include scrap charging, hot metal charging, sampling, tapping, and deslagging. These sources are often poorly controlled by the primary system. When the BOPF vessel is tipped out from under the hood of the primary control system, whether for charging, sampling, or tapping refined steel, the primary control system may be rendered entirely ineffective. Secondary furnace emissions are typically produced by unconfined sources such as leaks from the primary furnace hood or the open top of a ladle. These emissions may be captured by enclosures or hoods and ducted to a particulate control device.

Capture techniques for secondary furnace emissions include furnace enclosures, local hoods, full or partial building evacuation, and, in the case of open hood systems, adapting the primary furnace hooding to also capture secondary emissions. Particulate removal techniques that are currently in use include baghouses and wet scrubbers. These systems are described in detail below.

Furnace enclosures. A furnace enclosure is a structure that may partially (on at least two sides) or fully (on four sides plus the top) enclose a furnace vessel. Most recently constructed BOPF vessels are enclosed. A partial enclosure may be designed to shield the BOPF from most drafts, other natural convection, permitting hoods within or adjacent to the enclosure to be more effective at lower air flow rates. In comparison to a full enclosure, a partial enclosure is less expensive, easier to retrofit (possibly without interrupting production), and less likely to impede operations.

In a total enclosure system, the enclosure can be relatively simple on two sides because the vessel is designed routinely to tilt about only one horizontal axis. The enclosure roof is usually penetrated by the primary exhaust duct, and it must be high enough to permit maneuvering the hood in a closed system. Similarly, the flux chute and the oxygen lance of top blown vessels must penetrate either the roof of the enclosure or the primary hood. Within the enclosure, and sometimes as part of the enclosure, there may be charging and tapping hoods.

The enclosure can extend partially or completely to the operating floor at the rear-facing tapping aisle. Tapping is carried out at and below the level of the vessel, and there is a tendency for hot, dusty gases to escape in the natural draft induced by the process heat. A hood that is either permanently arranged so that it does not interfere with operations or that is otherwise retractable to collect tapping emissions is preferred. Most of the complications resulting from full enclosure arise in the front facing charging aisle. This side of the enclosure includes a door that is moved out of the way while charging scrap and hot metal. Because these operations occur at and above the vessel, natural convection will permit a plume of hot dusty gas to escape into the building.

The secondary control system (capture plus particulate removal) may be an extension of the primary control system. Hoods designed to capture charging and tapping emissions may be ducted to the primary system. Gas flow may also be adjusted for the differing demands of several parts of the cycle. In a closed hood system, the typical arrangement is to duct the charging and tapping hoods in the furnace enclosure to a secondary control unit, most commonly a baghouse.

Furnace operations dictate the necessity for opening and closing the doors on a furnace enclosure. For a total enclosure, the charging of scrap and hot metal to the furnace requires the doors to be open; immediately following hot metal charging, the doors may be closed. As the oxygen blow portion of the cycle is completed, it is necessary to take a metal sample and measure the metal temperature; most furnaces must be turned down to do this. Another opening in the enclosure door may be provided to insert a thermocouple and sampling spoon. Where such an opening has not been provided, it is necessary to open the doors at least partially, which may cause poor control of emissions during the sampling period. If the doors are left open for the remainder of the production cycle, generally poorer capture of secondary furnace emissions can be expected. Doors on the tapping side of the enclosure generally do not need to be opened except for maintenance.

Primary control systems used for secondary emission control. Consent decrees negotiated between EPA and steel companies have included provisions for reducing roof monitor discharges from BOPF shops. In several instances, roof monitor emissions have been decreased to levels complying with consent decree terms by using primary emission control systems to capture charging and tapping emissions. The use of the primary system to achieve compliance has been strengthened by the adoption of operating practices conducive to lesser fume generation and by the modification of, and in addition to, process equipment and pollution control.

Those shops with relatively large flow capacity in their primary control system are better suited to achieving low roof monitor emissions from furnace operations. Higher flow capacity means that higher indraft velocities can be achieved to capture fugitive emissions at a given distance from the hood. In addition, the use of clean, non-oil-bearing, non-galvanized scrap, the positioning of the hot metal ladle with respect to the hood face and furnace mouth, and the proper furnace tilt angle are all means of reducing charging emissions.

Extension (flanges) from the primary hood into the charging and tapping aisles helps to provide more draft closer to the points of emission. Similarly, an extension of the pouring spout on the hot metal charging ladle will move the emission generation point closer to or under the hood.

Canopy or roof hoods, partial building evacuation. The design of hoods for BOPF shop secondary emissions is complicated by cross drafts that develop within the building, interfering with fume capture. A hood that is located close to the source and intended to reduce cross drafts may get in the way of crane operations. Every design is a compromise between hood and vessel clearance and the clearance necessary for crane operations. In addition to emissions that are collected regularly at fixed locations, certain necessary maintenance operations generate dust that is less susceptible to collection by local hoods.

The canopy hood is one method for collecting some emissions that have either not been provided for or that inevitably escape the local hoods. A canopy hood will not interfere with furnace operations, can collect the fine, entrained particles at relatively low velocities, and can be ducted continuously to a collecting device. Disadvantages to canopy hoods include: (1) cross drafts in the shop that displace rising fume so that it evades the hood or the face; (2) a significantly larger volume of gas to be cleaned; and (3) when added to an existing system, canopy hoods may reduce draft in the rest of the system to the point that air velocity in the other hoods is too low to capture fume effectively.

One method of reducing the impact of cross drafts and avoiding the problem of the plume's becoming larger than the hood face dimensions is to use partial building evacuation. The building structure becomes the hood for a particular portion of the operation. Partition walls may be installed between building columns to prevent lateral movement of the plume into adjacent portions of the building. These partition walls may extend as low as crane operations will permit and may extend as high as the roof. Sheeting or partitions may also be used to seal the roof area to prevent the escape of emissions by natural thermal draft. One or more duct connections may be made into the sealed portion of the building to extract contaminated air for gas cleaning.

4.3.2.2 Ancillary Operations. Ancillary operations, including hot metal transfer, desulfurization, and slag skimming are usually controlled by hooding ducted to a control device separate from the primary control device, although one facility uses the primary furnace ESP to control secondary emissions in the BOPF shop.

Inland Steel No. 2 BOPF shop.[39] The hot metal transfer baghouse at Inland's No. 2 BOPF shop was upgraded in June 1994 in order to optimize the existing equipment. The 400,000 acfm negative pressure shaker baghouse operated at excessively high pressure drop, reducing system flow capacity and causing dust to bleed through the bags.

As part of the overall secondary emission control system upgrade, a baghouse appraisal study was completed to help define the problems. The investigation indicated that the absence of hopper air lock valves and leaks in the screw conveyor dust disposal system caused dust reintrainment which prevented regular dust disposal and resulted in a slow, steady rise in bag pressure drop, even with proper cleaning. The primary cause of bag failure was identified as abrasion resulting from under-tensioning of the bags in their attachment to the shaker mechanism. The strap bag attachment induced the bags to fold during shaking, which restricted dust removal. Ingress of moisture through poorly sealing access doors allowed bags to get wet, resulting in crust formation on the bags. A high degree of shaker maintenance was attributed to generally poor mechanical design and aggravated by wear on a knife edge support at the far ends of the shaker logs. In addition to mechanical problems, the original hard-wired relay control system was found to be unreliable and too difficult to maintain.

A new bag design, complete with a spring-tensioned attachment, and top and bottom sewn rings was installed in a test compartment and operated for several weeks. The new bag design was subsequently installed in all 18 compartments. A new screw conveyor system was installed utilizing a rotary air lock at each compartment hopper to eliminate reintrainment of dust through the hopper discharge conveyors. Other modifications included replacement of all compartment doors with a new design that provided better sealing, the replacement of butterfly outlet dampers with poppet dampers on all compartments, and a new PLC baghouse control system. Baghouse performance was greatly improved as a result of the modifications. The bag pressure drop was reduced to 6 in. water and the system capacity was restored to the original design.

4.3.3 Ladle Metallurgy Operations

After hot metal is refined into steel in the BOPF vessel, further alloy additions and refining of the steel occur during ladle treatment and vacuum degassing. Most BOPF shops have a separate ladle metallurgy station. Emissions are generally captured and controlled from ladle metallurgy operations using a baghouse, although one facility uses a wet scrubber. Several facilities also use a wet scrubber to control emissions from vacuum degassing operations. The control device parameters for each facility are presented in Table 4-10.

TABLE 4-8. SECONDARY EMISSION CONTROL SYSTEMS IN THE BOPF SHOP

Plant		Secondary Emission Controls				
		HM Reladle	**HM desulf**	**Skimming**	**Charging**	**Tapping**
Acme Steel, Riverdale, IL[20]		Baghouse with canopy hoods				
AK Steel, Ashland, KY[22]		Baghouse with canopy hoods				
AK Steel, Middletown, OH[9]		Baghouse		Baghouse	None	
Bethlehem, Burns Harbor, IN (3 vessels in 1 shop)[11]		Baghouse			1E Scrubber	
Bethlehem, Sparrows Pt., MD[13]		Baghouse	Baghouse	Baghouse	1E Scrubber	
Geneva Steel, Orem, UT[3]		None	Baghouse	None	Baghouse, doghouse	
Gulf States Steel, Gadsden, AL[20]		Baghouse with canopy hoods			1E ESP	
Inland Steel, East Chicago, IN (2 shops)[4]	(o)	Baghouse		None	Baghouse	
	(c)	Baghouse			Scrubber	
LTV Steel, East Chicago, IN[15]		Baghouse with side draft hoods			1E ESP	Flame suppression and tapside enclosure
LTV Steel, Cleveland, OH (2 shops)[25]	(o)	Baghouse			1E ESP	
	(c)	Baghouse with multiple hoods controlled by dampers				
National Steel, Granite City, IL[26]		Baghouse		Baghouse	Hood to 1E ESP	1E ESP, doghouse
National Steel, Ecorse, MI[26]		Baghouse			Baghouse	
Rouge Steel, Dearborn, MI[28]		Baghouse	Baghouse		1E ESP	
USX, Fairfield, AL[30]		Baghouse (2)		None	Baghouse**	1Escrubber
USX, Gary, IN (2 shops)[6]	(o)	Fume supp.	Baghouse-1	None	1Escrubber	None
	(o*)	Fume supp.	Baghouse-1	None	Enclosure to baghouse	
USX, Braddock, PA[32]		Baghouse		Baghouse		1E SCR
USS/Kobe Steel, Lorain, OH[34]		Baghouse	Baghouse	None	Baghouse, enclosure	
WCI Steel, Warren, OH[8]		Flame supp.	Baghouse		1E ESP	
Weirton Steel, Weirton, WV[36]		Baghouse	Baghouse		None	
Wheeling Pittsburgh Steel, Mingo Junction, OH[17]		Baghouse	Baghouse		Slow pour, 1E SCR	1E SCR

1E = primary furnace control

BH = baghouse o = open

SCR = scrubber c = closed

* Bottom blown

** To be installed by 2000.

TABLE 4-9. SECONDARY CONTROL DEVICE PARAMETERS

Plant	State	Capacity (million tpy)	Shop	Flow (dscfm)	Air/cloth ratio (acfm/ft^2)	) p (in. water)	Cleaning	Filter material	Location
Acme Steel[20]	IL	1.29	1	227,500	4.0	6-11	Pulse jet	Polyester Felt	HMT, DS, SS, C, T
AK Steel[22]	KY	2.17	1	450,000	4.8	5	Pulse jet	Polyester	HMT, DS, SS, C, T
AK Steel[9]	OH	2.71	1	149,000	5.0	2-5	Pulse jet	--	HMT, DS
				40,000	4.9	4-12	Pulse jet	Polyester	SS
Bethlehem Steel[13]	MD	4.0	1	200,000[1]	4.3	10	Pulse jet	Polyester	HMT
				80,000[1]	5.0	4	Pulse jet	Polyester	DS
				40,000[1]	4.9	6	Pulse jet	Polyester	SS
Bethlehem Steel[11]	IN	5.4	1	135,000-160,000[1]	4.1-5.1	4-18	Pulse jet	Polyester	HMT, DS, SS
Geneva Steel[3]	UT	2.5	1	30,700	--	--	Shaker	Polyester	DS
Gulf States Steel[24]	AL	1.3	1	150,000[1]	3.9	5	Pulse jet	Polyester	HMT, DS, SS
Inland Steel[4]	IN	2.5	2	288,000	3	--	Shaker	Polyester	HMT, DS, SS
		4.7	4	167,000	5.2	7.2	Pulse jet	Polyester	HMT, DS
				193,000	4.3	10	Pulse jet	Polyester	HMT, DS
				470,000	5	6	Pulse jet	Nomex	C, T, F

TABLE 4-9. SECONDARY CONTROL DEVICE PARAMETERS (continued)

Plant	State	Capacity (million tpy)	Shop	Flow (dscfm)	Air/cloth ratio (acfm/ft²)	Δp (in. water)	Cleaning	Filter material	Location
LTV Steel[15]	IN	4.2	1	220,000[1]	5.0	10	Pulse jet	Polyester felt	HMT, DS, SS
LTV Steel[25]	OH	3.3	1	163,000[1]	2.0	6	Shaker	Polyester	HMT, DS, SS
		4.4	2	680,000[1]	5.4	4-6	Pulse jet	Nomex	HMT, DS, SS, C, T
National Steel[26]	IL	2.6	1	90,000	2.8	10.0	Shaker	Polyester	HMT, DS
				30,000	3.4	11.7	Shaker	Orlon	SS
National Steel[26]	MI	3.5	1	210,000	2.8	6-8	Shaker	Polyester	HMT, DS, SS
				500,000	2.8	--	Shaker	Polyester	C, T
Rouge Steel[28]	MI	3.4	1	106,000	2.1	--	--	--	HMT
				68,000	--	--	--	--	DS, SS
USS/Kobe[34]	OH	2.6	1	349,000	5.45	3-10	Pulse Jet	Polyester	C, T, HMT
USX[30]	AL	2.2	1	126,000	3.3	--	--	Dacron	HMT, DS
				480,000	2.6	1.17[2]	--	Nomex	HMT, DS
USX[6]	IN	2.9	BOPF	--	--	--	--	--	HMT, DS
		4.0	Q-BOP	--	--	--	--	--	HMT, C, DS
USX[32]	PA	2.8	1	124,600	--	--	--	--	HMT, DS

TABLE 4-9. SECONDARY CONTROL DEVICE PARAMETERS (continued)

Plant	State	Capacity (million tpy)	Shop	Flow (dscfm)	Air/cloth ratio (acfm/ft[2])	)p (in. water)	Cleaning	Filter material	Location
				450,700	--	--	--	--	C
WCI Steel[8]	OH	1.73	1	--	--	--	--	--	HMT, DS
Weirton Steel[36]	WV	3.2	1	100,000[1]	4.5	5	Pulse jet	Nomex	HMT
				150,000[1]	5	6	Pulse jet	Polyester	DS, SS
Wheeling Pittsburgh[17]	OH	2.6	1	181,200	--	3-5	Pulse jet	Nomex	HMT
				80,000	--	5-6	Pulse jet	Nomex	DS, SS
Plants with wet scrubbers									
Plant	**State**	**Capacity (million tpy)**	**Shop**	**Flow (dscfm)**	**L/G (gal/1000 acf)**	**)p (in. water)**	**Scrubber type**	**Demister**	**Location**
Inland Steel[4]	IN	2.5	2	100,000	--	35-45	Venturi	No	C, T

[1]acfm
[2]in. Hg
HMT= hot metal transfer
DS = desulfurization
SS = slag skimming
C = charging
T = tapping

TABLE 4-10. LADLE METALLURGY STATION CONTROL DEVICE PARAMETERS

LMF stations with baghouses									
Plant	**State**	**Capacity (million tpy)**	**Shop**	**Flow (dscfm)**	**Air/cloth ratio (acfm/ft^2)**	**)p (in. water)**	**Cleaning**	**Filter material**	**Location**
Acme Steel[20]	IL	1.29	1	110,000	3.9	6-11	Pulse jet	Polyester felt	LMF at Continuous Caster
AK Steel[22]	KY	2.17	1	40,000	5.5	5-6	Pulse jet	Polyester felt	LMF
AK Steel[9]	OH	2.71	1	6,000	--	--	Pulse jet	--	Cas ob
Bethlehem Steel[11]	IN	5.35	1	13,500[a]	5.4	varies	Pulse jet	Polyester	Material handling
				45,000[a]	6.7	8	Pulse jet	Polyester	LMF
Bethlehem Steel[13]	MD	4.00	1	120,000[a]	3.8	4	Pulse jet	Polyester	LMF
Gulf States Steel[24]	AL	1.30	1	70,000[a]	--	--	Pulse jet	Polyester	LMF
Inland Steel[4]	IN	2.50	2	45,000-120,000	5	2-8	Pulse jet	Polyester felt	LMF
LTV Steel[15]	IN	4.16	1	144,000	3.9	5	Pulse jet	Polyester felt	LMF
LTV Steel[25]	OH	3.34	1	192,800[a]	4.3	0-6	Pulse jet	Polyester	LMF
		4.38	2	120,000[a]	--	5	Pulse jet	Nomex	LMF

TABLE 4-10. LADLE METALLURGY STATION CONTROL DEVICE PARAMETERS (continued)

LMF stations with baghouses									
Plant	**State**	**Capacity (million tpy)**	**Shop**	**Flow (dscfm)**	**Air/cloth ratio (acfm/ft^2)**	**) p (in. water)**	**Cleaning**	**Filter material**	**Location**
National Steel[26]	IL	2.58	1	60,000[a]	3.5	--	Shakeout pulse	Woven polyester	LMF
National Steel[26]	MI	3.50	1	165,000	2.9	--	Shaker	Polyester	LMF
Rouge Steel[28]	MI	3.3	1	144,000	--	--	Pulsejet	--	LMF
				37,400	--	--	Pulsejet	--	LMF
USS/Kobe[34]	OH	1.4	1	37,700	--	3-12	Pulsejet	Nomex	LMF
		1.2	2	60,000	5.7	4-12	Pulsejet	Gortex	LMF
USX[30]	AL	2.20	1	--	2.4	--	Pulse jet	Nomex	LMF
USX (Q-BOP)[6]	IN	4.0	2	--	--	--	--	--	LMF
WCI Steel[8]	OH	1.73	1	--	--	--	--	--	LMF
Weirton Steel[36]	WV	3.20	1	8,000[a]	4.5	5	Pulse jet	Nomex	LMF
Wheeling-Pittsburgh[17]	OH	2.60	1	40,000[a]	5	6-8	Pulse jet	Nomex	LMF

TABLE 4-10. LADLE METALLURGY STATION CONTROL DEVICE PARAMETERS (continued)

LMF Stations with wet scrubbers									
Plant	**State**	**Capacity (million tpy)**	**Shop**	**Flow (dscfm)**	**L/G (gal/1000 acf)**	**Δp (in. water)**	**Scrubber type**	**Demister**	**Location**
AK Steel[9]	OH	1.71	1	2,200	--	--	Condenser	--	Vacuum degassing
Inland[4]	IN	2.74	4	3,100[a]	--	--	Condenser	--	Vacuum degassing
LTV Steel[25]	OH	4.38	2	72,000[a]	--	--	Hot well	--	Vacuum degassing

[a] acfm; LMF = ladle metallurgy

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5.0 EXISTING STATE REGULATIONS

5.1 SINTER PLANT

5.1.1 Windbox

There are nine sinter plants in the U.S.; however, only seven were operating in 2000. The windbox exhaust is controlled by a baghouse at four plants and by a venturi scrubber at five plants. State emission limits for the windbox are given in Table 5-1. Most of the limits are in concentration units of gr/dscf; however, two States have limits in lb/hr, and one has a limit in lb/ton.

TABLE 5-1. SINTER PLANTS IN THE U.S.

Plant	State	Control	PM emission limit
Inland	IN	Baghouse	0.007 gr/dscf
USS	IN	Baghouse	0.01 gr/dscf
Geneva*	UT	Baghouse	0.0122 gr/dscf; 27 lb/hr
WCI Steel	OH	Baghouse	50 lb/hr
LTV	IN	Scrubber	0.02 gr/dscf
Bethlehem	IN	Scrubber	0.277 lb/ton
Bethlehem	MD	Scrubber	0.03 gr/dscf
Wheeling-Pittsburgh*	WV	Scrubber	0.03 gr/dscf
AK Steel	OH	Scrubber	50 lb/hr

* These plants were not operating in 1999 - 2000.

5.1.2 Discharge End

The sinter plant discharge end is comprised of sinter breakers (crushers), hot screens, conveyors, and transfer points that are designed to separate undersize sinter and to transfer the hot sinter to the cooler. In most cases, these discharge end operations are housed in a building. Emissions are usually controlled by local hooding and ventilation to one or more baghouses or wet scrubbers. Seven plants use baghouses and two plants use wet scrubbers. Details on existing limits are given in

Table 5-2. For comparison purposes, the equivalent concentration limits were estimated for plants with limits expressed as a mass rate (lb/hr) based on the typical volumetric flow rate. The PM limits for control devices vary substantially from plant to plant both in terms of format and numerical values. Four plants have concentration limits for total PM (0.01, 0.02, 0.02, and 0.03 gr/dscf), one has concentration limits for PM_{10}, and three have mass rate limits (42.9, 50, and 50 lb/hr).

Existing State regulations also include both building opacity standards to limit releases of fugitive emissions (those escaping capture). As shown in Table 5-3, five of the seven operating sinter plants are subject to a building opacity limit. One plant is subject to a 10 percent limit (6-minute average), and four plants are subject to 20 percent limits (6-minute average).

5.1.3 Sinter Cooler

Sinter plant coolers are large diameter circular tables through which ambient air is drawn to cool the hot sinter after screening. Seven plants operate sinter coolers to cool the sinter product prior to storage. Two plants that are not currently operating have no cooler and stockpile hot sinter directly. Of the seven plants with coolers, three vent directly to the atmosphere, one vents to a cyclone, two vent to a baghouse, and one vents half of the cooler exhaust to a baghouse with the remainder vented directly to the atmosphere. Five plants have emission limits expressed as concentration or mass rate while two plants have no emission limits (see Table 5-4).

TABLE 5-2 . CONTROLS AND EMISSION LIMITS FOR THE DISCHARGE END

Plant	Control	Emission Points	Emission limit	Flow rate (dscfm)	Best estimate of TSP (gr/dscf)
AK Steel, OH	Baghouse	discharge, crusher, hot screen, cooler	50.0 lb/hr	112,000	0.05
Bethlehem, MD	Baghouse	discharge, crusher, hot screen, cold screen	0.03 gr/dscf	340,000	0.03
Bethlehem, IN	Baghouse	discharge, crusher, hot screen	42.9 lb/hr	212,000	0.024
Geneva, UT	Rotoclones (scrubbers)	discharge	0.0096 gr/dscf PM_{10}	105,000	--
Ispat-Inland, IN	Baghouse	discharge, crusher, hot screen, ½ cooler	0.01 gr/dscf	122,000	0.01
LTV, IN	Scrubber	discharge	0.02 gr/dscf	100,000	0.02
USX Gary, IN	Baghouse 1	discharge, crusher	0.02 gr/dscf PM_{10}	161,322	--
	Baghouse 2	hot and cold screens, conveyors	0.0052 gr/dscf PM_{10}	180,000	--
WCI, OH	Baghouse A	discharge, crusher, hot screen, cold screen	50.0 lb/hr	141,470	0.04
Wheeling-Pittsburgh, WV	Baghouse	discharge	0.02 gr/dscf	32,900	0.02

TABLE 5-3. DISCHARGE END FUGITIVE EMISSIONS: OPACITY LIMITATIONS

Plant	Limit for sinter building and fugitives
Bethlehem, Sparrows Point, MD	10% (6-min average)
Ispat-Inland, East Chicago, IN	20% (6-min average)
LTV Steel, East Chicago, IN	20% (6-min average)
USX Steel, Gary, IN	20% (6-min average)
Geneva Steel, Provo, UT	20% (6-min average)

TABLE 5-4. SINTER COOLER DESCRIPTIONS AND LIMITS

Plant	Description	Limit
Ispat-Inland	Baghouse controls the discharge, scrubber, hot screen and ½ of cooler (one quadrant where the sinter is transferred to the cooler and one quadrant where it is removed); the other half is covered and vents through an uncontrolled stack. 20 minute residence time. Baghouse flow is 120,000 dscfm.	0.01 gr/dscf (for controlled portion)
WCI Steel	Baghouse with forced air at 189,000 dscfm	42.9 lb/hr (about 0.027 gr/dscf)
Bethlehem, Sparrows Point	Cyclone at 320,000 dscfm and 0.02 gr/dscf; 90 to 120 min residence time	0.03 gr/dscf
USS, Gary	3 coolers, uncontrolled; with hood and stack; 360,000 dscfm each	0.03 gr/dscf
AK Steel, OH	Baghouse controls discharge, crusher, hot screen and cooler; flow of 112,000 dscfm	50 lb/hr (about 0.05 gr/dscf)
Bethlehem, Burns Harbor	Uncontrolled, with hood over cooler; 30-ft diameter and 575,000 dscfm; 60 min residence time	no limit
LTV, East Chicago	Uncontrolled; 60-ft diameter and 320,000 dscfm; 100 min residence time	no limit

Geneva Steel	**These plants do not have coolers**. Sinter is transferred from the hot screen to a storage pile and cooled by ambient air. Wheeling-Pittsburgh also uses water sprays.
Wheeling-Pittsburgh	

5.2 BLAST FURNACE

The casthouse is a building or structure that encloses the section of the blast furnace where hot metal and slag are tapped from the furnace. These emissions are controlled in one of two fundamentally different ways, flame suppression or conventional ventilation practices and control. Flame suppression consists of blowing natural gas over the iron runners and torpedo cars. The combustion of the gas consumes oxygen, which retards (suppresses) the formation of emissions. Ventilation practices employed include the use of localized hooding and ventilation applied at the iron trough and iron and slag runners. Alternatively, the casthouse may be totally enclosed and evacuated. Eighteen of the 39 blast furnaces have capture and control systems, 16 are controlled by baghouses and two are controlled by one wet scrubber.

As a means for limiting fugitive emissions of PM from the casthouse during hot metal tapping, most States have developed visible emission standards that limit the opacity of emissions discharged from the casthouse roof monitor or other openings. As shown in Table 5-5, the most common limit is 20 percent (6-minute average), which is applied to 24 of the 39 casthouses.

States also apply particulate limits on gases discharged from control devices used to capture tapping emissions. The most common form is a concentration limit, typically on the order of 0.01 gr/dscf (Table 5-6).

TABLE 5-5. CASTHOUSE EMISSION CONTROLS AND OPACITY LIMITS

Plant	Furnace	Casthouse control	Casthouse opacity limit
Acme Steel, IL	A	Flame suppression (FS), covered runners	20%, 6 minute average
AK Steel, KY	Amanda	FS, covered runners	20%, 6 minute average
AK Steel, OH	3	Flame suppression	Covered under a “bubble”
Bethlehem Steel, IN	C D	Inert suppression, FS Inert suppression, FS	No opacity limit No opacity limit
Bethlehem Steel, MD	L	Baghouse, evacuated runner covers & hoods	5%, 6 minute average, 20% drilling, O_2 lance and mudding
Geneva Steel, UT	1 2 3	FS, partially covered runners FS, partially covered runners FS, partially covered runners	For all 3: 20%, except for any aggregate of 3 min. (12 readings) in any 60 min.
Gulf States Steel, AL	1	No controls	None
Inland Steel, IN	7 5 6	Baghouse Scrubber Scrubber	15%, 6 minute average 20%, 6 minute average 20%, 6 minute average
LTV Steel, OH	C1 C5 C6	FS, covered runners FS, covered runners Fume suppression hoods	20%, 6 minute average 15%, 6 min., w/ exceptions to 20% 20%, 6 minute average
LTV Steel, IN	H3 H4	FS, covered runners FS, covered runners, baghouse	20%, 6 minute average 20%, 6 minute average
National Steel, IL	A B	Baghouse, covered runners Baghouse, covered runners	20%, 6 minute average 20%, 6 minute average
National Steel, MI	A B D	Baghouse Baghouse Baghouse	20%, 6 minute average 20%, 6 minute average 20%, 6 minute average
Rouge Steel, MI	B C	Covered runners, FS Covered runners, FS	20%, 6 minute average 20%, 6 minute average
USX, PA	1 3	Baghouse Baghouse	For both: Not to equal or exceed 20% except for 12 readings per hour
USX, AL	8	Covered runners, Baghouse	20%, 6 minute average
USX, IN	4 6 8 13	FS FS FS Baghouse, covered runners, evac. hood	20%, 6 minute average 20%, 6 minute average 20%, 6 minute average 20%, 6 minute average
USS/Kobe Steel, OH	3 4	Baghouse, covered runners FS	15%, 6 minute average 20%, 6 minute average
WCI Steel, OH	1	Baghouse	20%, 6 minute average

Plant	Furnace	Casthouse control	Casthouse opacity limit
Weirton Steel, WV	1 4	Covered runners, FS, baghouse Covered runners, FS	20%, except 40% for 5 minutes/hour 20%, except 40% for 5 minutes/hour
Wheeling Pittsburgh Steel, OH	1 5	Covered runners, FS Covered runners, FS, baghouse	20%, 6 minute average 5% to 20%

TABLE 5-6. EMISSION LIMITS FOR CASTHOUSE CONTROL DEVICES

Plant	Furnace	Control	Capture Points	Emission Limit
Bethlehem Steel, MD	L	Baghouse	Evacuated runner covers & hoods	0.03 gr/dscf
Ispat-Inland, IN	7	Baghouse 1 Baghouse 2	Canopy hood Runners	0.003 gr/dscf 0.011 gr/dscf
LTV Steel, IN	H4	Baghouse	Hood over tilting spout & iron trough	No limit
National Steel, IL	A B	Baghouse #1 Baghouse #2	Suspended hood 6 air hoods, 3 at each furnace with damper control	0.01 gr/dscf 0.01 gr/dscf
National Steel, MI	A B D	Baghouse Baghouse Baghouse	Hoods over trough & pouring spouts — each furnace	0.0075 gr/dscf 0.02 lb PM/1000 lb exhaust 0.0052 gr/dscf
USX, PA	1 3	Baghouse Baghouse	Air curtain	No limit No limit
USS/Kobe, OH	3	Baghouse	Evacuated runner covers & hoods	0.0052 gr/dscf
WCI Steel, OH	1	Baghouse		0.03 lb/ton
Wheeling-Pittsburgh, OH	5	Baghouse	Trough hood, covered runners, hood at tilting runners	0.31 lb/hr; proposed PM_{10} limit of 5.93 lb/hr

5.3 BOPF SHOP

5.3.1 Primary Control Devices

There are 50 BOPF located in 23 BOPF shops. The 50 BOPF include 34 furnaces with open hood systems at 16 shops and 16 furnaces with closed hood systems at 8 shops. All of the BOPF have capture and control systems for the primary emissions. For the open hood systems, 8 shops are controlled by venturi scrubbers and 8 shops are controlled by ESP. All 8 of the closed hood shops are controlled by venturi scrubbers. Open and closed hood vessels are very different in terms of operation, pollutant loading, and emissions. Open hood systems are characterized by very high primary exhaust air flowrates due to the large quantities of combustion air introduced at the furnace mouth to support CO combustion. In contrast, closed hood systems, which include hoods that are tightly fitted to the vessel to suppress CO combustion, are characterized by much lower exhaust air flowrates. Typical flowrates for open hood shops are 200,000 to 500,000 acfm, while closed hood designs are usually less than 100,000 acfm.

Each shop is subject to existing State limits with a wide variety of formats, including concentration limits in gr/dscf and lb/1,000 lb gas for PM or PM_{10}, mass emission rate limits in lb/hr, and process weighted limits in lb/ton of steel. In addition, the emission test period required for compliance with the existing State limits varies from testing over the steel production cycle, only during the oxygen blow, for 1-hour runs, and for 2-hour runs. Emission limits are summarized in Tables 5-7 and 5-8.

5.3.2 BOPF Secondary Controls

Secondary or fugitive emissions occur from the BOPF when the molten iron and scrap metal are charged to the furnace and when the molten steel and slag are tapped from the furnace. The emissions generated are primarily metal oxides formed when oxygen in the air reacts with the molten iron or steel. Twelve of the 23 BOPF shops have a separate capture and control system for BOPF charging and tapping emissions. Ten of these shops use baghouses and the other two use scrubbers. Existing State limits for the control devices are shown in Tables 5-9 and 5-10 and range from 0.0052 to 0.015 gr/dscf and the NSPS limit is 0.01 gr/dscf. The most common limit is 0.01 gr/dscf.

TABLE 5-7. EMISSION LIMITS FOR PRIMARY CONTROL -- OPEN HOOD

Open Hood BOPF Shops			
Plant	**State**	**Control**	**Emission Limit**
Acme Steel	IL	ESP	0.028 gr/dscf
Bethlehem Steel[a]	IN	Scrubber	0.09 lb/ton liquid steel
Bethlehem Steel	MD	Scrubber	0.03 gr/dscf
Gulf States Steel	AL	ESP	--
Ispat-Inland No. 4	IN	Scrubber	0.187 lb/ton
LTV Steel	IN	ESP	0.018 gr/dscf PM_{10}
LTV No. 1 Shop	OH	ESP	39.8 lb/hr
National Steel	IL	ESP	60.0 lb/hr or 0.255 lb/ton
National Steel	MI	ESP	0.057 lb/1000 lb gas
Rouge Steel	MI	ESP	
USX Gary (BOPF)	IN	Scrubber	0.02 gr/dscf PM_{10}
USX Gary(Q-BOP)	IN	Scrubber	0.02 gr/dscf PM_{10}
USX Edgar Thomson	PA	Scrubber	Process rate
WCI Steel	OH	ESP	62.90 lb/hr
Weirton Steel	WV	Scrubber	0.03 gr/dscf
Wheeling-Pittsburgh	OH	Scrubber	21.40 lb/hr; 7.09 lb/hr PM_{10} (pending)

[a] Two furnaces are open hood and one is closed hood.

TABLE 5-8. EMISSION LIMITS FOR PRIMARY CONTROL -- CLOSED HOOD

Closed Hood BOPF Shops			
Plant	**State**	**Control**	**Emission Limit**
AK Steel	KY	Scrubber	0.03 gr/dscf
AK Steel	OH	Scrubber	114 lb/hr[a]
Geneva Steel	UT	Scrubber	0.02 gr/dscf[b] PM_{10}
Inland No. 2	IN	Scrubber	0.058 lb/ton
LTV No. 2	OH	Scrubber	15 lb/hr (for each of 2 stacks)
USS/Kobe Steel	OH	Scrubber	45.0 lb/hr
USX Fairfield	AL	Scrubber	0.022 gr/dscf;[c] process rate[d]

[a] Both vessels combined
[b] During oxygen blow
[c] Furnace C, subject to NSPS, Subpart NN, which is 0.022 gr/dscf for closed hood shops
[d] Furnaces X & U

TABLE 5-9. LIMITS FOR SECONDARY CONTROL DEVICES AT CLOSED HOOD BOPF SHOPS

Closed Hood BOPF Shops			
Plant	**State**	**Control**	**Limit**
Bethlehem Steel	IN	Scrubber	0.05 lb/ton liquid steel (#3)
Geneva Steel	UT	Baghouse	0.002 gr/dscf[a]
Inland No. 2 Shop	IN	Scrubber	0.015 lb/ton TSP
LTV No. 2 Shop	OH	Baghouse	0.010 gr/dscf
USS/Kobe Steel	OH	Baghouse	0.012 gr/dscf
USX Fairfield	AL	Baghouse	0.010 gr/dscf

TABLE 5-10. STATE EMISSION LIMITS FOR SECONDARY CONTROL DEVICES AT OPEN HOOD BOPF SHOPS

Open Hood BOPF Shops			
Plant	**State**	**Control**	**Actual Limit**
Acme Steel	IL	Baghouse	10.22 lb/hr, 0.0052 gr/dscf
Inland No. 4 Shop	IN	Baghouse	0.006 gr/dscf TSP
USX, Gary (Q-BOP)	IN	Baghouse	0.0052 gr/dscf[a]
USX, Braddock	PA	Baghouse	Process weight limit

[a] gr/dscf PM_{10}

5.3.3 Hot Metal Transfer, Desulfurization, Slag Skimming, and Ladle Metallurgy

There are several different ancillary operations performed within the BOPF shop: (1) operations associated with the molten iron before it is charged to the BOPF (hot metal transfer, desulfurization, and slag skimming), and (2) treatment of the molten steel after tapping (various ladle metallurgy operations). The emissions from these operations are primarily metal oxides formed when oxygen in the air reacts with the molten iron or steel.

Molten iron is transported from the blast furnace casthouse to the BOPF shop in a torpedo car and transferred to a vessel at the reladling (or hot metal) station, where it is usually desulfurized and slag is skimmed from the surface. Emissions from these operations are captured by local hooding and controlled by a baghouse. Existing State emission limits for these operations shown in Table 5-11 range from 0.0052 to 0.04 gr/dscf, but most are on the order of 0.01 gr/dscf.

The steel from the BOPF is usually transferred to a ladle where final adjustments in temperature and chemistry are made in an operation known as ladle metallurgy. Emissions from ladle metallurgy are captured by a close fitting hood and ducted to a baghouse. Existing State limits for ladle metallurgy shown in Table 5-12 are a mixture of mass emission rates in lb/hr and concentration limits in gr/dscf. The mass emission rate limits range from 0.42 to 7.5 lb/hr and the concentration limits range from 0.0052 to 0.02 gr/dscf.

5.3.4 BOPF Shop Roof Monitor

The BOPF shop is a building or structure that houses several operations involved in steelmaking. These include hot metal transfer, desulfurization, slag skimming stations; one or more BOPF for refining iron into steel; and ladle metallurgy stations. Fugitive emissions from these operations in the BOPF shop exit through the roof monitor.

States have set roof monitor opacity standards to limit these fugitive emissions (see Table 5-13). The most stringent existing limit is the NSPS opacity limit of 10 percent (6-minute average, with one exception per cycle up to 20 percent). The most common standard is a 20 percent limit (3-minute average) that is applied to 14 of the 23 BOPF shops. In addition, there is an NSPS limit of 10 percent opacity during the steel production cycle of any top-blown BOPF or during hot metal transfer or skimming operations for any bottom-blown BOPF; except that an opacity greater than 10 percent but less than 20 percent may occur once per steel production cycle.

TABLE 5-11. STATE LIMITS FOR TRANSFER, DESULFURIZATION, AND SLAG SKIMMING--ALL BAGHOUSES

Plant	State	Process	Emission Limit
Acme Steel	IL	Transfer, desulfurization, skimming	10.2 lb/hr
AK Steel	KY	Transfer, desulfurization, skimming	0.01 gr/dscf
AK Steel	OH	Transfer and desulfurization	58 lb/hr
		Deslagger	0.03 gr/dscf
Bethlehem Steel	IN	Transfer, desulfurization, skimming	23.1 lb/hr
Geneva Steel	UT	Desulfurization Buildings 1& 2	0.011 gr/dscf PM_{10}
Inland Steel, No. 2	IN	Reladle and desulfurization	0.011 gr/dscf
Inland Steel, No. 4	IN	Reladle and desulfurization	0.0052 gr/dscf
LTV Steel	IN	Reladle and desulfurization	0.008 gr/dscf PM_{10}
National Steel	IL	Transfer, desulfurization, skimming	0.01 gr/dscf
Rouge Steel	MI	Transfer and desulfurization	--
National Steel	MI	Hot metal transfer	0.007 gr/dscf
USS, Edgar	PA	Reladle and desulfurization	Process weight rate
USS, Fairfield	AL	Reladle and desulfurization	0.01 gr/dscf
USS Gary Works,	IN	Desulfurization	0.01 gr/dscf
USS Gary	IN	Reladle and desulfurization	0.0052 gr/dscf PM_{10}
USS/Kobe Steel	OH	Transfer and desulfurization	
WCI Steel	OH	Desulfurization	0.03 gr/dscf
Weirton Steel	WV	Hot metal transfer	0.04 gr/dscf
		Desulfurization	0.01 gr/dscf
Wheeling-Pittsburgh Steel	OH	Hot metal transfer	5.97 lb/hr
		Desulfurization	5.01 lb/hr (proposed)
		Hot metal transfer backup	6.41 lb/hr (proposed)

TABLE 5-12. STATE LIMITS FOR LADLE METALLURGY PROCESS

Plant	State	Control	Emission Limit
Acme Steel	IL	Baghouse	0.037 lb PM_{10}/ton
AK Steel	KY	Baghouse	3.8 lb/hr
AK Steel	OH	Baghouse	0.02 gr/dscf
AK Steel	OH	Baghouse[a]	0.03 gr/dscf
Inland Steel, No. 2	IN	Baghouse	0.0052 gr/dscf
LTV Steel	IN	Baghouse	0.004 gr/dscf PM_{10}
National Steel	IL	Baghouse 1	0.01 gr/dscf
National Steel	IL	Baghouse 2	0.01 gr/dscf
National Steel	MI	Baghouse 1[b]	1.26 lb/hr
National Steel	MI	Baghouse 2[a]	2.13 lb/hr
National Steel	MI	Baghouse 3[c]	1.1 lb/hr
Rouge Steel	MI	Baghouse 1	7.50 lb/hr
Rouge Steel	MI	Baghouse 2	1.6 lb/hr
USS Fairfield	AL	Baghouse	0.02 gr/dscf
USS Gary Q-BOP	IN	Baghouse 1	0.01 gr/dscf PM_{10}
USS Gary Q-BOP	IN	Baghouse 2	0.01 gr/dscf PM_{10}
USS/Kobe	OH	Baghouse	0.002 gr/dscf
Weirton Steel	WV	Baghouse	0.42 lb/hr
Wheeling-Pittsburgh	OH	Baghouse	0.54 lb/hr[d]
Wheeling-Pittsburgh	OH	Baghouse	2.3 lb/hr, 0.02 gr/dscf[d]

[a] Vacuum degassing
[b] Ladle metallurgy, No. 2 argon stirring
[c] No. 1 argon stirring station
[d] Proposed limit

TABLE 5-13. SUMMARY OF BOPF ROOF MONITOR OPACITY LIMITS

Plant	Open or closed	Primary control	Secondary control	Roof monitor opacity limit
Acme Steel, Riverdale, IL	Open	ESP	Baghouse	20%, 3 minute average
AK Steel, Ashland, KY	Closed	Scrubber	Baghouse	20% except for 3 min/hr
AK Steel, Middletown, OH	Closed	Scrubber	None	Covered under "bubble"
Bethlehem, Burns Harbor, IN (3 vessels in 1 shop)	Open(2) Closed(1)	Scrubber	None Scrubber	40%, 6 minute average; <60% for 15-min in 6 hr
Bethlehem, Sparrows Point, MD	Open	Scrubber	None	3-day roll avg of 15% (6-min avg), except 3 min/hr
Geneva Steel, Orem, UT	Closed[a]	Scrubber	Baghouse	10%, 6 minute average
Gulf States, Gadsden, AL	Open	ESP	None	20%, 3 minute average
Inland Steel, East Chicago, IN (2 shops)	Closed Open	Scrubber Scrubber	Scrubber Baghouse	20%, 3 minute average 20%, 3 minute average
LTV, Cleveland, OH (2 shops)	Open Closed	ESP Scrubber	 Baghouse	20%, 3 minute average 20%, 3 minute average
LTV, East Chicago, IN	Open	ESP	None	20%, 3 minute average
National, Granite City, IL	Open	ESP	None	20%, 3 minute average
National, Ecorse, MI	Open	ESP	Baghouse	20%, 3 minute average
Rouge Steel, Dearborn, MI	Open	ESP	None	20%, 3 minute average
USX, Braddock, PA	Open	Scrubber	Baghouse	Not to equal or exceed 20% except for 12 readings per hour.
USX, Fairfield, AL	Closed[a]	Scrubber	Baghouse[b]	20%, 6 minute average
USX, Gary, IN (2 shops)	Open Open[a]	Scrubber Scrubber	 Baghouse	20%, 3 minute average 20%, 3 minute average
USS/Kobe, Lorain, OH	Closed	Scrubber	Baghouse	20%, 3 minute average
WCI Steel, Warren, OH	Open	ESP	None	None
Weirton Steel Weirton, WV	Open	Scrubber	None	20%
Wheeling-Pittsburgh, OH	Open	Scrubber	None	20%, 3 minute average

[a] Bottom blown

[b] Canopy hood baghouse controls emissions from "C" furnace only; new secondary control system under construction.

[c] The NSPS for the roof monitor is 10 percent opacity based on 6-minute averages, except one period per cycle can go to 20 percent.

6. CONTROL COSTS

6.1 APPROACH

The costs associated with improved emission control are based on what each plant may have to do with respect to upgrading or replacing emission control equipment. The estimates are worst case or upper bound estimates because they assume in several cases that plants will have to replace existing control equipment, when if fact, it may be possible to upgrade existing controls.

The cost estimates are derived from industry survey responses, information from vendors, and procedures in EPA's manual for estimating costs.

6.2 BOPF PRIMARY CONTROL SYSTEMS

Two plants were identified as candidates for upgrading or replacing their venturi scrubbers used as the primary control devices for BOPF. Ispat-Inland's Number 4 BOPF shop has three venturi scrubbers that are over 30 years old and were designed with a lower pressure drop (25 inches of water) than most scrubbers that are currently used. The company had performed an engineering analysis in 1990 to estimate the cost of replacing these scrubbers with higher pressure scrubbers.[1] The estimate is based on an entirely new emission control system that includes three venturi scrubbers and three new capture hoods for the BOPF. The capital cost estimates are presented below and are indexed to 1998 dollars:

Item	Capital cost (millions of dollars)
Three venturi scrubbers	11
Three new BOPF hoods	6.6
Engineering	0.7
Miscellaneous	0.4
Total ($1990)	18.7
Total ($1998) index = 389.5/357.6	20

The increase in operating cost for the new scrubbers is primarily the cost of increased energy (electricity) due to operating at the higher pressure drop. A cost function is provided in EPA's cost manual[2] that expresses electricity cost as a function of the volumetric flow rate and pressure drop:

Electricity cost ($/yr) = 0.00018 x acfm x) p x hrs/yr x $/kW-hr

Estimates of electrical costs are given below for pressure drops of 25 and 50 inches of water based on 600,000 acfm , 8,760 hrs/yr, and $0.059/kW-hr:

) p (in. water)	Cost ($ millions/yr)
25	1.4
50	2.8

The increase in operating cost for the higher pressure drop scrubbers is estimated as $1.4 million per year.

Test data indicated that the venturi scrubbers at AK Steel (Middletown, OH) may require a minor upgrade to improve emission control. These scrubbers were designed with an adequate pressure drop (50 to 60 inches of water). However, the water supply system may need to be upgraded, and the scrubbers do not have demisters. Estimates obtained from a vendor (Coastal Technologies, Inc.) indicated that two demisters for two 72-inch diameter stacks would cost about $7,000 (316 stainless steel chevrons). The cost of new water supply piping[2] for venturi scrubbers of this size was estimated as $10,600 for a total equipment cost of $17,600. Based on a retrofit factor of 1.3 and an indirect cost factor (from the cost manual[2]) of 36 percent of the purchased equipment cost, the total installed capital cost for the minor scrubber upgrade is estimated as $31,000.

6.3 SECONDARY CAPTURE AND CONTROL SYSTEMS

Capture and control systems are used for fugitive emissions in many blast furnace casthouses and BOPF shops. Table 6-1 summarizes the capital and operating costs reported by several plants that use a baghouse as the control device.

Only one plant reported no controls for their casthouse -- Gulf States Steel in Gadsden, Alabama. This plant may be able to use flame suppression and covered runners to provide adequate control to meet an opacity limit for the casthouse. However, a worst case approach is used by assuming that a capture system and baghouse may need to be installed. Based on the cost for such a system as reported by USS/Kobe Steel in Table 6-1, costs are estimated as an installed capital cost of $3.3 million, an operating cost of $0.7 million per year, and a total annualized cost of $1.0 million per year (includes capital recovery based on a 20-year life and 7 percent interest rate.)

TABLE 6-1. BAGHOUSE COSTS

Plant	**Geneva Steel[3]**	**WCI Steel[4]**	**USS/Kobe[5]**	**Geneva Steel[3]**	**AK Steel[6]**	**Gulf States[7]**
Process	sinter windboxes	sinter windboxes	blast furnace fugitives	Q-BOP fugitives	BOPF fugitives	hot metal transfer, slag skimming, desulfurization
Date installed	1993	1991	1992	1991	1992	1992
Type	pulse jet	pulse jet	pulse jet	pulse jet	pulse jet	pulse jet
Air:cloth	4.0	4.0	6.3	4.8	4.8	3.9
Flow (acfm)	540,000	400,000	300,000	440,000	880,000	150,000
Temperature (EF)	275	300	250	145	275	250
Bag type	polyester	Nomex®	polyester	Nomex®	polyester	polyester
Installed capital cost ($1998)	$4,300,000	$4,700,000	$3,300,000	$3,400,000	--	$4,300,000
Annual operating cost ($1998/yr)	$610,000	$1,000,000	$730,000	$460,000	$500,000	--

AK Steel has a closed hood BOPF shop in Middletown, OH that does not have a secondary capture and control system. The cost of a new system, including a baghouse control device, is estimated from the costs reported by two plants in Table 6-1 (Geneva Steel and AK Steel in Kentucky): capital cost of $3.4 million, an operating cost of $0.5 million per year, and a total annualized cost of $0.8 million per year (includes capital recovery based on a 20-year life and 7 percent interest rate.)

The MACT technology for secondary capture and control systems is a baghouse, and all plants except two use baghouses. Ispat-Inland and Bethlehem Steel (Burns Harbor, IN) use scrubbers as the control device for secondary emissions in the BOPF shop. There is uncertainty about the level of emission control these scrubbers can achieve. As a worst case, assume these scrubbers must be replaced by a baghouse at a capital cost of $3.4 million. There would be no increase in operating cost (the operating cost for baghouses would be less than the current operating costs for the scrubbers).

6.4 BAG LEAK DETECTION SYSTEMS

Each baghouse will be equipped with a bag leak detection system. These systems have an installed capital cost of $9,000 each with an annual operating cost of $500/year[8]. There are approximately 88 baghouses at the 20 iron and steel plants. Consequently, the total capital cost for bag leak detectors is $0.8 million with an annual operating cost of $44,000/year.

6.5 TOTAL NATIONWIDE COSTS

The nationwide costs are summarized in Table 6-2 and represent a somewhat worst case estimate because some of these plants may not have to install new controls. The nationwide capital cost is estimated as $34 million with a total annualized cost of $5.9 million/year.

TABLE 6-2 NATIONWIDE COST ESTIMATES

Source	Capital ($ million)	Operating ($ million/yr)	Total annual ($ million/yr)
Gulf States, baghouse for casthouse	3.3	0.7	1.0
AK Steel (Middletown, OH), baghouse for secondary BOPF system	3.4	0.5	0.8
AK Steel, BOPF scrubber upgrade	0.03	0	0.003
Ispat Inland, new primary scrubbers and hoods for No. 4 BOPF shop (50") p)	20	1.4	3.3
Ispat-Inland, baghouse to replace scrubber for secondary BOPF system	3.4	0	0.3
Bethlehem, Burns Harbor, baghouse to replace scrubber for secondary BOPF system	3.4	0	0.3
Bag leak detection systems	0.8	0.04	0.2
Total	34	2.6	5.9

6.6 REFERENCES

1. Carson, J. No. 4 BOF Gas Cleaning Upgrade (dated 9/21/90). Provided on April 6, 2000.

2. U.S. Environmental Protection Agency. OAQPS Control Cost Manual. 5th edition. EPA 453/B-96-001. February 1996.

3. Shaw, K.C. Geneva Steel's response to pollution control equipment cost survey. January 26, 1996.

4. Shepker, T. WCI Steel's response to pollution control equipment cost survey. January 12, 1996.

5. Stinson, R. USS/Kobe Steel's response to pollution control equipment cost survey. March 6, 1996.

6. Bradley, L. AK Steel's response to pollution control equipment cost survey. January 1996.

7. Stewart, E.M. Gulf States Steel's response to pollution control equipment cost survey. January 17, 1996.

8. EPA. Supporting Statement for the Primary Lead MACT Information Collection Request. April 1998.

7. ENVIRONMENTAL IMPACTS

7.1 EMISSION REDUCTIONS

There are four integrated iron and steel plants that may be impacted by MACT. Each plant, emission points, controls, and assumptions for emission reductions are described below.

Gulf States Steel Gulf States Steel has neither suppression controls nor a capture and control system for the blast furnace casthouse. Assume as a worst case the installation of a capture and control systems that will achieve a 90-percent reduction in fugitive emissions.

Ispat-Inland. Ispat-Inland's Number 4 BOPF shop has venturi scrubbers that operate at a pressure drop of about 25 inches of water. Assume these scrubbers must be replaced by higher energy scrubbers that will achieve a 50 percent reduction in emissions. The plant uses scrubbers to control secondary emission from the BOPF, and most plants use baghouses. Assume as a worst case that the scrubbers may be replaced by baghouses for secondary emissions and will result in a 50 percent decrease in baseline emissions.

AK Steel. AK Steel (Middletown, Ohio) may have to upgrade the venturi scrubbers in their BOPF shop. Assume the upgrade will result in a 50 percent reduction in emissions. The plant does not have a capture and control system for secondary emissions from the BOPF. Assume a capture system and baghouse will be installed that will achieve a 90 percent reduction in secondary emissions.

Bethlehem Steel. Bethlehem Steel (Burns Harbor) has a scrubber for the control of emissions from hot metal transfer, desulfurization, charging, and tapping in their BOPF shop. Assume the scrubber may be replaced by a baghouse and will result in an emission reduction of 50 percent.

Table 7-1 summarizes the baseline emissions and expected reductions based on reductions of 50 percent for upgrading control systems and 90 percent for new capture and control systems for fugitive emissions. Details on the estimates of baseline emissions are given in Chapter 3.

TABLE 7-1. ESTIMATES OF EMISSION REDUCTIONS

Plant	Source	Baseline emissions (tpy)		Emission reduction (tpy)	
		PM	HAP	PM	HAP
Gulf States[a]	blast furnace casthouse	360	2.2	324	2.0
Ispat-Inland No. 4 BOPF[b]	oxygen blow	400	3.4	200	1.7
	secondary emissions	94	0.9	47	0.5
AK Steel (OH) BOPF[b]	oxygen blow	230	2.2	115	1.1
	secondary emissions	672	6.4	605	5.8
Bethlehem (Burns Harbor) BOPF[b]	transfer, desulfurization	58	0.6	29	0.3
	charging	127	1.2	64	0.6
	tapping	259	2.5	130	1.3
Totals		2,200	19	1,514	13

[a] Estimates of baseline emissions are from Tables 3-6 and 3-8.
[b] Estimates of baseline emissions are from Tables 3-15 and 3-16.

7.2 SECONDARY IMPACTS

Secondary impacts include the increased generation of solid waste or wastewater and increased energy usage as a result of upgrading or installing new pollution control equipment. From Table 7-1, the installation of baghouses will result in an increase in dust generation of 1,200 tpy. Upgrading venturi scrubbers will result in a reduction in PM emissions of 320 tpy. Assuming 10 percent solids in the sludge generated, the increase in sludge to be disposed of is 3,200 tpy.

The largest increase in energy usage will be from the venturi scrubbers at Ispat-Inland if the pressure drop is increased from 25 to 50 inches of water. The minor scrubber upgrade at AK Steel is associated with improving water supply and not pressure drop because the scrubbers already operate at 50 inches of water. Baghouses for uncontrolled sources will also result in increased energy usage; however, baghouses that replace existing scrubbers will reduce energy usage because scrubbers require more energy.

The OAQPS control cost manual[1] provides the following empirical equation for estimating a fan's energy usage for capture and control systems based primarily on the system's pressure drop and the volumetric flow rate.

kw-hr/yr = 0.00018 x acfm x pressure drop (inches of water) x hrs/yr

For Ispat-Inland's venturi scrubber with a flow rate of 600,000 acfm, an increased pressure drop of 25 inches of water, and operation 8,760 hrs/yr, the increased energy usage would be:

$$kw\text{-}hr/yr = 0.00018 \times 600{,}000 \times 25 \times 8{,}760 = 24 \times 10^{6}\ kw\text{-}hr/yr$$

The increased energy usage for the two new baghouses at Gulf States Steel and AK Steel is more than offset by the replacement of venturi scrubbers with baghouses at Ispat-Inland and Bethlehem Steel. Consequently, there is no net increase in energy usage from the installation of baghouses.

7.3 REFERENCES

1. U.S. Environmental Protection Agency. OAQPS Control Cost Manual. 5th edition. EPA 453/B-96-001. February 1996.

APPENDIX A
SUMMARY OF SINTER PLANT TESTING

A.1 LTV Steel's Sinter Plant at East Chicago, Indiana

LTV Steel's sinter plant at their Indiana Harbor Works was constructed in 1959 and is a part of the integrated iron and steel plant that also includes blast furnaces, BOPF, ladle metallurgy, continuous casting, rolling mills, and galvanizing lines. The sinter plant has a maximum rated capacity of 5,280 tpd and operates 24 hours per day, 7 days a week. Typically, the plant produces 3,800 tpd and operates 24 hours per day for about 310 days per year. Emission testing was performed June 25-27, 1997.

Emissions are generated in the process as sinter dust and combustion products and are discharged through the grates and windboxes to a common collector main. Coarse dust particles settle out of the air stream in the collector main and are discharged through flapper valves to a conveyor belt. This conveyor also receives the returns from a series of hoppers that collect any particles that fall under the sinter machine. This material is returned by conveyor to the sinter mix feed for recycle to the process. The exhaust then passes through a battery of cyclones and a series of chambers (originally designed for an ESP that is no longer used). The cyclones and chambers remove dust particles, which are also deposited onto a conveyor (through air actuated valves) for recycle to the process.

The exhaust is moved by a 6,000 horsepower fan to the primary control device, which is a double-throat Kinpactor scrubber designed by American Air Filter. The parameters associated with the scrubber that are monitored include the pressure drop across the scrubber, flow rate of water to the scrubber, exhaust fan draft and amperage, and the scrubber water blowdown rate.

A.1.1 Parameter Montoring

The operating parameters associated with the process and control device were recorded at 15-minute intervals throughout each test day. The process parameters that were monitored included the feed rate from each of the 10 bins that were used in the sinter mix, the temperatures and the fan draft for the windboxes, percent water in the feed, sinter machine speed, and the sinter production rate. The emission control device parameters that were monitored included the pressure drop across the scrubber, the water flow rate, blowdown rate, fan draft, and fan amps. Tables A-1 and A-2 present a summary of the range of values for these parameters for each test period.

The process and control device appeared to be stable throughout the three test days; consequently, sampling was conducted under normal and representative conditions. The feed rates of mill scale and other materials were typical of the historical rates in recent years that had been reported by the plant. In addition, the oil content of the mill scale was typical (target is 0.2 percent, maximum) with an average of 0.21 percent oil (a range of 0.17 to 0.24 percent) based on the analysis of 5 samples. An examination of the monitoring data showed that the average pressure drop across the scrubber was 43.1, 42.8, and 42.4 inches of water for the 3 test days. The coke rate seemed to be the most variable parameter during the tests because adjustments were made frequently to change the sintering temperature. The coke rate for the 3 tests averaged 1.7, 1.15, and 0.67 ton per hour; consequently, the emission test results may provide some insight into the effect of coke rate on emissions. The windbox temperatures also varied somewhat during the tests. Using Windbox 20 as an example, the average temperatures during the 3 tests were 538, 567, and 443EF.

A.1.2 Analysis of Monitoring and Test Results

Table A-3 summarizes the emission results for each run along with selected parameters that were monitored during the test. Only a few comparisons can be made because the process operated stably and consistently during the 3 test runs. One difference is that the coke (fuel) rate during Run 3 was only 39 percent of the rate during Run 1 and only 58 percent of the rate during Run 2. The lower fuel rate during Run 3 is reflected in the lower windbox temperature during Run 3, which was about 100EF lower than in the previous 2 runs. The pollutants most likely to be affected by the change in combustion conditions are D/F and PAH.. During Run 3, the emission rates for all of these compounds were lower than in the previous 2 runs.

The highest emissions of PM and Pb occurred during Run 3. The cause is not conclusive, but some of the possible factors affecting this, perhaps in combination, were that Run 3 had the highest sinter feed and production rate and the lowest average pressure drop across the scrubber. In addition, Table A-1 indicates that Run 3 had a higher feed rate of fines (pellet fines and BOPF slag fines) than that recorded during the previous 2 runs. Service water was used in the scrubber during Run 1 and recycled blast furnace water was used during Runs 2 and 3. There is no obvious difference in emissions that can be clearly attributed to the type of scrubber water.

The major metal HAP that was found was Pb, which accounted for over 97 percent of the total metal HAP emissions. Discussions with the plant and examination of data from the analysis of blast furnace fines and sludge indicated that a likely source of the Pb emissions was from this fine material recycled from the blast furnace. Data in the literature showed that the Pb content of blast furnace dust and sludge was generally in the range of 0.01 to 0.1 percent. At a typical feed rate for the dust and sludge of 28,000 lb/hr (14 tph), these materials would introduce 2.8 to 28 lb/hr of Pb into the process, which could easily account for the Pb that was found entering the scrubber (4.2 lb/hr). In addition, the small particle size of these pollution control residues from the blast furnace may increase the probability that they become airborne, and the volatility of Pb and some Pb compounds from combustion processes may tend to increase the concentration of Pb in the windbox emissions.

Table A-4 through A-6 presents a summary of the annual emissions and the emission factors derived from this test.

TABLE A-1. PROCESS PARAMETER VALUES DURING THE TESTS

Parameter	Run 1 (6/25/97)	Run 2 (6/26/97)	Run 3 (6/27/97)
Feed rate (tph):			
Mill scale	25.2 (24.8 - 25.5)	25.2 (24.9 - 25.5)	25.2 (24.8 - 25.6)
BOPF slag/filter cake	16.7 (16.1 - 17.9)	16.9 (15.9 - 18.2)	16.9 (15.5 - 17.9)
Fines	16.7 (16.1 - 17.6)	16.4 (15.9 - 18.0)	16.7 (15.3 - 18.0)
Pellet chips	77.4 (75.9 - 78.8)	77.7 (76.2 - 79.0)	77.6 (76.5 - 79.5)
Pellet fines-- blend	9.5 (8.5 - 10.2)	10.7 (10.1 - 11.4)	12.3 (11.3 - 13.6)
Limestone	27.2 (26.9 - 27.7)	27.5 (26.8 - 27.8)	27.7 (27.4 - 28.8)
Cold fines	19.6 (17.6 - 21.4)	17.2 (15.2 - 19.5)	17.8 (16.8 - 23.2)
Coke breeze	1.7 (1.5 - 1.9)	1.2 (0.9 - 1.5)	0.7 (0.34 - 1.1)
Flue dust	5.9 (5.8 - 6.0)	5.9 (5.8 - 6.0)	5.9 (5.8 - 6.0)
BOPF slag fines	7.9 (7.6 - 8.2)	9.3 (9.4 - 10.1)	10.0 (9.8 - 10.1)
Other parameters:			
Percent water	6.7 - 7.5	6.5 - 7.4	7.2 - 8.2
Grate speed	70 - 76	70 - 76	70 - 82
Windbox 20 temperature (EF)	453 - 656	474 - 659	334 - 571
Windbox draft (in. water)	13.6 - 17.4	13.3 - 18.2	14.2 - 18.2
Feed rate (tph)	205 - 210	201 - 212	209 - 213
Sinter production (tph)	155 - 158	153 - 161	159 - 161

TABLE A-2. CONTROL DEVICE OPERATING PARAMETERS DURING THE TESTS

Parameter	Run 1 (6/25/97)	Run 2 (6/26/97)	Run 3 (6/27/97)
Pressure drop (in. water)	38.4 - 46.6	39.4 - 46.3	39.8 - 47.0
Water flow (gal/min)	3,040 - 3,085	3,080 - 3,130	3,080 - 3,110
Blowdown (gal/min)	236 - 239	242 - 246	241 - 244
Fan amps	663 - 695	685 - 700	700 - 730
Fan draft (in. water)	3.1 - 5.8	3.2 - 5.8	3.8 - 5.1
Type of water	service (lake)	recycled blast furnace	

TABLE A-3. VENTURI SCRUBBER: RESULTS FOR EACH TEST RUN

Parameter	Units	Run 1	Run 2	Run 3	Average
PM[a] - inlet	lb/hr	419	479	550	483
PM - outlet	lb/hr	34	38	43	38
PM efficiency	percent	92	92	92	92
PM - inlet	gr/dscf	0.20	0.23	0.25	0.23
PM - outlet	gr/dscf	0.014	0.017	0.019	0.017
HAP metals - in[b]	lb/hr	4.5	4.5	4.9	4.6
HAP metals - out[b]	lb/hr	3.8	3.7	3.9	3.8
Metals efficiency	percent	16	18	20	17
D/F congeners[c]	Fg/hr	810	768	694	757
D/F TEQ[d]	Fg/hr	93	91	79	88
7 PAH[e]	g/hr	1.9	2.0	1.4	1.7
16 PAH	g/hr	69	78	61	69
TOTAL PAH	g/hr	83	92	73	83
Sinter production	tons/hr	156	159	160	158
Scrubber) p	in. water	43.1	42.8	42.4	42.8
Windbox 20 temperature	EF	538	567	443	516

[a] PM = particulate matter
[b] Mostly lead
[c] D/F congeners are those dioxins and furans that have a toxicity equivalent factor relative to 2,3,7,8-TCDD.
[d] D/F TEQ is the toxicity equivalent expressed relative to 2,3,7,8-TCDD.
[e] PAH = polycyclic aromatic hydrocarbons.

TABLE A-4. VENTURI SCRUBBER: SUMMARY OF RESULTS FOR PM AND HAP METALS

Pollutant	Concentration (gr/dscf)		Emission rate (lb/hr)		Efficiency (%)	Annual rate (tpy)[a]		Emission factor (lb/t sinter)	
	Inlet	Outlet	Inlet	Outlet		Inlet	Outlet	Inlet	Outlet
Particulate matter	0.23	0.017	483	38	92	1,800	142	3.1	0.24

Pollutant: HAP metals	Concentration (Fg/dscm)		Emission rate (g/hr)		Efficiency (%)	Annual rate (tpy)		Emission factor (lb/ton sinter)	
	Inlet	Outlet	Inlet	Outlet		Inlet	Outlet	Inlet	Outlet
Mercury	0.96	1.5	0.41	0.69	0	3.3×10^{-3}	5.7×10^{-3}	5.7×10^{-6}	9.7×10^{-6}
Arsenic	4.3	1.1	1.8	0.50	73	1.5×10^{-2}	4.1×10^{-3}	2.5×10^{-5}	7.0×10^{-6}
Beryllium	0.054	0.052	0.023	0.023	0	1.9×10^{-4}	1.9×10^{-4}	3.2×10^{-7}	3.3×10^{-7}
Cadmium	20	17	8.4	7.8	7.4	6.9×10^{-2}	6.4×10^{-2}	1.2×10^{-4}	1.1×10^{-4}
Cobalt	0.30	0.050	0.18	0.023	87	1.5×10^{-3}	1.9×10^{-4}	2.5×10^{-6}	3.3×10^{-7}
Chromium	24	5.2	9.9	2.4	76	8.1×10^{-2}	1.9×10^{-2}	1.4×10^{-4}	3.3×10^{-5}
Manganese	400	17	171	7.9	95	1.4	6.4×10^{-2}	2.4×10^{-3}	1.1×10^{-4}
Nickel	23	22	9.8	9.9	0	8.0×10^{-2}	8.1×10^{-2}	1.4×10^{-4}	1.4×10^{-4}
Lead	4,500	3,700	1,900	1,690	11	16	$1.4 \times 10^{+1}$	2.7×10^{-2}	2.4×10^{-2}
Antimony	2.6	1.6	1.1	0.75	32	9.0×10^{-3}	6.1×10^{-3}	1.5×10^{-5}	1.0×10^{-5}
Selenium	13	8.7	5.5	4.0	28	4.5×10^{-2}	3.2×10^{-2}	7.7×10^{-5}	5.5×10^{-5}
Total HAP metals	5,000	3,800	2,100	1,700	18	17	$1.4 \times 10^{+1}$	2.9×10^{-2}	2.4×10^{-2}

[a] Based on operation for 24 hours per day for 310 days per year.

TABLE A-5. VENTURI SCRUBBER: RESULTS FOR PAH AND D/F

Pollutant: PAH[a]	**Concentration (Fg/dscm)**	**Emission rate (g/hr)**	**Emissions**[b] **(tpy)**	**lb/ton sinter**
Benzo(a)anthracene	0.53	0.24	0.0019	3.3×10^{-6}
Benzo(a)pyrene	0.23	0.11	0.00086	1.5×10^{-6}
Benzo(b)fluoranthene	1.2	0.54	0.0044	7.5×10^{-6}
Benzo(k)fluoranthene	0.22	0.10	0.00082	1.4×10^{-6}
Chrysene	1.3	0.60	0.0049	8.4×10^{-6}
Dibenzo(a,h)anthracene	0.097	0.044	0.00036	6.1×10^{-7}
Indeno(1,2,3-cd)pyrene	0.26	0.12	0.00096	1.6×10^{-6}
Total 7 PAH	**3.9**	**1.7**	**0.014**	$\mathbf{2.4 \times 10^{-5}}$
Acenaphthene	3.5	1.6	0.013	2.2×10^{-5}
Acenaphthylene	7.6	3.4	0.028	4.8×10^{-5}
Anthracene	1.8	0.81	0.0067	1.1×10^{-5}
Benzo(g.h,l)perylene	0.36	0.16	0.0013	2.2×10^{-6}
Fluoranthene	6.9	3.1	0.026	4.3×10^{-5}
Fluorene	5.4	2.4	0.020	3.4×10^{-5}
Naphthalene	78	35	0.29	4.9×10^{-4}
Phenanthrene	43	19	0.16	2.7×10^{-4}
Pyrene	3.0	1.4	0.011	1.9×10^{-5}
Total 16 PAH	**153**	**69**	**0.57**	$\mathbf{9.7 \times 10^{-4}}$
2-Methylnaphthalene	29	13	0.11	1.8×10^{-4}
2-Chloronaphthalene	0.039	0.018	0.00015	2.5×10^{-7}
Benzo(e)pyrene	0.76	0.30	0.0028	4.8×10^{-6}
Perylene	0.058	0.026	0.00022	3.7×10^{-7}
Total - all PAH	**183**	**83**	**0.68**	$\mathbf{1.2 \times 10^{-3}}$
D/F	**Concentration (ng/dscm)**	**Emission rate (Fg/hr)**	**g/yr**	**g/ton**
D/F TEQ[c]	0.19	88	0.66	5.5×10^{-7}
D/F Congeners[d]	1.7	757	5.6	5.0×10^{-6}

[a] PAH = polycyclic aromatic hydrocarbons.
[b] Based on operation for 24 hours per day for 310 days per year.
[c] D/F TEQ is the toxicity equivalent expressed relative to 2,3,7,8-TCDD.

[d] D/F congeners are those dioxins and furans that have a toxicity equivalent factor relative to 2,3,7,8-TCDD.

A.2 Youngstown Sinter Company's Sinter Plant

The Youngstown sinter plant is operated by Youngstown Sinter Company, a wholly owned subsidiary of WCI Steel. The plant was purchased from LTV Steel Company and was brought on line in June 1991. The sinter plant is located a few miles from the WCI Steel integrated iron and steel plant in Warren, OH. The integrated plant includes one blast furnace, a BOPF shop containing two BOPF vessels, ladle metallurgy, continuous casting, rolling mills, and galvanizing lines. The sinter plant has a capacity of 60,000 tons per month (tpm) and operates 24 hours per day with 2 days scheduled downtime every seven days for routine maintenance. Testing was performed August 12-15, 1997.

Emissions are generated in the process as sinter dust and combustion products are discharged through the grates and the 21 windboxes to a common collector main and are then collected by the strand baghouse. The pulse jet baghouse is manufactured by Environmental Elements and uses Nomex® bags that are coated with an acid-resistant finish. There are 14 modules, each containing 306 bags. The bags are 6 inches in diameter and 15 feet in length, and the total cloth area for each module is 7,215 square feet. The gross air-to-cloth ratio is 3.96 acfm/ft^2 and the net air-to-cloth ratio, with one module off-line for cleaning is 4.26 acfm/ft^2.

The flow to the baghouse is approximately 400,000 cfm. A preheat burner is used to minimize condensation and to bring the gas up to the desired inlet temperature. The dust is removed from the baghouse by rotary screw to bins where it is stored on the ground to gather moisture and is blended back into the sinter feed. The parameters associated with the baghouse that are monitored include the pressure drop across the baghouse, inlet temperature, stack temperature, damper percent, and fan amps.

Three additional baghouses are used to control emissions from the sinter plant. The C baghouse, a pulse jet baghouse utilizing polyester bags, is used to control emissions from the material handling bins and the conveyors that transfer the sinter mix to the sinter machine. The cooler baghouse controls emissions from the sinter cooler and from the main truck loadout station. The baghouse is a shaker baghouse that utilizes Nomex® bags and contains nine compartments. Eight of the compartments are used for the cooler and one compartment is used for the truck loadout station. There are four 200 horsepower fans on the sinter cooler. The first fan is the dirtiest fan and is directed back to hoods on the sinter machine and sent back through as preheat air. The other three fans are ducted to the baghouse. In addition, the truck loadout station has a 70,000 cfm fan. These baghouses were not evaluated as part of this test program.

The A baghouse that serves the discharge end of the sinter plant was evaluated as part of this test program. This baghouse controls emissions from discharge end emission points, including the hood before the sinter machine; the hood over sinter discharge; the sinter breaker and hot screen which is enclosed by a cloth curtain; the tail end of the sinter cooler; emissions from each of the ten sinter feed bins; a variety of transfer points for the transport of sinter, dust, and fines; and emissions from sinter bins located in the sinter overflow storage area. At any point where there is hot sinter, emissions are first ducted to a cyclone before going to the baghouse.

All of the baghouses are monitored on a weekly basis by an outside contractor to check the operation and for any visible opacity. A whole compartment is dye- tested if there is more than 5 percent visible emissions observed, and the broken bags are then replaced. Every other month, a complete compartment of either the strand or cooler baghouse is replaced; each compartment is replaced approximately every 3 years.

A.2.1 Monitoring Results During the Tests

The operating parameters associated with the process and control device were recorded at 15-minute intervals throughout each test day. The process parameters that were monitored included the temperatures and the fan draft for the windboxes, percent water in the feed, sinter machine speed, and the temperature of each of the four cooling fans. In addition, the turn supervisor's report provided additional information, including tons per hour of pre-blend, and tons per 8-hour turn of limestone, dolomite, coke fines, and cold fines. The emission control device parameters that were monitored included the pressure drop across the baghouse, damper percent, inlet temperature, stack temperature, fan amps, and the pressure drop of each of the 14 compartments of the baghouse. Tables A-6 and A-7 present a summary of the range of values for these parameters for each test period. Table A-8 presents a summary of the pressure drops of each compartment of the baghouse for the four days of testing.

The process and control device appeared to be stable throughout the four test days; consequently, sampling was conducted under normal and representative conditions. An examination of the monitoring data showed that the average pressure drop across the baghouse was 10.8, 12.0, 12.9 and 13.5 inches of water for the 4 test days. The pressure drop across the baghouse did increase slightly during each day of testing. On the third day, the compartments were double cleaned to try to reduce the pressure drop. The temperatures and draft of the windboxes varied somewhat during the tests; plant operators stated that the temperature of windboxes 19 and 20, should generally be 475-500 EF to achieve proper burnthrough of the sinter bed.

During each run of testing performed on A baghouse, the pressure drops of each compartment and the pressure drop across the baghouse were monitored periodically, generally every 20 to 30 minutes. The plant does not monitor any other parameters on A baghouse; since the A baghouse is responsible for the capture and control of dust sources throughout the sintering process, malfunctions are readily apparent. Table A-9 presents a summary of the pressure drops of each compartment and the pressure drop across the baghouse during each test period.

A.2.2 Analysis of Monitoring and Test Results

Table A-10 summarizes the emission results for each run for key pollutants from the outlet of the control device on the sinter strand, along with selected parameters that were monitored during the test. Only a few comparisons can be made because the process operated stably and consistently during the 3 test runs. One difference is that the pressure drop across the strand baghouse increased over the four days of testing, from an average of 10.78 on the first day of testing, to an average of 13.48 on the final day of testing. However, the results were fairly stable and did not appear to be impacted by the increased pressure drop over the course of testing. Table A-11 presents emission results for each run for key pollutants from the baghouse that controls emissions from the discharge end ("A" baghouse).

Particulate matter and HAP metal emissions were fairly steady over three runs. One interesting factor is that while particulate matter emissions during Run 2 were three times lower than during Run 1, and two times lower than during Run 3, HAP metal emissions were steady over the course of the three runs. The major metal HAPs that were found were Pb and Mn; both were effectively captured and controlled by both the Strand baghouse and A baghouse.

TABLE A-6. PROCESS PARAMETER RANGES DURING THE TESTS

Parameter	Test 1 (8/12/97)	Test 2 (8/13/97)	Test 3 (8/14/97)	Test 4 (8/15/97)
Feed rate:				
Pre-blend (ore) (tons/hour)	120	120	120	120
Limestone (tons/turn)	144	114	167	—
Dolomite (tons/turn)	43	39	43	—
Coke fines (tons/turn)	19	17	18	—
Cold fines (tons/turn)	1738	1545	1787	—
Other parameters:				
Percent water	7.0 - 7.2	6.7 - 7.6	6.8 - 7.0	6.7 - 6.8
Grate speed (feet/min)	—	—	—	6.3 - 7.0
Windbox 1 temperature (EF)	177-211	150-202	157-207	166-220
Windbox 1 draft (in. H_2O)	18.0-22.1	20.3-23.5	19.5-22.3	19.5-21.8
Windbox 3 temperature (EF)	167-195	108-186	149-181	159-198
Windbox 3 draft (in. H_2O)	16.2-20.3	18.6-21.5	18.1-20.5	18.0-20.1
Windbox 13 temperature (EF)	187-266	184-233	169-231	165-342
Windbox 13 draft (in. H_2O)	—	—	—	—
Windbox 18 temperature (EF)	327-463	251-459	288-457	301-521
Windbox 18 draft (in. H_2O)	14.7-18.3	16.6-19.9	15.7-18.5	16.0-17.8
Windbox 19 temperature (EF)	396-542	357-513	350-460	363-545
Windbox 19 draft (in. H_2O)	16.4-21.1	18.4-21.9	18.0-20.4	17.2-20.5
Windbox 20 temperature (EF)	373-580	391-546	372-496	385-545
Windbox 20 draft (in. H_2O)	14.5-18.9	17.0-20.7	16.2-18.9	16.5-18.6
Windbox 21 temperature (EF)	—	360-465	332-429	355-443
Windbox 21 draft (in. H_2O)	14.9-17.7	15.7-19.3	15.1-17.5	15.3-17.2

Cooling Fan Temperatures (EF)				
A	420-463	411-460	395-415	376-413
B	505-546	405-544	456-530	456-507
C	430-460	205-458	372-440	385-435
D	185-243	116-237	157-200	172-192

TABLE A-7. CONTROL DEVICE PARAMETERS DURING THE TESTS -- WINDBOX BAGHOUSE

Parameter	Test 1 (08/12/97)	Test 2 (08/13/97)	Test 3 (08/14/97)	Test 4 (08/15/97)
Pressure drop (in. H_2O)	9.30-11.87	10.60-12.59	11.61-13.57	12.09-14.12
Inlet Temp. (EF)	242 - 265	217-253	211-245	217-236
Stack Temp. (EF)	243 - 248	231-248	216-243	227-248
Fan amps	684 - 735	667-690	667-694	659-690
Damper (%)	88.9-90.1	89.5-91.2	88.8-90.9	89.0-90.8

TABLE A-8. PRESSURE DROP ACROSS EACH COMPARTMENT OF THE WINDBOX BAGHOUSE

Compartment Pressure Drop	Test 1 (08/12/97)	Test 2 (08/13/97)	Test 3 (08/14/97)	Test 4 (08/15/97)
1	7.0-8.6	6.8-9.3	7.0-9.6	8.6-9.9
2	8.2-9.2	6.7-9.6	6.9-9.8	8.0-10.0
3	7.1-8.6	8.6-9.8	9.4-10+	9.9-10+
4	5.6-8.0	6.8-8.8	7.4-9.8	7.9-10+
5	7.1-8.5	8.0-9.8	9.1-10+	10.0-10+
6	6.6-7.9	7.8-9.3	8.3-9.9	8.9-10+
7	6.4-8.0	7.1-9.4	8.9-10.0	9.7-10+
8	6.7-8.4	6.0-8.8	7.7-9.7	7.2-10+

Compartment Pressure Drop	Test 1 (08/12/97)	Test 2 (08/13/97)	Test 3 (08/14/97)	Test 4 (08/15/97)
9	7.6-9.4	8.6-9.9	9.4-10+	9.5-10+
10	7.1-9.0	7.8-9.7	9.3-10+	9.9-10+
11	6.8-8.9	7.3-9.4	8.5-10+	8.2-10+
12	7.6-9.4	8.8-10+	9.6-10+	10+
13	6.4-9.0	7.6-10+	9.8-10+	10.0-10+
14	6.4-9.2	7.6-10+	9.4-10+	8.5-10+
Total	9.9-11.5	10.0-11.5	11.4-12.3	12.0-13.0

TABLE A-9. PRESSURE DROP ACROSS EACH COMPARTMENT OF DISCHARGE END BAGHOUSE ("A")

Compartment	Test 1 (08/15/97)	Test 2 & 3 (08/16/97)
1	2.6-3.8	3.0-4.7
2	2.8-3.7	3.7-5.5
3	4.7-5.5	1.5-2.0
4	4.4-6.0	5.5-7.4
Total	7.7-8.1	7.9-10.9

TABLE A-10. WINDBOX BAGHOUSE: RESULTS FOR EACH TEST RUN

Parameter	Units	Run 1	Run 2	Run 3	Runs 4 & 5	Average
PM — inlet	lb/hr	1,960	1,120	1,490	--	1,520
PM — outlet	lb/hr	2.35	0.71	1.30		1.45
PM efficiency	%	99.9	99.9	99.9	--	99.9
PM — inlet	gr/dscf	0.68	0.41	0.52	--	0.54
PM — outlet	gr/dscf	0.001	0.0003	0.00055	--	0.0006
HAP metals - inlet[a]	lb/hr	11.7	11.9	11.8	--	11.8
HAP metals - outlet	lb/hr	0.063	0.120	0.068	--	0.084
Metals efficiency	%	99.5	99.0	99.4	--	99.3
Parameter	**Units**	**Runs 1 & 2**	**Run 3**	**Run 4**	**Run 5**	**Average**
Dioxin/furan congeners[b]	Fg/hr	**unacceptable leak checks**	2,142	2,444	2,186	2,257
Dioxin/furan TEQ[c]	Fg/hr		342	404	375	374
7 PAH	g/hr		28.9	34.8	33.9	32.5
16 PAH	g/hr		510	457	575	514
Total PAH	g/hr		691	634	755	693
Sinter production	tons/hr	110	110	110	110	110
Baghouse) P	in. H_2O	10.8	12.0	12.9	13.5	12.3
Windbox 20 Temp.	EF	474	467	446	457	461

[a] Mostly Pb.
[b] D/F congeners are those dioxins and furans that have a toxicity equivalent factor relative to 2,3,7,8-TCDD
[c] D/F TEQ is the toxicity equivalent expressed relative to 2,3,7,8-TCDD

TABLE A-11. DISCHARGE END BAGHOUSE ("A") -- RESULTS FOR EACH RUN

Parameter	Units	Run 1	Run 2	Run 3	Average
PM — outlet	lb/hour	0.53	0.67	0.26	0.48
Mn — outlet	lb/hour	0.0033	0.036	0.016	0.019
HAP metals — outlet	lb/hour	0.012	0.046	0.028	0.029

A surprising result is the emission rate of PAH that was measured during the testing. Emissions for PAH were slightly higher than PM emissions from the outlet of the strand baghouse. These results were consistent over all test runs; even though the first two test runs resulted in questionable data, the results still are consistent with the remaining three test runs. It is not known if the higher emissions were present in the inlet stream or if the baghouse performed poorly in the capture and control of PAH emissions, since inlet testing for PAH was not performed. The major PAH present in the outlet stream were naphthalene and 2-methylnaphthalene, with 3,660 and 2,920 lbs/yr being emitted respectively.

Table A-12 presents a summary of PM and metal HAP results for the strand baghouse, including concentrations, efficiencies, annual emission rates, and emissions factors for each metal HAP. Table A-13 presents similar results for PAH and D/F. Table A-14 presents a summary of results for the discharge end baghouse for PM and metal HAP .

TABLE A-12. WINDBOX BAGHOUSE: SUMMARY OF RESULTS FOR PM AND HAP METALS

Pollutant	Concentration (gr/dscf)		Emission rate (lb/hr)		Efficiency (%)	Annual rate (tpy)[a]		Emission factor (lb/t sinter)	
	Inlet	Outlet	Inlet	Outlet		Inlet	Outlet	Inlet	Outlet
Particulate matter	0.54	0.0006	1,520	1.45	99.9	5,700	5.4	13.8	0.013

Pollutant: HAP metals	Concentration (μg/dscm)		Emission rate (g/hr)		Efficiency (%)	Annual rate (tpy)		Emission factor (lb/t sinter)	
	Inlet	Outlet	Inlet	Outlet		Inlet	Outlet	Inlet	Outlet
Mercury	6.23	5.02	3.5	2.35	32.5	0.03	0.02	7.0×10^{-5}	4.7×10^{-5}
Arsenic	8.27	0.452	4.6	0.21	95.4	0.04	0.00	9.3×10^{-5}	4.2×10^{-6}
Beryllium	0.075	0.038	0.04	0.02	57.7	0.00	0.00	8.4×10^{-7}	3.6×10^{-7}
Cadmium	32.2	0.180	18.0	0.08	99.5	0.15	0.00	3.6×10^{-4}	1.7×10^{-6}
Cobalt	9.35	0.135	5.2	0.06	98.8	0.04	0.00	1.0×10^{-4}	1.3×10^{-6}
Chromium	90.2	4.47	50.5	2.09	95.9	0.41	0.02	1.0×10^{-3}	4.2×10^{-5}
Manganese	2230	29.1	1,247	13.62	98.9	10.16	0.11	2.5×10^{-2}	2.7×10^{-4}
Nickel	18.3	2.07	10.2	0.97	90.5	0.08	0.01	2.0×10^{-4}	1.9×10^{-5}
Lead	7153	21.3	4,001	9.97	99.8	32.61	0.08	8.0×10^{-2}	2.0×10^{-4}
Antimony	2.48	1.21	1.4	0.57	59.3	0.01	0.00	2.8×10^{-5}	1.1×10^{-5}
Selenium	23.1	18.0	12.9	8.42	34.7	0.11	0.07	2.6×10^{-4}	1.7×10^{-4}
Total HAP metals	9,573	82	5,354	38	99.3	44	0.31	1.1×10^{-1}	7.7×10^{-4}

[a] Based on operation for 24 hours per day, 6 days per week, 52 weeks per year (7400 hours/year).

TABLE A-13. WINDBOX BAGHOUSE: RESULTS FOR PAH AND D/F

Pollutant: PAH	**Concentration (Fg/dscm)**	**Emission rate (g/hr)**	**Emissions[a] tpy**	**lb/ton sinter**
Benzo(a)anthracene	21.2	9.79	0.0799	1.96x10^{-4}
Benzo(a)pyrene	2.07	0.956	0.0078	1.92x10^{-5}
Benzo(b)fluoranthene	8.81	4.07	0.0332	8.16x10^{-5}
Benzo(k)fluoranthene	2.79	1.29	0.0105	2.58x10^{-5}
Chrysene	34.6	16.0	0.1305	3.21x10^{-4}
Dibenzo(a,h)anthracene	0.590	<0.273	0.0022	5.47x10^{-6}
Indeno(1,2,3-cd)pyrene	0.433	<0.200	0.0016	4.01x10^{-6}
Total 7 PAH	**70.7**	**32.6**	**0.266**	**6.53x10^{-4}**
Acenaphthene	19.0	8.80	0.072	1.76x10^{-4}
Acenaphthylene	34.5	16.0	0.1305	3.21x10^{-4}
Anthracene	44.2	20.4	0.1664	4.09x10^{-4}
Benzo(g.h,l)perylene	0.419	<0.194	0.0016	3.89x10^{-6}
Fluoranthene	122	56.3	0.459	1.13x10^{-3}
Fluorene	40.3	18.8	0.1534	3.77x10^{-4}
Naphthalene	478	221	1.80	4.43x10^{-3}
Phenanthrene	250	115	0.938	2.30x10^{-3}
Pyrene	54.8	25.3	0.206	5.07x10^{-4}
Total 16 PAH	**1114**	**514**	**4.19**	**1.03x10^{-2}**
2-Methylnaphthalene	382	176	1.44	3.53x10^{-3}
2-Chloronaphthalene	1.74	0.804	0.0066	1.61x10^{-5}
Benzo(e)pyrene	4.27	1.98	0.0162	3.97x10^{-5}
Perylene	0.557	<0.257	0.0021	5.15x10^{-6}
Total - all PAH	**1503**	**693**	**5.65**	**1.39x10^{-2}**
D/F	**Concentration (ng/dscm)**	**Emission rate (Fg/hr)**	**g/yr**	**g/ton**
D/F TEQ[b]	0.81	374	2.8	3.4 x 10^{-6}
D/F Congeners[c]	4.9	2,257	16.7	2.1 x 10^{-5}

[a] PAH = polycyclic aromatic hydrocarbons.
[b] Based on operation for 24 hours per day for 310 days per year.
[c] D/F TEQ is the toxicity equivalent expressed relative to 2,3,7,8-TCDD.
[d] D/F congeners are those dioxins and furans that have a toxicity equivalent factor relative to 2,3,7,8-TCDD.

TABLE A-14. DISCHARGE END BAGHOUSE ("A") -- RESULTS FOR PM AND METAL HAP

Pollutant — PM	**Outlet**		**Emissions** [a]	**Emission Factor**
	lb/hr	**gr/dscf**	**tpy**	**lb/ton sinter**
PM	0.48	0.0007	1.8	0.0044
Pollutant — Metal HAP	**Outlet**		**Emissions** [a]	**Emission Factor**
	g/hr	**Fg/dscm**	**tpy**	**lb/ton sinter**
Arsenic	0.10	0.755	0.0008	2.4×10^{-6}
Beryllium	0.013	0.098	0.0001	2.6×10^{-7}
Cadmium	0.017	0.126	0.0001	3.4×10^{-7}
Cobalt	0.039	0.292	0.0003	7.8×10^{-7}
Chromium	1.2	8.92	0.0099	2.4×10^{-5}
Mercury	0.29	2.13	0.0024	5.8×10^{-6}
Manganese	8.4	62.3	0.070	1.7×10^{-4}
Nickel	1.0	7.59	0.0084	2.0×10^{-5}
Lead	1.1	7.88	0.0086	2.2×10^{-5}
Antimony	0.48	3.57	0.0040	9.6×10^{-6}
Selenium	0.43	3.21	0.0036	8.6×10^{-6}
HAP metals	13.1	96.9	0.11	2.6×10^{-4}

[a] Based on operation for 24 hours per day, 6 days per week, 52 weeks per year (7400 hours/year)

APPENDIX B

DOCUMENTATION FOR THE MACT FLOOR

This appendix documents the data analyses used to develop the MACT floor for integrated iron and steel manufacturing facilities. The data are presented and referenced, and all references are available in EPA Docket Number A-2000-44. The proposal preamble provides details on the rationale for selection of the floor and MACT, and all data summarized in the preamble are presented in detail in this appendix. Additional details on existing State limits are given in Chapter 5.

B.1 SINTER PLANT WINDBOXES

The sintering process converts fine-sized raw materials, including iron ore, coke breeze, limestone, mill scale, and flue dust, into an agglomerated product (sinter) of suitable size for charging into the blast furnace. There are nine sinter plants in the U.S.; however, only seven are currently operating. The windbox exhaust is controlled by a baghouse at four plants and by a venturi scrubber at five plants (see Table B-1).

B.1.1 PM Emission Control Performance

Useful test data on actual PM emissions are given in Table B-2 and are available for six of the nine plants, two equipped with baghouses and four equipped with venturi scrubbers. In each case, the data reflect the results of performance tests comprised of the average of three test runs, expressed in terms of total PM. Details for each run are given in Table B-3 and are plotted in Figure 1.

An initial characterization of achievable performance based on concentration (gr/dscf) suggested that baghouses perform substantially better than do scrubbers. Concentration values recorded for the two baghouses are two to nearly four times lower than those recorded for the four scrubbers. Upon closer scrutiny, the results show that much of the difference in perceived performance is due to the fact that baghouses require the addition of relatively large quantities of ambient air to cool the hot windbox exhaust gases prior to control, whereas scrubbers do not. To correct for this difference, the test results were transformed into a pounds of emissions per ton of sinter (lb/ton) format. The test results expressed in terms of the hourly mass rate were converted to annual emissions assuming 8,760 hours per operating year. The resultant annual emissions were then divided by a best estimate of annual sinter production for each plant (average for the 5-year period from 1995 through 1999). The results range from 0.26 to 0.33 lb PM/ton of sinter.

TABLE B-1. SINTER PLANTS IN THE U.S.

Plant	State	Control	PM emission limit
Inland	IN	Baghouse	0.007 gr/dscf
USS	IN	Baghouse	0.01 gr/dscf
Geneva*	UT	Baghouse	0.0122 gr/dscf; 27 lb/hr
WCI Steel	OH	Baghouse	50 lb/hr
LTV	IN	Scrubber	0.02 gr/dscf
Bethlehem	IN	Scrubber	0.277 lb/ton
Bethlehem	MD	Scrubber	0.03 gr/dscf
Wheeling-Pittsburgh*	WV	Scrubber	0.03 gr/dscf
AK Steel	OH	Scrubber	50 lb/hr

* These plants were not operating in 1999 - 2000.

TABLE B-2. TEST RESULTS FOR SINTER PLANT WINDBOX EXHAUST

Sinter plant	Control device	PM emissions (lb/ton of sinter)	Concentration (gr/dscf)	Flow rate (dscfm)
WCI Steel, Youngstown, OH	Baghouse	0.26	0.009	270,000
Ispat-Inland, East Chicago, IN	Baghouse	0.26	0.007	470,000
Bethlehem Steel, Sparrows Point, MD	Venturi scrubber	0.30	0.026	530,000
LTV Steel, East Chicago, IN	Venturi scrubber	0.31	0.017	270,000
AK Steel, Middletown, OH	Venturi scrubber	0.32	0.017	220,000
Bethlehem Steel, Burns Harbor, IN	Venturi scrubber	0.33	0.025	460,000
Average of the top five		0.29	--	–

FIGURE B-1. SINTER PLANT -- LB/TON FOR INDIVIDUAL RUNS

TABLE B-3. SUMMARY OF SINTER PLANT TEST DATA

WCI Steel[a] **(05/27/92)**[1] Method 5				
Run	**Flow, dscfm**	**gr/dscf**	**lb/hr**	**lb/ton**
Run 1	261,036	0.0072	16.07	0.20
Run 2	264,472	0.0107	24.22	0.31
Run 3	274,274	0.0084	19.72	0.25
Average	*266,594*	*0.0088*	*20.00*	*0.26*
Inland Steel[b] **(05/17/95)**[2] Method 5				
Run 1	438,188	0.0088	33.19	0.31
Run 2	484,168	0.0038	15.58	0.15
Run 3	477,703	0.0083	33.87	0.32
Average	*466,686*	*0.0070*	*27.55*	*0.26*
Bethlehem Steel, Sparrows Point[c] **(07/23/91)**[3] Method MD1005				
North stack	246,980	0.0243	51.4	--
	255,087	0.0285	62.3	--
	251,521	0.0257	55.5	--
Average	251,196	0.0262	56.4	--
South stack	278,081	0.0272	64.8	--
	280,540	0.0256	61.5	--
Average	279,311	0.0264	63.2	--
Both stacks 1	--	--	116.0	0.29
Both stacks 2	--	--	123.8	0.31
Both stacks 3	--	--	118.7	0.30
Overall	--	*0.0263*	*119.5*	*0.30*
LTV Steel -EPA test[d] **(06/25/97)**[4] Method 29				
Run 1	271,569	0.0140	34.00	0.27
Run 2	268,850	0.0170	38.00	0.30
Run 3	260,870	0.0190	43.00	0.34
Average	*267,085*	*0.0170*	*38.00*	*0.31*
AK Steel[e] **(11/22/93)**[5] Method 5				
Run 1	218,090	0.0146	27.38	0.27
Run 2	225,994	0.0139	26.88	0.27
Run 3	220,965	0.0219	41.42	0.42
Average	*221,683*	*0.0168*	*31.89*	*0.32*

Run	Flow, dscfm	gr/dscf	lb/hr	lb/ton
Bethlehem Steel, Burns Harbor[f] (03/11/92)[6] Method 5				
Run 1	458,088	0.0208	81.85	0.28
Run 2	457,195	0.0273	106.90	0.36
Run 3	477,942	0.0254	104.21	0.36
Average	*464,408*	*0.0245*	*97.65*	*0.33*

[a] Based on the average annual production of 686,828 tpy.
[b] Based on the average annual production of 935,743 tpy.
[c] Based on the average annual production of 3,460,737 tpy.
[d] Based on the average annual production of 1,103,202 tpy
[e] Based on the average annual production of 874,112 tpy.
[f] Based on the average annual production of 2,568,117 tpy.

B.1.2 Organic HAP

The windbox exhaust gas can contain appreciable quantities of organic HAP, including both volatile and semivolatile compounds. There is strong evidence that demonstrates that the quantity of organic HAP emitted is directly related to the quantity and oil content of the mill scale component of the sinter feed. United States sinter plants limit organic emissions by carefully monitoring and limiting the oil content of the sinter feed. This pollution prevention control measure is an effective method for preventing, and thus reducing, emissions of organic HAP. Two plants in Indiana have performed testing to relate oil content with emissions of VOC. The test results show a strong correlation between oil content and potential VOC emissions.

One of the organic pollutants of concern that has been related to oil content is a family of compounds called polychlorinated dibenzodioxins and furans (D/F). A 1994 paper[7] identified sinter plants in Germany as one of the most important industrial sources of D/F. Tests showed an average concentration in the windbox exhaust of 47 ng toxicity equivalent (TEQ)/m^3 and annual emissions of 122 g TEQ. The D/F emissions were attributed to high levels of oils and chlorinated organics in the waste materials recycled to the sinter plant.

EPA conducted emission tests at two representative facilities to characterize D/F emissions from U.S. sinter plants, one that uses a venturi scrubber as the windbox control device and one that uses a baghouse. The test results are presented in Appendix A. The tests were performed in 1997 on the venturi scrubber at LTV Steel in East Chicago, IN[4] and on the baghouse at WCI Steel in Youngstown, OH.[8] These plants routinely monitor the oil content of their sinter feed, which averages

0.014 percent oil at the East Chicago, IN facility and 0.025 percent oil at the Youngstown, OH facility. The average D/F concentration from three 4-hour runs at each plant ranged from 0.2 ng TEQ/m^3 at the East Chicago, IN facility to 0.8 ng TEQ/m^3 at the Youngstown, OH facility, both far below the levels reported for the German sinter plant. Assuming typical operation of each plant (310 days/yr), annual emissions would range from 0.7 to 2.8 g TEQ/yr, well below the levels indicated by the German data. Based upon emission factors derived from these test results, nationwide emissions from all U.S. sinter plants are estimated to be 26 g TEQ/yr, which corresponds to less than one percent of current estimates of the national inventory from all sources.

The operators of all seven active sinter plants as well as the two inactive plants were surveyed to obtain information on the oil content of their sinter feed. As shown in Table B-4, four of the active plants provided data that ranged in magnitude from 976 samples collected over one year (sampling about three times per day) to 14 samples collected over 14 months (monthly sampling). All four plants carefully monitor their sinter feed for oil to minimize emissions of volatile organic compounds. In addition, plants with baghouses are motivated to limit oil content due to concerns over blinding of bags and possible fire hazards. The other three active plants and the two inactive plants provided little data since none routinely monitor oil content. The four plants providing data reported long-term averages of 0.014, 0.02, 0.02 and 0.025 percent, respectively.

TABLE B-4. HISTORICAL DATA FOR FOUR PLANTS WITH LOW OIL CONTENT*

Plant	Percent oil in sinter feed		Description
	Average	Range	
LTV, IN[9]	0.014	0.001 to 0.03	Plant samples routinely three times per day; results based on 976 samples
Bethlehem, IN[10]	0.02	0.00 to 0.086	Plant samples routinely once per month; results based on 48 samples
USS, IN[11]	0.02	0.003 to 0.086	Plant samples twice per week when blending with purchased scale; results are for 69 samples taken over one year (1999)
WCI, OH[12]	0.025	0.01 to 0.046	Plant samples routinely once per month; results based on 14 samples over 14 months

* The oil content results for Ispat Inland[13] and Bethlehem Steel (MD)[14] were not considered representative because they were collected over a short period of time for special purposes. No data were available for AK Steel, Geneva Steel, and Wheeling-Pittsburgh Steel.

B.2 SINTER PLANT DISCHARGE END

The sinter plant discharge end is comprised of sinter breakers (crushers), hot screens, conveyors, and transfer points that are designed to separate undersize sinter and to transfer the hot sinter to the cooler. In most cases, these discharge end operations are housed in a building. Emissions are usually controlled by local hooding and ventilation to one or more baghouses or wet scrubbers. Seven plants use baghouses and two plants use wet scrubbers. Details are given in Table B-5.

Existing State regulations include both building opacity standards to limit releases of fugitive emissions (those escaping capture) and PM emission standards assigned to control devices. Five of the seven operating sinter plants are subject to a building opacity limit. One plant is subject to a 10 percent limit (6-minute average), and four plants are subject to 20 percent limits (6-minute average). The PM limits for control devices vary substantially from plant to plant both in terms of format and numerical values. Four plants have concentration limits for total PM (0.01, 0.02, 0.02, and 0.03 gr/dscf), one has concentration limits for PM_{10}, and three have mass rate limits (42.9, 50, and 50 lb/hr).

Credible source test data on actual emissions were available from only one plant -- the refurbished sinter plant in Youngstown, Ohio (Table B-6). Captured emissions from the discharge end are ventilated to a relatively new baghouse (1991) for control. No data were available on the opacity of fugitive emissions that escape capture from the discharge end.

As noted above, five plants are subject to standards that limit the opacity of visible emissions released from the discharge end building (Table B-7). These range from 10 percent (one plant) to 20 percent (four plants) with a median value of 20 percent opacity based on a 6-minute average.

For control devices, the top five most stringent existing emission limits for total PM are shown in Table B-8. These include the four concentration limits cited above and a fifth value derived from the lowest mass rate limit to which a plant is subject (42.9 lb/hr), which is equivalent to 0.02 gr/dscf. The average of these five values is 0.02 gr/dscf.

TABLE B-5 . CONTROLS AND EMISSION LIMITS FOR THE DISCHARGE END[a]

Plant	Control	Emission Points	Emission limit	Flow Rate (dscfm)	Best estimate of PM (gr/dscf)
AK Steel, OH	Baghouse	discharge, crusher, hot screen, cooler	50.0 lb/hr	112,000	0.05
Bethlehem, MD	Baghouse	discharge, crusher, hot screen, cold screen	0.03 gr/dscf	340,000	0.03
Bethlehem, IN	Baghouse	discharge, crusher, hot screen	42.9 lb/hr	212,000	0.02
Geneva, UT	Rotoclones (scrubbers)	discharge	0.0096 gr/dscf PM_{10}	105,000	b
Ispat-Inland, IN	Baghouse	discharge, crusher, hot screen, ½ cooler	0.01 gr/dscf	122,000	0.01
LTV, IN	Scrubber	discharge	0.02 gr/dscf	100,000	0.02
USX Gary, IN	Baghouse 1	discharge, crusher	0.02 gr/dscf PM_{10}	161,322	b
	Baghouse 2	hot and cold screens, conveyors	0.0052 gr/dscf PM_{10}	180,000	b
WCI, OH	BaghouseA	discharge, crusher, hot screen, cold screen	50.0 lb/hr	141,470	0.04
Wheeling-Pittsburgh, WV	Baghouse	discharge	0.02 gr/dscf	32,900	0.02

[a] Compiled from 1993 industry survey

[b] No equivalent PM limit could be estimated because the existing limit is expressed in terms of PM_{10}.

TABLE B-6. SUMMARY OF EMISSIONS DATA FOR THE DISCHARGE END[15]

Plant	gr/dscf	lb/hr
WCI - baghouse for discharge, crusher, hot screen, cold screen (1991)	0.0059	7.5
	0.0053	6.3
	0.0059	7.0
average	0.0057	7.0

TABLE B-7. DISCHARGE END FUGITIVE EMISSIONS: TOP FIVE LIMITATIONS

Plant	Limit for sinter building and fugitives
Bethlehem, Sparrows Point, MD	10% (6-min average)
Ispat-Inland, East Chicago, IN	20% (6-min average)
LTV Steel, East Chicago, IN	20% (6-min average)
USX Steel, Gary, IN	20% (6-min average)
Geneva Steel, Provo, UT	20% (6-min average)
Median	**20% (6-min average)**

TABLE B-8. DISCHARGE END CONTROL DEVICE: TOP FIVE LIMITATIONS

Plant	gr/dscf
Ispat-Inland, East Chicago, IN	0.01
Wheeling-Pittsburgh	0.02
LTV Steel, East Chicago, IN	0.02
Bethlehem, IN	0.02*
Bethlehem, MD	0.03
Average	**0.02**

*Estimated from lb/hr limit and volumetric flowrate.

B.3 SINTER PLANT COOLER

Sinter plant coolers are large diameter circular tables through which ambient air is drawn to cool the hot sinter after screening. Seven plants operate sinter coolers to cool the sinter product prior to storage. Two plants that are not currently operating have no cooler and stockpile hot sinter directly. Of the seven plants with coolers, three vent directly to the atmosphere, one vents to a cyclone, two vent to a baghouse, and one vents half of the cooler exhaust to a baghouse with the remainder vented directly to the atmosphere. Five plants have emission limits expressed as concentration or mass rate while two plants have no emission limits (see Table B-9).

TABLE B-9. SINTER COOLER DESCRIPTIONS AND LIMITS[a]

Plant	Description	Limit
Ispat-Inland	Baghouse controls the discharge, scrubber, hot screen and ½ of cooler (one quadrant where the sinter is transferred to the cooler and one quadrant where it is removed); the other half is covered and vents through an uncontrolled stack. 20 minute residence time. Baghouse flow is 120,000 dscfm.	0.01 gr/dscf (for controlled portion)
WCI	Baghouse with forced air at 189,000 dscfm	42.9 lb/hr (about 0.03 gr/dscf)
Bethlehem, Sparrows Point	Cyclone at 320,000 dscfm and 0.02 gr/dscf; 90 to 120 minute residence time	0.03 gr/dscf
USS, Gary	3 coolers, uncontrolled; with hood and stack; 360,000 dscfm each	0.03 gr/dscf
AK Steel, OH	Baghouse controls discharge, crusher, hot screen and cooler; flow of 112,000 dscfm	50 lb/hr (about 0.05 gr/dscf)
Bethlehem, Burns Harbor	Uncontrolled, with hood over cooler; 30-ft diameter and 575,000 dscfm; 60 minute residence time	no limit
LTV, East Chicago	Uncontrolled; 60-ft diameter and 320,000 dscfm; 100 minute residence time	no limit
Geneva Steel	**These plants do not have coolers**. Sinter is transferred from the hot screen to a storage pile and cooled by ambient air. Wheeling-Pittsburgh also uses water sprays.	

Wheeling-Pittsburgh	

[a] Compiled from 1993 industry survey

Information on actual releases is limited to one source test of controlled emissions from the cooler located at Youngstown, Ohio that is equipped with a baghouse (Table B-10).

TABLE B-10. SUMMARY OF EMISSIONS DATA FOR THE SINTER COOLER[16]

Description	Run	gr/dscf	lb/hr
WCI - baghouse (1991)	1	0.018	29
	2	0.0050	8.3
	3	0.0052	8.0
	average	0.0093	15

As shown in Table B-9, three plants have concentration limits (0.01, 0.03, and 0.03 gr/dscf), and two plants have mass rate limits. The mass rates in lb/hr were converted to equivalent concentration limits in gr/dscf based on the volumetric flow rate through the coolers. The two mass rate limits resulted in equivalent concentration values of 0.03 and 0.05 gr/dscf. The average of the five concentration limits shown in Table B-11 is 0.03 gr/dscf.

TABLE B-11. SINTER COOLER: TOP FIVE LIMITATIONS

Plant	gr/dscf
Ispat-Inland, East Chicago, IN	0.01
WCI	0.03*
Bethlehem, MD	0.03
USS Gary	0.03
AK Steel, OH	0.05*
Average	**0.03**

* Estimated from the lb/hr limit and volumetric flowrate.

B.4 BLAST FURNACE CASTHOUSE

The casthouse is a building or structure that encloses the section of the blast furnace where hot metal and slag are tapped from the furnace. The emissions from the blast furnace casthouse are fugitive emissions that escape through the roof monitor and other building openings during tapping. The emissions are primarily metal oxide fumes that are formed when air contacts the surface of the molten metal. Factors affecting these emissions include the duration of tapping, the exposed surface area of metal and slag, and the presence or absence of runner covers and flame suppression, which reduce contact with air.

These emissions are controlled in one of two fundamentally different ways, flame suppression or conventional ventilation practices and control. Flame suppression consists of blowing natural gas over the iron runners and torpedo cars. The combustion of the gas consumes oxygen, which retards (suppresses) the formation of emissions. Ventilation practices employed include the use of localized hooding and ventilation applied at the iron trough and iron and slag runners. Alternatively, the casthouse may be totally enclosed and evacuated. Eighteen of the 39 blast furnaces have capture and control systems, 16 are controlled by baghouses, and two are controlled by wet scrubbers (see Table B-12).

As a means for limiting fugitive emissions of PM from the casthouse during hot metal tapping, most States have developed visible emission standards that limit the opacity of emissions discharged from the casthouse roof monitor or other openings. These limits are given in Table B-12. The most common limit is 20 percent (6-minute average), which is applied to 24 of the 39 casthouses. States also apply particulate limits on gases discharged from control devices used to capture tapping emissions (see Table B-13). The most common form is a concentration limit, typically on the order of 0.01 gr/dscf.

As shown in Table B-14, the most stringent opacity limit is 15 percent (6-minute average) and is applied to two casthouses. The next most stringent limit is 20 percent (6-minute average), which is applied to 24 casthouses.

TABLE B-12. CASTHOUSE EMISSION CONTROLS AND OPACITY LIMITS

Plant	Furnace	Casthouse control	Casthouse opacity limit
Acme Steel, IL	A	Flame suppression, covered runners	20%, 6 minute average
AK Steel, KY	Amanda	Flame suppression, covered runners	20%, 6 minute average
AK Steel, OH	3	Flame suppression	Covered under a "bubble"
Bethlehem Steel, IN	C D	Flame suppression, inert suppression Flame suppression, inert suppression	No opacity limit No opacity limit
Bethlehem Steel, MD	L	Baghouse, covered runners	5%, 6 minute average, 20% drilling, O_2 lance and mudding
Geneva Steel, UT	1 2 3	Flame suppression, covered runners Flame suppression, covered runners Flame suppression, covered runners	For all: 20%, except for any aggregate of 3 min. (12 readings) in any 60 min.
Gulf States Steel, AL	1	No controls	
Ispat-Inland Steel, IN	7 5 6	Baghouse Scrubber Scrubber	15%, 6 minute average 20%, 6 minute average 20%, 6 minute average
LTV Steel, OH	C1 C5 C6	Flame suppression, covered runners Flame suppression, covered runners Flame suppression, covered runners	20%, 6 minute average 15%, 6 min.avg, exceptions to 20% 20%, 6 minute average
LTV Steel, IN	H3 H4	Flame suppression, covered runners Baghouse, flame suppression, covered runners	20%, 6 minute average 20%, 6 minute average
National Steel, IL	A B	Baghouse, covered runners Baghouse, covered runners	20%, 6 minute average 20%, 6 minute average
National Steel, MI	A B D	Baghouse Baghouse Baghouse	20%, 6 minute average 20%, 6 minute average 20%, 6 minute average
Rouge Steel, MI	B C	Flame suppression, covered runners Flame suppression, covered runners	20%, 6 minute average 20%, 6 minute average
USX, PA	1 3	Baghouse Baghouse	For both: Not to equal or exceed 20% except for 12 readings per hr.
USX, AL	8	Baghouse, covered runners	20%, 6 minute average
USX, IN	4 6 8 13	Flame suppression Flame suppression Flame suppression Baghouse, covered runners	20%, 6 minute average 20%, 6 minute average 20%, 6 minute average 20%, 6 minute average
USS/Kobe Steel, OH	3 4	Baghouse, covered runners Flame suppression	15%, 6 minute average 20%, 6 minute average
WCI Steel, OH	1	Baghouse	20%, 6 minute average

Plant	Furnace	Casthouse control	Casthouse opacity limit
Weirton Steel, WV	1 4	Baghouse, flame suppression, covered runners Flame suppression, covered runners	20%, except 40% for 5 min/hour 20%, except 40% for 5 min/hour
Wheeling Pittsburgh Steel, OH	1 5	Flame suppression, covered runners Baghouse, flame suppression, covered runners	20%, 6 minute average 5% to 20%

TABLE B-13. EMISSION LIMITS FOR CASTHOUSE CONTROL DEVICE

Plant	Furnace	Control	Capture Points	Emission Limit
Bethlehem Steel, MD	L	Baghouse	Evacuated runner covers & hoods	0.03 gr/dscf
Ispat-Inland, IN	7	Baghouse 1 Baghouse 2	Canopy hood Runners	0.003 gr/dscf 0.011 gr/dscf
LTV Steel, IN	H4	Baghouse	Hood over tilting spout & iron trough	No limit
National Steel, IL	A B	Baghouse 1 Baghouse 2	Suspended hood 6 air hoods, 3 at each furnace with damper control	0.01 gr/dscf 0.01 gr/dscf
National Steel, MI	A B D	Baghouse Baghouse Baghouse	Hoods over trough & pouring spouts — each furnace	0.0075 gr/dscf 0.02 lb/1000 lb gas 0.0052 gr/dscf
USX, PA	1 3	Baghouse Baghouse	Air curtain	No limit No limit
USS/Kobe, OH	3	Baghouse	Evacuated runner covers & hoods	0.0052 gr/dscf
WCI Steel, OH	1	Baghouse		0.03 lb/ton
Wheeling-Pittsburgh, OH	5	Baghouse	Trough hood, covered runners, hood at tilting runners	0.31 lb/hr; proposed PM_{10} limit of 5.93 lb/hr

TABLE B-14. BLAST FURNACE CASTHOUSE: TOP FIVE LIMITATIONS

Plant	Furnace	Opacity limit
Ispat-Inland, East Chicago, IN	7	15% (6-min average)
USS/Kobe, Lorain, OH	3	15% (6-min average)
WCI Steel, Warren, OH	1	20% (6-min average)
Acme, Riverdale, IL	A	20% (6-min average)
AK Steel, KY (and several others)	A	20% (6-min average)
Median		**20% (6-min average)**

As shown in Table B-12, there are 18 casthouses equipped with hooding and ventilation equipment to limit fugitive emissions. Sixteen use a baghouse for the control of captured emissions. Industry survey information on the baghouses indicate they are similar in design and performance (Table B-15). Most are pulse jet baghouses with air to cloth ratios of around 4 acfm/ft^2.

Performance test data were available for four of the 16 baghouses and are presented in Figure B-2 and Table B-16. The database includes a total of eight source tests; four tests at one facility, two tests at another facility, and single tests at the two other facilities. Each performance test is comprised of three individual test runs. The three run averages for each of the eight tests range from 0.002 to 0.009 gr/dscf. Results from individual runs range from 0.001 to 0.009 gr/dscf. The highest emitting unit is the one at National Steel in Granite City, IL facility for which there are four independent performance tests. The performance tests range from 0.006 to 0.009 gr/dscf with individual runs ranging from 0.003 to 0.009 gr/dscf. Three tests were conducted in 1988 and one in 1985, and all tests met the facility's State limit of 0.01 gr/dscf.

FIGURE B-2. TEST RESULTS FOR BAGHOUSES IN BLAST FURNACE CASTHOUSES

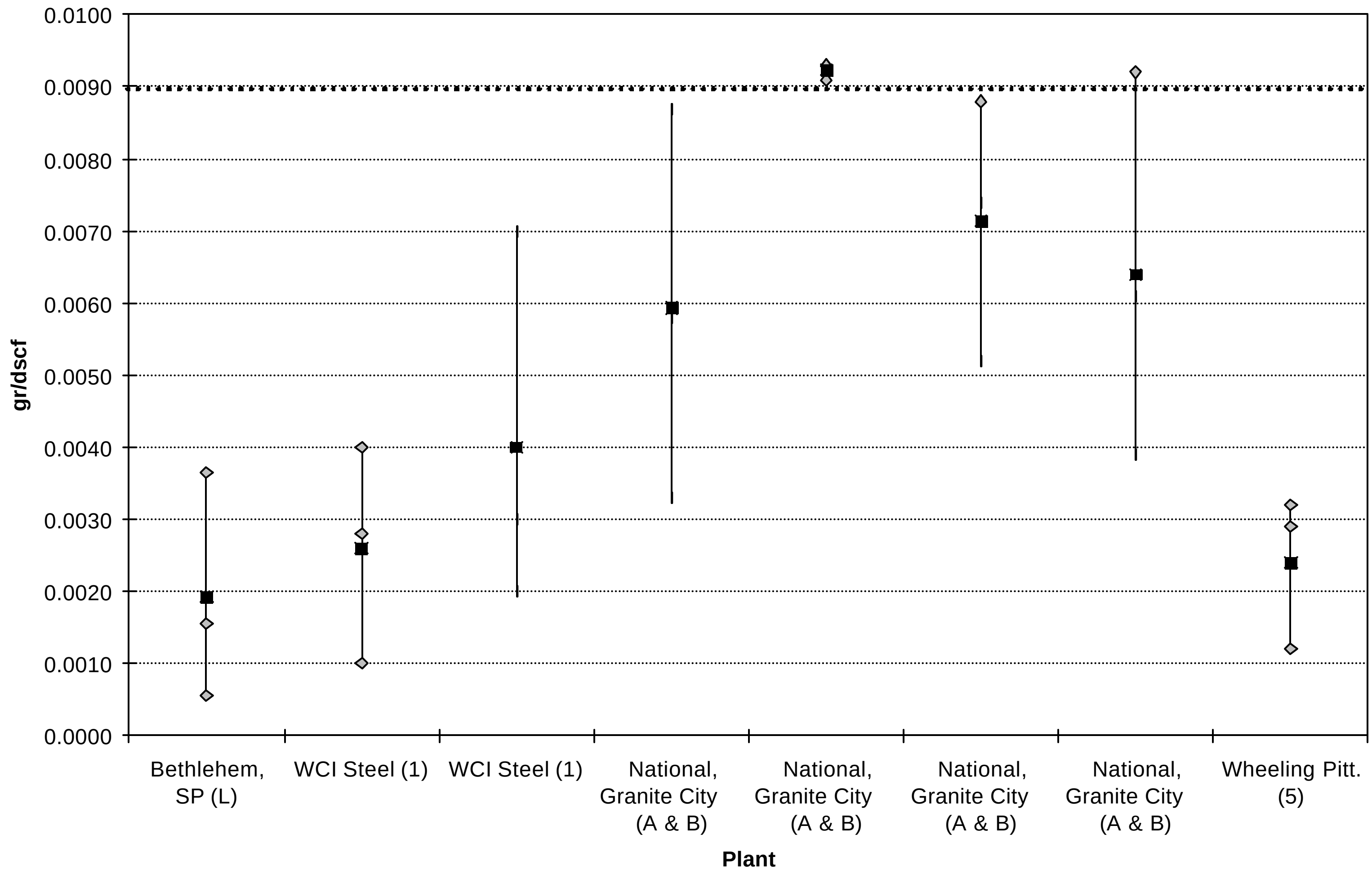

TABLE B- 15. CONTROL DEVICE PARAMETERS[a]

Furnaces with baghouses									
Plant	**State**	**Capacity (tpy)**	**Furnace**	**Flow (dscfm)**	**Air/cloth ratio (acfm/ft^2)**	**Δp (in. water)**	**Cleaning**	**Filter material**	**Location**
Bethlehem Steel	MD	3,450,000	1	420,000 acfm @170-200	4.0	8	pulse jet	polyester	
Inland Steel	IN	4,000,000	7	-	-	-	-	-	Runner covers
				250,000-275,000	4.2	7	pulse jet	polyester	Canopies over 4 notches
LTV Steel	IN	1,971,000	H4	220,000	4.4	7	pulse jet	polyester	Iron trough & tilting spout
National Steel	IL	2,372,500	A B	369,000	6.88	14	pulse jet	polyester	"A" & "B" taphole
				100,000 acfm	5.82	10	shaker	polyester	Torpedo cars
National Steel	MI	2,000,000	A	400,000	5.15	3-8	reverse air	polyester needle felt	Iron trough/ tilting spout
		900,000	B	170,000	9.0	4-8	pulse jet	polyester felt	
		2,000,000	D	275,000	5.38	3-6	pulse jet	polyester woven	
USX Steel	PA	1,200,000	1	140,000	-	3-12	-	-	Casthouse
		1,100,000	3	140,000	-	3-12	-	-	
USX Steel	IN	3,440,000	13	600,000 acfm	4.8	<8	pulse jet	polyester felt	Casthouse
USS/Kobe	OH	1,300,000	3	224,000	6.28	3-10	pulse jet	polyester	Casthouse

TABLE B- 15. CONTROL DEVICE PARAMETERS (continued)

Furnaces with baghouses

Plant	State	Capacity (tpy)	Furnace	Flow (dscfm)	Air/cloth ratio (acfm/ft^2)	)p (in. water)	Cleaning	Filter material	Location
WCI Steel	OH	1,500,000	1	125,000	1.98-2.23	-	shaker	-	Casthouse
Wheeling-Pittsburgh	OH	1,682,000	5	103,200	4.5	4-6	pulse jet	polyester felt	

Furnaces with wet scrubbers

Plant	State	Capacity (tpy)	Furnace	Flow (dscfm)	L/G (gal/1000 acf)	)p (in. water)	Scrubber type	Demister	Location
Inland Steel	IN	1,253,000	5	40,000 acfm @250EF x(2)	10.0	24-30	Multi-element fixed throat vertical rod type scrubber (2 scrubbers)	vanes in tank	Local hoods over notch, iron and slag runners, and pugh ladles
		1,253,000	6	40,000 acfm @250EF	10.0	35	Multi-element fixed throat (1 scrubber)		

[a] Compiled from 1993 industry survey

air/cloth ratio = ratio of air flow to cloth area in actual cubic feet per minute per square foot of cloth
)p = pressure drop in inches of water

TABLE B-16. PM DATA FOR CASTHOUSE CONTROL DEVICE

National Steel, Granite City (A & B)[17]			
24 August 1988	dscfm	gr/dscf	lb/hr
Run 1	333,787	0.0087	25.00
Run 2	324,833	0.0058	16.23
Run 3	333,206	0.0033	9.41
average	330,609	0.0059	16.88
4 May 1988	dscfm	gr/dscf	lb/hr
Run 1		0.0093	25.68
Run 2		0.0093	24.49
Run 3		0.0091	25.21
average		0.0093	25.13
23 February 1988	dscfm	gr/dscf	lb/hr
Run 1		0.0074	21.14
Run 2		0.0088	26.06
Run 3		0.0052	14.93
average		0.0071	20.71
4 January 1985	dscfm	gr/dscf	lb/hr
Run 1	340,906	0.0092	
Run 2	360,747	0.0061	
Run 3	373,219	0.0039	
average	358,291	0.0064	
WCI Steel[18]			
29 May 1996	dscfm	gr/dscf	lb/hr
Run 1	268,200	0.0030	7.03
Run 2	266,220	0.0020	5.04
Run 3	264,960	0.0070	15.64
average	266,460	0.0040	9.24
17 November 1992	dscfm	gr/dscf	lb/hr
Run 1		0.0040	7.66
Run 2		0.0010	1.45
Run 3		0.0028	4.45
average	193,700	0.0026	4.52
Wheeling Pittsburgh (5)[19]			
August 1999	dscfm	gr/dscf	lb/hr
Run 1	102,840	0.0029	2.56

Run 2	106,120	0.0012	1.09
Run 3	100,640	0.0032	2.76
average	103,200	0.0024	2.14
Bethlehem, SP "L" Furnace[20]			
18 June 1996	dscfm	gr/dscf	lb/hr
Run 1	140,016	0.0037	4.38
Run 2	140,474	0.0006	0.67
Run 3	140,897	0.0016	1.87
average	140,462	0.0019	2.30

B.5 BOPF PRIMARY EMISSIONS

Primary emissions from the BOPF refer to the particulate emissions generated during the steel production cycle which are captured and controlled by the furnace's primary emission control system. The majority of the emissions occur during the oxygen blow. The oxygen blow is the period in the steel production cycle when oxygen is lanced or injected into the vessel. Some shops operate open hood furnaces and others use closed hood systems. Open and closed hood vessels are very different in terms of operation, pollutant loading, and emissions. Open hood systems are characterized by very high primary exhaust air flowrates due to the large quantities of combustion air introduced at the furnace mouth to support CO combustion. In contrast, closed hood systems, which include hoods that are tightly fitted to the vessel to suppress CO combustion, are characterized by much lower exhaust air flowrates. Typical flowrates for open hood shops are 200,000 to 500,000 acfm, while closed hood designs are usually less than 100,000 acfm.

There are 50 BOPF located in 23 BOPF shops. The 50 BOPF include 34 furnaces with open hood systems at 16 shops and 16 furnaces with closed hood systems at 8 shops. All of the BOPF have capture and control systems for the primary emissions. For the open hood systems, 8 shops are controlled by venturi scrubbers and 8 shops are controlled by electrostatic precipitators (ESPs). All 8 of the closed hood shops are controlled by venturi scrubbers. Each shop is subject to existing State limits with a wide variety of formats, including concentration limits in gr/dscf and lb/1,000 lb gas for PM or PM_{10}, mass emission rate limits in lb/hr, and process weighted limits in lb/ton of steel. In addition, the emission test period required for compliance with the existing State limits varies from testing over the steel production cycle, only during the oxygen blow, for 1-hour runs, and for 2-hour runs. Emission limits are summarized in Tables B-17 and B-18.

TABLE B-17. EMISSION LIMITS FOR PRIMARY CONTROL -- OPEN HOOD

Open Hood BOPF Shops			
Plant	**State**	**Control**	**Emission Limit**
Acme Steel	IL	ESP	0.028 gr/dscf
Bethlehem Steel[a]	IN	Scrubber	0.09 lb/ton liquid steel
Bethlehem Steel	MD	Scrubber	0.03 gr/dscf
Gulf States Steel	AL	ESP	--
Inland No. 4	IN	Scrubber	0.187 lb/ton
LTV Steel	IN	ESP	0.018 gr/dscf PM_{10}
LTV No. 1 Shop	OH	ESP	39.8 lb/hr
National Steel	IL	ESP	60.0 lb/hr or 0.255 lb/ton
National Steel	MI	ESP	0.057 lb/1000 lb gas
Rouge Steel	MI	ESP	
USX Gary (BOPF)	IN	Scrubber	0.02 gr/dscf PM_{10}
USX Gary(Q-BOP)	IN	Scrubber	0.02 gr/dscf PM_{10}
USX Edgar Thomson	PA	Scrubber	Process rate
WCI Steel	OH	ESP	62.90 lb/hr
Weirton Steel	WV	Scrubber	0.03 gr/dscf
Wheeling-Pittsburgh	OH	Scrubber	21.40 lb/hr; 7.09 lb/hr PM_{10} (pending)

[a] Two furnaces are open hood and one is closed hood.

For the data analysis, the control performance for open and closed hood furnaces was evaluated separately due to the operational differences and volumetric air flowrates between the two designs as discussed previously. This is consistent with the development of separate standards for open and closed hood vessels for the NSPS in 40 CFR Part 60, Subpart N. The NSPS for open hood

BOPF is a PM limit of 0.022 gr/dscf and for closed hood the PM standard is 0.030 gr/dscf. For both types of furnaces the NSPS PM limit is measured during the primary oxygen blow.

TABLE B-18. EMISSION LIMITS FOR PRIMARY CONTROL -- CLOSED HOOD

Closed Hood BOPF Shops			
Plant	**State**	**Control**	**Emission Limit**
AK Steel	KY	Scrubber	0.03 gr/dscf
AK Steel	OH	Scrubber	114 lb/hr[1]
Geneva Steel	UT	Scrubber	0.02 gr/dscf PM_{10} [2]
Inland No. 2	IN	Scrubber	0.058 lb/ton
LTV No. 2	OH	Scrubber	15 lb/hr (for each of 2 stacks)
USS/Kobe Steel	OH	Scrubber	45.0 lb/hr
USX Fairfield	AL	Scrubber	0.022 gr/dscf;[3] process rate[4]

[1] Both vessels combined
[2] During oxygen blow
[3] Furnace C, subject to NSPS, Subpart NN, which is 0.022 gr/dscf for closed hood shops
[4] Furnaces X & U

B.5.1 Open Hood BOPF

Control devices applied to primary emissions at open hood shops include both ESP and venturi scrubbers (see Table B-19). Source test data and design information are available for seven of the 16 open hood shops, five with ESP and two with venturi scrubbers. The test data indicate that the ESP perform better than the venturi scrubbers. All the test data (based on charge-to-tap measurements) for the ESP are less than 0.019 gr/dscf (see Figure B-3 and Table B-20). All of the ESP are similar in design and operation. All have three to five fields in series and operate at specific collection areas greater than 300 ft^2/1,000 cfm. Data for the two plants with venturi scrubbers, operating at pressure drops of 25 to 35 inches of water, averaged 0.025 and 0.035 gr/dscf, respectively.

TABLE B-19. OPERATING PARAMETERS OF OPEN HOOD PRIMARY CONTROL

Wet Scrubber Control Technology

Plant	State	Capacity (million tpy)	Flow (dscfm)	L/G (gal/1,000 acf)	Δp (in. water)
Bethlehem	IN	5.4	113,200[1] x 3	20	55
Bethlehem	MD	4.0	600,000[1]	8	50
Inland (#4)	IN	2.7	310,000-380,000	1.0	25
USS Steel (BOPF)	IN	2.9	268,000 x 3	13.1	70-75
USS Steel (Q-BOP)	IN	4.0	267,000 x 3	34.7	70
USS Steel	PA	2.8	174,000 x 2	--	68-76
Weirton Steel	WV	3.2	280,000	--	50[2]
Wheeling-Pittsburgh	OH	2.95	210,000	10	50

ESP Control Technology

Plant	State	Capacity (million tpy)	Flow (dscfm)	Collection plate area (ft^2)	No. of fields in series	SCA (ft^2/1,000 cfm)[3]
Acme Steel	IL	1.3	288,000	92,000	3	320
Gulf States	AL	1.3	327,000	150,000	4 (2 sets)	460
LTV Steel	IN	4.2	847,000[1]	650,000	5	770
LTV (#1)	OH	3.3	550,000	255,000	4	560
National	IL	3.6	330,000	--	4	--
National	MI	4.1	500,000[1]	80,200	4	160
Rouge Steel	MI	3.3	500,000	--	4	--
WCI Steel	OH	1.7	440,000	114,000	6	260

[1] acfm
[2] Scrubber upgrade increased the pressure drop from 35 to 50 inches.
[3] SCA = specific collection area

FIGURE B-3. OPEN HOOD SHOPS WITH ESPs (charge to tap testing)

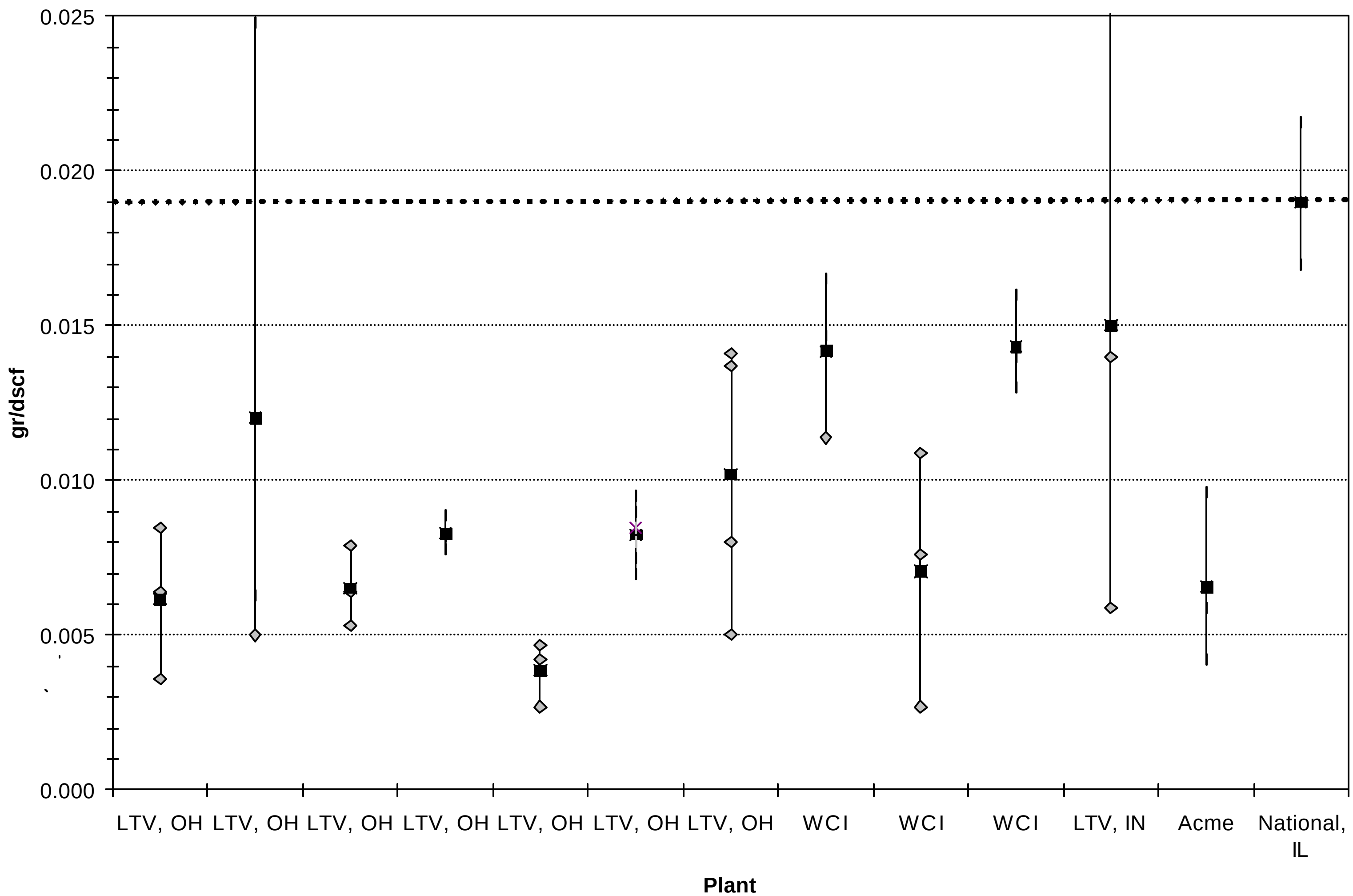

TABLE B-20. BOPF TEST DATA: OPEN HOOD SHOPS WITH ESP AND CHARGE-TO-TAP TESTING

Acme Steel[21]			
November 1998	dscfm	gr/dscf	lb/hr
Run 1	129,149	0.0059	6.49
Run 2	139,031	0.0096	11.43
Run 3	140,072	0.0042	5.02
average	136,084	0.0066	7.65
LTV, Cleveland #1 BOPF shop[22]			
26 October 1989	dscfm	gr/dscf	lb/hr
Run 1	510,238	0.0085	37.10
Run 2	531,430	0.0064	29.34
Run 3	580,559	0.0036	17.78
average	540,742	0.0062	28.07
LTV Cleveland #1 BOPF shop[23]			
20 November 1986	dscfm	gr/dscf	lb/hr
Run 1	486,825	0.0248	104.46
Run 2	493,755	0.0063	26.97
Run 3	504,465	0.0050	21.49
average	495,015	0.0120	50.97
LTV Cleveland #1 BOPF shop[24]			
25 November 1985	dscfm	gr/dscf	lb/hr
Run 1	544,252	0.0079	36.78
Run 2	573,541	0.0053	26.28
Run 3	531,181	0.0064	29.40
average	549,658	0.0065	30.82
LTV Cleveland #1 BOPF shop[25]			
8 April 1985	dscfm	gr/dscf	lb/hr
Run 1	503,922	0.0089	34.81
Run 2	466,345	0.0082	30.36
Run 3	463,267	0.0078	26.95
average	477,845	0.0083	30.71

TABLE B-20. BOPF TEST DATA: OPEN HOOD SHOPS WITH ESP AND CHARGE-TO-TAP TESTING

LTV Cleveland #1 BOPF shop[26, 27]			
18 October 1984	dscfm	gr/dscf	lb/hr
Run 1	337,400	0.0047	13.51
Run 2	348,300	0.0042	12.40
Run 3	356,700	0.0027	8.16
average	347,467	0.0038	11.36
LTV Cleveland #1 BOPF shop[28]			
Particulate emissions with 7 of 8 sections of ESP			
3 January 1983	dscfm	gr/dscf	lb/hr
Run 1	384,000	0.0090	30.20
Run 2	388,000	0.0095	32.00
Run 3	372,800	0.0070	23.70
Run 4	388,300	0.0080	25.80
Run 5	363,700	0.0085	24.90
Run 6	334,800	0.0080	23.60
Run 7	347,400	0.0085	19.90
Run 8	378,800	0.0075	24.10
average	369,725	0.0083	25.53
LTV Cleveland #1 BOPF shop[29]			
9 December 1982	dscfm	gr/dscf	lb/hr
Run 1	426,000	0.0136	48.60
Run 2	439,200	0.0141	52.60
Run 3	441,400	0.0080	29.50
Run 4	425,900	0.0050	17.90
average	433,125	0.0102	37.15
LTV, East Chicago[30]			
20 August 1992	dscfm	gr/dscf	lb/hr
Run 1	490,329	0.0059	24.83
Run 2	433,827	0.0251	93.26
Run 3	450,196	0.0140	54.05
average	458,117	0.0150	57.38

National Steel, Granite City[31]			
30 March 1989	dscfm	gr/dscf	lb/hr
Run 1	349,127	0.0216	64.64
Run 2	332,540	0.0190	54.16
Run 3	337,902	0.0170	49.17
average	339,856	0.0192	55.99
WCI Steel[18, 32, 33]			
12 April 1996	dscfm	gr/dscf	lb/hr
Run 1	460,970	0.0130	52.07
Run 2	436,470	0.0140	52.28
Run 3	423,450	0.0160	56.34
average	440,297	0.0143	53.56
25 August 1993	dscfm	gr/dscf	lb/hr
Run 1	380,200	0.0165	53.91
Run 2	391,552	0.0114	38.27
Run 3	413,012	0.0147	52.05
average	394,921	0.0142	48.08
17 May 1990	dscfm	gr/dscf	lb/hr
Run 1	371,888	0.0076	24.31
Run 2	372,305	0.0109	34.91
Run 3	368,611	0.0027	8.41
average	370,935	0.0071	22.54

B.5.2 Closed Hood BOPF

All 16 of the furnaces at the 8 closed hood shops use high-energy venturi scrubbers. Closed hood systems produce an exhaust gas high in CO which precludes the use of other types of control devices (such as baghouses or ESP) due to potential explosion or fire hazards. Information on the design and operation of these scrubbers shown in Table B-21 were obtained through an industry survey. These scrubbers operate at a pressure drop of 50 inches of water or more, and most have liquid-to-gas ratios greater than 10 gallons per thousand cubic feet of gas.

Recent test data were available for only one of the eight closed hood shops with testing during the oxygen blow. However, performance test data were available from five other furnaces that were used to develop the NSPS. All tests include three test runs and all were performed only during the oxygen blow. Each of these plants use a high-energy venturi scrubber with a pressure drop of 50 inches of water or more. The three run averages for each of the six tests range from 0.015 to 0.024 gr/dscf. Results from individual runs range from 0.013 to 0.031 gr/dscf. The data are presented in Figure B-4 and Table B-22.

TABLE B-21. OPERATING PARAMETERS OF CLOSED HOOD VENTURI SCRUBBERS

Plant	State	Capacity (million tpy)	Vessel	Flow (dscfm)	L/G (gal/1,000 acf)	)p (in. water)
AK Steel	KY	2.17	1	78,000	11.5	60
			2	78,000	11.5	60
AK Steel	OH	2.71	15	40,000	2.9	45-50
			16	51,000	2.6	40-50
Bethlehem Steel	IN	--	3	197,000[a]	21	55
Geneva (Q-BOP)	UT	2.5	1	78,300	--	70-80
			2	77,300	--	70-80
Inland Steel (No. 2)	IN	2.5	1	50,000-60,000	10.0	55
			2	50,000-60,000	10.0	55
LTV Steel (No. 2)	OH	4.38	1	55,000	--	--
			2	55,000	--	--
USS/Kobe	OH	2.6	L	58,000	--	--
			N	59,000	--	--
US Steel	AL	2.2	U	--	--	60-95
			X	76,000	--	51-92
			C	76,000	--	59-96

[a]acfm

FIGURE B-4. CLOSED HOOD BOPF TEST DATA (all for the oxygen blow)

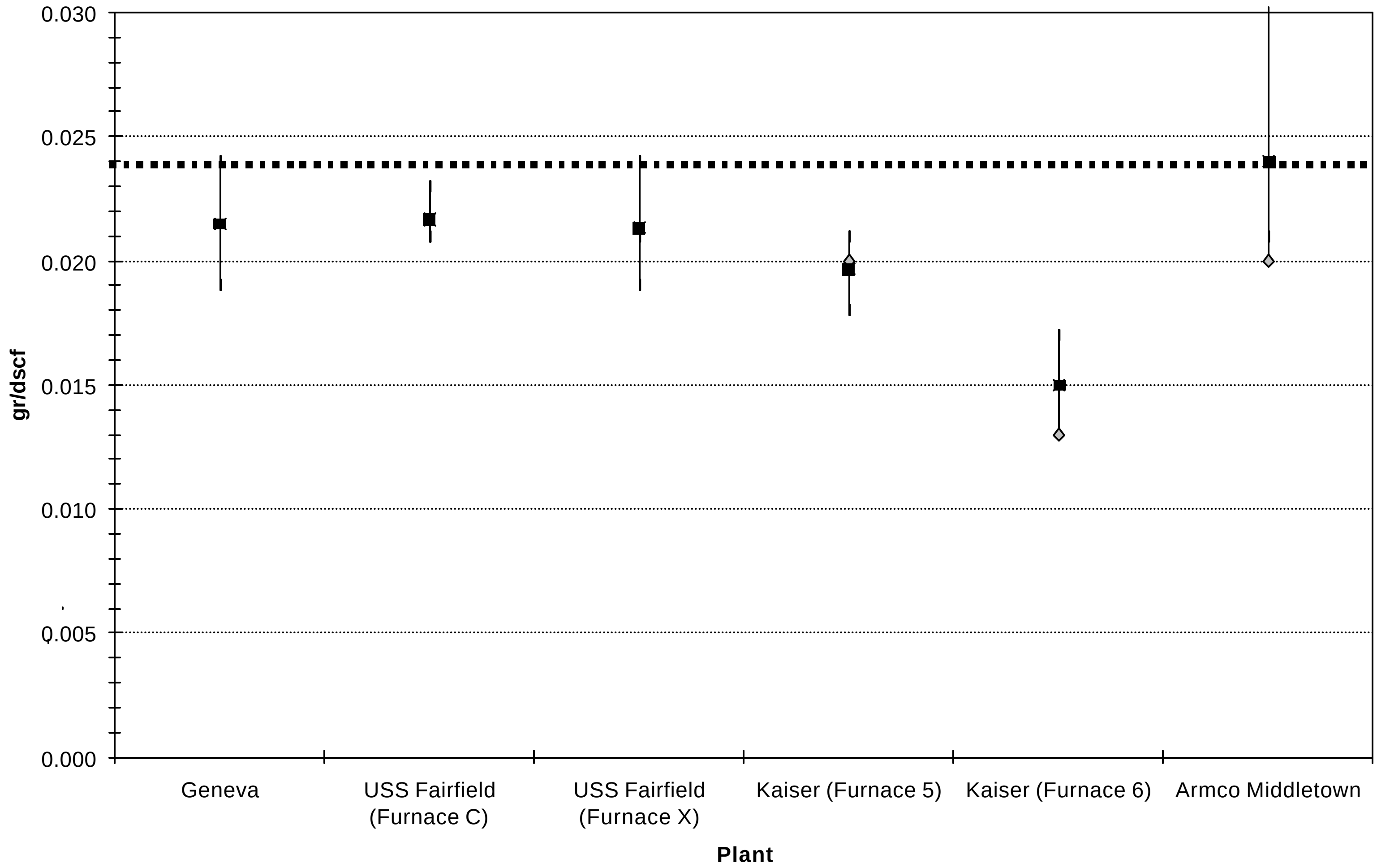

TABLE B-22. BOPF TEST DATA: CLOSED HOOD SHOPS WITH VENTURI SCRUBBERS AND TESTING DURING THE OXYGEN BLOW

Geneva Steel[34]			
16 June 1992	dscfm	gr/dscf	lb/hr
Scrubber 1	82,000	0.024	16.90
Scrubber 2	77,000	0.019	12.60
average	79,500	0.022	14.80
USS Fairfield, Furnace C[35]			
October 1978	dscfm	gr/dscf	lb/hr
Run 1	74,600	0.021	13.58
Run 2	76,600	0.021	13.86
Run 3	77,600	0.023	15.43
average	76,300	0.022	14.29
USS Fairfield, Furnace X[35]			
December 1978	dscfm	gr/dscf	lb/hr
Run 1	78,600	0.019	12.67
Run 2	76,100	0.024	15.39
Run 3	74,600	0.021	13.21
average	76,400	0.021	13.76
Kaiser No. 5[35]			
December 1978	dscfm	gr/dscf	lb/hr
Run 1	82,000	0.021	6.44
Run 2	87,000	0.020	5.46
Run 3	90,400	0.018	6.02
average	86,571	0.020	5.97
Kaiser No. 6[35]			
December 1978	dscfm	gr/dscf	lb/hr
Run 1	79,000	0.015	4.68
Run 2	68,000	0.013	3.48
Run 3	83,000	0.017	3.75
average	76,500	0.015	3.97
Armco Steel[35]			
October 1971	dscfm	gr/dscf	lb/hr
Run 1	37,000	0.021	--
Run 2	32,000	0.031	--

Run 3	49,000	0.020	--
average	39,000	0.024	--

B.6 SECONDARY BOPF EMISSION CONTROL

Secondary or fugitive emissions occur from the BOPF when the molten iron and scrap metal are charged to the furnace and when the molten steel and slag are tapped from the furnace. The emissions generated are primarily metal oxides formed when oxygen in the air reacts with the molten iron or steel. Twelve of the 23 BOPF shops have a separate capture and control system for BOPF charging and tapping emissions. Ten of these shops use baghouses and the other two use scrubbers. Existing State limits for the control devices are summarized in Table B-23 and range from 0.0052 to 0.015 gr/dscf, and the NSPS limit is 0.01 gr/dscf. The most common limit is 0.01 gr/dscf.

TABLE B-23. STATE LIMITS FOR BOPF SECONDARY CONTROLS

Closed Hood BOPF Shops			
Plant	**State**	**Control**	**Limit**
Bethlehem Steel	IN	Scrubber	0.05 lb/ton liquid steel (#3)
Geneva Steel	UT	Baghouse	0.002 gr/dscf PM_{10}
Inland No. 2 Shop	IN	Scrubber	0.015 lb/ton
LTV No. 2 Shop	OH	Baghouse	0.010 gr/dscf
USS/Kobe Steel	OH	Baghouse	0.012 gr/dscf
USX Fairfield	AL	Baghouse	0.010 gr/dscf
Open Hood BOPF Shops			
Plant	**State**	**Control**	**Actual Limit**
Acme Steel	IL	Baghouse	10.22 lb/hr, 0.0052 gr/dscf
Inland No. 4 Shop	IN	Baghouse	0.006 gr/dscf
USX, Gary (Q-BOP)	IN	Baghouse	0.0052 gr/dscf PM_{10}
USX, Braddock	PA	Baghouse	Process weight limit

The top five most stringent existing emission limits for total PM are given in Table B-24. The five plants with the most stringent secondary BOPF emission State limits are subject to concentration limits of 0.0052, 0.006, 0.01, 0.01 and 0.012 gr/dscf. Each of these is associated with a facility with baghouse controls. The median of the five values is 0.01 gr/dscf.

Available data on secondary BOPF emissions (Table B-25) is limited to one test run at a facility using a baghouse. This one test run includes measurements of multiple baghouse modules and averaged 0.001 gr/dscf. It is not likely that one test run will adequately reflect the full range of performance of a particular technology, and the results of the one available test run appear to represent, at most, what this type of control is able to achieve under very favorable circumstances.

TABLE B-24. BOPF SECONDARY CONTROLS: TOP FIVE LIMITATIONS

Plant	Shop	gr/dscf
Acme Steel, IL	1	0.0052
Inland, IN	4	0.006
LTV, OH	2	0.01
USX, AL	1	0.01
USS/Kobe Steel, OH	1	0.012
Median		0.01

TABLE B-25. BOPF SECONDARY BAGHOUSE TEST AT USX, BRADDOCK, PA[36]
(October 12-13, 1993)

Baghouse module	dscfm	gr/dscf
1	66,700	0.00157
2	59,800	0.00008
3	64,000	0.00075
4	63,400	0.00011
5	61,400	0.00151
6	65,200	0.00163
7	66,400	0.00233
Weighted average gr/dscf		0.001

B.7 HOT METAL TRANSFER, DESULFURIZATION, SLAG SKIMMING, AND LADLE METALLURGY

There are several different ancillary operations performed within the BOPF shop: (1) operations associated with the molten iron before it is charged to the BOPF (hot metal transfer, desulfurization, and slag skimming), and (2) treatment of the molten steel after tapping (various ladle metallurgy operations). The emissions from these operations are primarily metal oxides formed when oxygen in the air reacts with the molten iron or steel.

Molten iron is transported from the blast furnace casthouse to the BOPF shop in a torpedo car and transferred to a vessel at the reladling (or hot metal) station, where it is usually desulfurized and slag is skimmed from the surface. Emissions from these operations are captured by local hooding and controlled by a baghouse. Existing State emission limits for these operations range from 0.0052 to 0.04 gr/dscf, but most are on the order of 0.01 gr/dscf (see Table B-26).

The steel from the BOPF is usually transferred to a ladle where final adjustments in temperature and chemistry are made in an operation known as ladle metallurgy. Emissions from ladle metallurgy are captured by a close fitting hood and ducted to a baghouse. Existing State limits for ladle metallurgy are a mixture of mass emission rates in lb/hr and concentration limits in gr/dscf. The mass emission rate limits range from 0.42 to 7.5 lb/hr and the concentration limits range from 0.0052 to 0.02 gr/dscf (Table B-27).

TABLE B-26. STATE LIMITS FOR TRANSFER, DESULFURIZATION, AND SLAG SKIMMING--ALL BAGHOUSES

Plant	State	Process	Emission Limit
Acme Steel	IL	Transfer, desulfurization skimming	10.2 lb/hr
AK Steel	KY	Transfer, desulfurization skimming	0.01 gr/dscf
AK Steel	OH	Transfer and desulfurization	58 lb/hr
		Deslagger	0.03 gr/dscf
Bethlehem Steel	IN	Transfer, desulfurization skimming	23.1 lb/hr
Geneva Steel	UT	Desulfurization Buildings 1&2	0.011 gr/dscf PM_{10}
Inland Steel, No. 2	IN	Reladle and desulfurization	0.011 gr/dscf
Inland Steel, No. 4	IN	Reladle and desulfurization	0.0052 gr/dscf
LTV Steel	IN	Reladle and desulfurization	0.008 gr/dscf PM_{10}
National Steel	IL	Transfer, desulfurization skimming	0.01 gr/dscf
Rouge Steel	MI	Transfer and desulfurization	--
National Steel	MI	Hot metal transfer	0.007 gr/dscf
USS, Edgar	PA	Reladle and desulfurization	Process weight rate
USS, Fairfield	AL	Reladle and desulfurization	0.01 gr/dscf
USS Gary	IN	Desulfurization	0.01 gr/dscf
USS Gary	IN	Reladle and desulfurization	0.0052 gr/dscf PM_{10}
USS/Kobe Steel	OH	Transfer and desulfurization	
WCI Steel	OH	Desulfurization	0.03 gr/dscf
Weirton Steel	WV	Hot metal transfer	0.04 gr/dscf
		Desulfurization	0.01 gr/dscf
Wheeling-Pittsburgh Steel	OH	Hot metal transfer	5.97 lb/hr
		Desulfurization	5.01 lb/hr (proposed)
		Hot metal transfer backup	6.41 lb/hr (proposed)

TABLE B-27. STATE LIMITS FOR LADLE METALLURGY PROCESS

Plant	State	Control	Emission Limit
Acme Steel	IL	Baghouse	0.037 lb PM_{10}/ton
AK Steel	KY	Baghouse	3.8 lb/hr
AK Steel	OH	Baghouse	0.02 gr/dscf
AK Steel	OH	Baghouse[a]	0.03 gr/dscf
Inland Steel, No. 2	IN	Baghouse	0.0052 gr/dscf
LTV Steel	IN	Baghouse	0.004 gr/dscf PM_{10}
National Steel	IL	Baghouse 1	0.01 gr/dscf
National Steel	IL	Baghouse 2	0.01 gr/dscf
National Steel	MI	Baghouse 1[b]	1.26 lb/hr
National Steel	MI	Baghouse 2[a]	2.13 lb/hr
National Steel	MI	Baghouse 3[c]	1.1 lb/hr
Rouge Steel	MI	Baghouse 1	7.50 lb/hr
Rouge Steel	MI	Baghouse 2	1.6 lb/hr
USS Fairfield	AL	Baghouse	0.02 gr/dscf
USS Gary Q-BOP	IN	Baghouse 1	0.01 gr/dscf PM_{10}
USS Gary Q-BOP	IN	Baghouse 2	0.01 gr/dscf PM_{10}
USS/Kobe	OH	Baghouse	0.002 gr/dscf
Weirton Steel	WV	Baghouse	0.42 lb/hr
Wheeling-Pittsburgh	OH	Baghouse	0.54 lb/hr[d]
Wheeling-Pittsburgh	OH	Baghouse	2.3 lb/hr, 0.02 gr/dscf[d]

[a] Vacuum degassing
[b] Ladle metallurgy, No. 2 argon stirring
[c] No. 1 argon stirring station
[d] Proposed limit

Source test data were available for three of the 23 baghouses that control emissions from hot metal transfer and desulfurization and for seven of the 20 baghouses that control emissions from ladle metallurgy. These data are shown in Figures B-5 and B-6, and data for each run are given in Tables B-28 and B-29. Each performance test is comprised of three individual runs. The three run averages for the ten tests range from 0.001 to 0.012 gr/dscf. Results from individual runs range from 0.001 to 0.021 gr/dscf.

The highest three run averages and highest individual runs were examined more closely. In this case, both were obtained on the same baghouse, 0.012 and 0.021 gr/dscf. An examination of the test results on all 10 baghouses indicates that these results are 2 to 2.5 times higher than those obtained on the next highest emitting unit, suggesting that this baghouse is either an underperformer or that the test results include an outlier. Eliminating the 0.021 gr/dscf value from the three run average produces an average of 0.007 gr/dscf which is in line with the next highest emitting unit's three run average of 0.006 gr/dscf and the highest individual run of 0.0085 gr/dscf. Consequently, the 0.021 gr/dscf value is an outlier and does not reflect the level of performance demonstrated to be achievable for a baghouse applied to emissions from hot metal transfer, desulfurization, and ladle metallurgy operations.

FIGURE B-5. TRANSFER AND DESULFURIZATION TEST DATA -- ALL BAGHOUSES

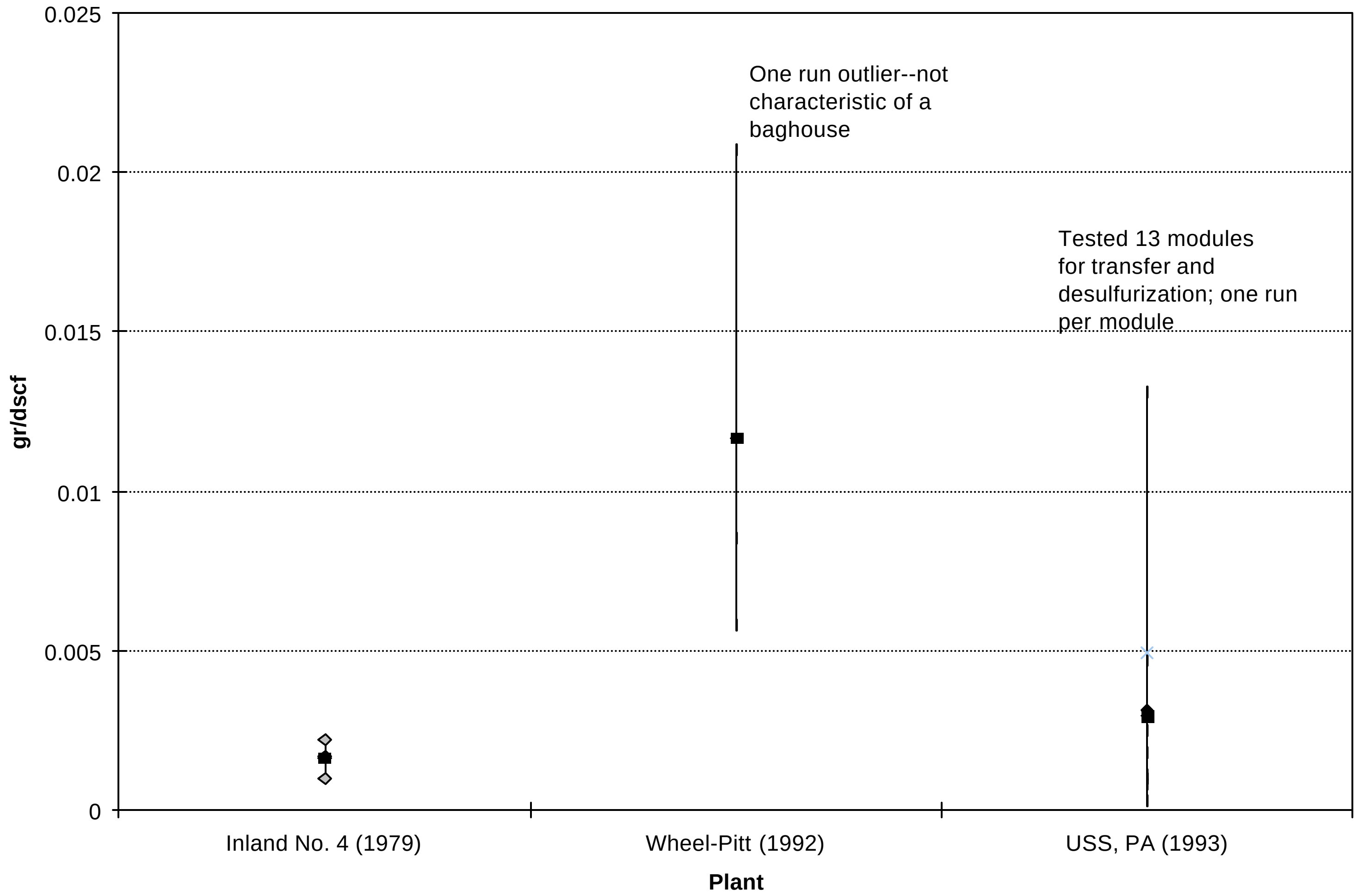

FIGURE B-6. LADLE METALLURGY TEST DATA -- ALL BAGHOUSES

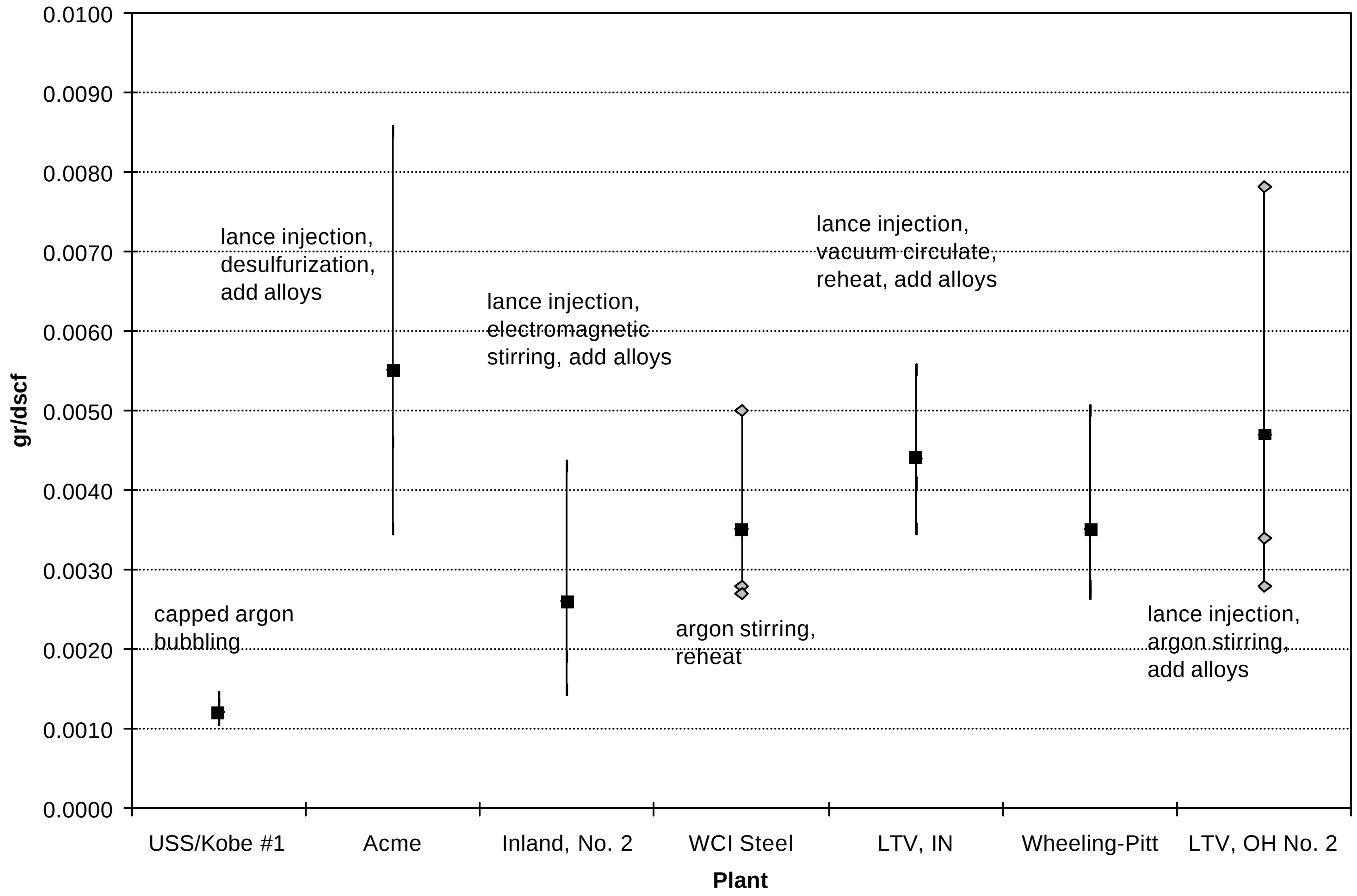

TABLE B-28. TEST DATA FOR METAL TRANSFER, DESULFURIZATION

Inland #4 (July 1979)[37]			
	Flowrate, dscfm	gr/dscf	lb/hr
Run 1	165,000	0.0022	3.11
Run 2	165,000	0.0017	2.41
Run 3	163,000	0.0010	1.40
3-run average		0.0016	2.31
Wheeling-Pittsburgh (October 1992 - desulfurization)[19, 38]			
	Flowrate, dscfm	gr/dscf	lb/hr
Run 1	69,930	0.0058	3.5
Run 2	65,030	0.0207	11.5
Run 3	69,070	0.0085	5.0
average	68,010	0.0117	6.7
Wheeling-Pittsburgh (July 1980 - hot metal transfer)[19, 38]			
	Flowrate, dscfm	gr/dscf	lb/hr
Run 1	182,336	0.0051	8.0
Run 2	176,416	0.0016	2.4
Run 3	179,656	0.0016	2.5
average	179,469	0.0027	4.3

TABLE B-29. TEST DATA FOR LADLE METALLURGY

Acme Steel, Chicago, IL[21]			
	Flowrate, dscfm	gr/dscf	lb/hr
Run 1	71,923	0.0085	5.24
Run 2	74,924	0.0035	2.25
Run 3	78,618	0.0046	3.10
average	75,155	0.0055	3.53
Inland, No. 2 BOPF shop[39]			
11 Sept 86	Flowrate, dscfm	gr/dscf	lb/hr
Run 1	46,920	0.0043	1.70
Run 2	47,490	0.0015	0.60
Run 3	44,080	0.0019	0.70
average	46,163	0.0026	1.00

LTV, E. Chicago[40]			
15 Jun 89	Flowrate, dscfm	gr/dscf	lb/hr
Run 1	130,324	0.0055	6.18
Run 2	125,203	0.0041	4.35
Run 3	134,437	0.0035	4.02
average	129,988	0.0044	4.85
LTV Cleveland, No. 2 BOPF shop[41]			
21 Apr 93	Flowrate, dscfm	gr/dscf	lb/hr
Run 1	127,872	0.0078	8.59
Run 2	147,083	0.0034	4.28
Run 3	125,950	0.0028	3.02
average	133,635	0.0047	5.30
USS/Kobe Steel, #2 LMF[42]			
5 Nov 97	Flowrate, dscfm	gr/dscf	lb/hr
Run 1		0.0011	0.55
Run 2		0.0014	0.72
Run 3		0.0013	0.65
Average		0.0012	0.64
WCI Steel[43]			
4 Nov 91	Flowrate, dscfm	gr/dscf	lb/hr
Run 1	71,139	0.0050	3.07
Run 2	85,810	0.0028	2.09
Run 3	76,195	0.0027	1.79
average	77,715	0.0035	2.32
Wheeling Pittsburgh[38]			
29 Sept 95	Flowrate, dscfm	gr/dscf	lb/hr
Run 1	39,400	0.0010	0.35
Run 2	36,830	0.0016	0.50
Run 3	39,330	0.0037	1.24
average	38,540	0.0021	0.70

B.8 BOPF SHOP FUGITIVE EMISSIONS

The BOPF shop is a building or structure that houses several operations involved in steelmaking. These include hot metal transfer, desulfurization, slag skimming stations; one or more BOPF's for refining iron into steel; and ladle metallurgy stations. Fugitive emissions from these operations in the BOPF shop exit through the roof monitor and other building openings.

Table B-30 summarizes existing opacity limits for BOPF shops. Top and bottom blown furnaces were evaluated independently based on operational differences between the two designs. For top blown furnaces, the most stringent and also the most common State standard is a 20 percent limit (3-minute average) that is applied to 13 of the 20 BOPF shops that operate top blown furnaces. For bottom blown furnaces, the BOPF shop with the most stringent standard (Geneva Steel) is subject to a 10 percent opacity limit (6-minute average, with one exception per cycle up to 20 percent). A second shop (USX Gary) has three furnaces subject to a 20 percent limit (3-minute average). A third shop (USX Fairfield) has two furnaces subject to a 20 percent limit (6-minute average), and a third furnace subject to a 10 percent limit (3-minute average), with one 3-minute average greater than 10 percent but less than 20 percent applied only during hot metal transfer or skimming operations.

Similar to the existing State standards, the NSPS for top blown furnaces applies during the entire production cycle. However, the NSPS for bottom blown furnaces applies only during periods of hot metal transfer and slag skimming. Both standards limit opacity to less than 10 percent (3-minute average), except that one 3-minute average greater than 10 percent but less than 20 percent can occur during each applicable performance period.

TABLE B-30. SUMMARY OF BOPF SHOP OPACITY LIMITS

BOPF Shop	Type	Primary control	Secondary control	Roof monitor opacity limit
Acme Steel, Riverdale, IL	Top	ESP	Baghouse	20%, 3 minute average
AK Steel, Ashland, KY	Top	Scrubber	Baghouse	20% except for 3 min/hr
AK Steel, Middletown, OH	Top	Scrubber	None	Covered under "bubble"
Bethlehem, Burns Harbor, IN (3 vessels in 1 shop)	Top (2) Top (1)	Scrubber	None Scrubber	40%, 6 minute average; <60% for 15-min in 6 hr
Bethlehem, Sparrows Point, MD	Top	Scrubber	None	3-day roll avg of 15% (6-min avg), except 3 min/hr
Gulf States, Gadsden, AL	Top	ESP	None	20%, 3 minute average
Inland Steel, East Chicago, IN (2 shops)	Top Top	Scrubber Scrubber	Scrubber Baghouse	20%, 3 minute average 20%, 3 minute average
LTV, Cleveland, OH (2 shops)	Top Top	ESP Scrubber	 Baghouse	20%, 3 minute average 20%, 3 minute average
LTV, East Chicago, IN	Top	ESP	None	20%, 3 minute average
National, Granite City, IL	Top	ESP	None	20%, 3 minute average
National, Ecorse, MI	Top	ESP	Baghouse	20%, 3 minute average
Rouge Steel, Dearborn, MI	Top	ESP	None	20%, 3 minute average
USX, Braddock, PA	Top	Scrubber	Baghouse	Not to equal or exceed 20% except for 12 readings per hour.
USX, Gary, IN	Top	Scrubber		20%, 3 minute average
USS/Kobe, Lorain, OH	Top	Scrubber	Baghouse	20%, 3 minute average
WCI Steel, Warren, OH	Top	ESP	None	None
Weirton Steel Weirton, WV	Top	Scrubber	None	20%
Wheeling-Pittsburgh, OH	Top	Scrubber	None	20%, 3 minute average
Geneva Steel, Orem, UT	Bottom	Scrubber	Baghouse	10%, 6 minute average[a]
USX, Fairfield, AL	Bottom	Scrubber	Baghouse	10%, 3-min avg/20%, 6-min avg[b]
USX, Gary, IN	Bottom	Scrubber	Baghouse	20%, 3 minute average

[a] Allows one 6-min average per steel production cycle up to 20%.

[b] One furnace has a limit of 10% (3-min average) for hot metal transfer and skimming with one 3-min average per cycle over 10% but less than 20%; the other 2 furnaces have a 20% (6-min average) limit.

B.9 COST ESTIMATES FOR BAGHOUSES APPLIED TO SINTER PLANT DISCHARGE END AND COOLER

The cost estimates are based on guidance provided in the OAQPS Cost Manual (Chapter 5: Fabric Filters)[44] and the associated spreadsheet.[45] The baghouse design is a pulse jet unit with an air-to-cloth ratio of 3 acfm/ft^2. For the discharge end, a typical ventilation rate of 120,000 acfm is used, and a typical rate of 200,000 acfm is used for the sinter cooler.

B.9.1 Capital and Total Annual Costs

The capital cost elements for the two baghouses are given in Table B-31. The list of items associated with annual operating costs from the OAQPS cost manual are given in Table B-32 and are used to estimate the total annualized costs presented in Table B-33.

TABLE B-31. CAPITAL COST ELEMENTS

Item	Capital cost (120,000 acfm)	Capital cost (200,000 acfm)
Baghouse	368,827	607,352
Bags	73,784	122,973
Cages	25,460	42,436
Auxiliaries (hoods, ductwork, fans, stacks)	209,287	280,525
Total	678,359	1,053,286
Purchased equipment cost (1.18)	800,463	1,242,872
Index (1.02 for 1998 to 1999)	816,472	1,267,729
Retrofit factor (2)	1,630,000	2,536,000
Total capital investment, including installation (2.17)	3,500,000	5,500,000

TABLE B-32. OPERATING COST ELEMENTS

Item	Value
Operating hours per year	8,760
Operating labor rate	$17.27/hr
Maintenance labor rate	$17.74/hr
Labor overhead	60%
Operating labor required	2 hr/shift
Maintenance labor required	1 hr/shift
Supervisory labor	15%
Maintenance materials	equal to maintenance labor
Electricity usage	kw-hr/yr = 0.00018 x acfm x) p x 8,760
Electricity cost	$0.0671 kw-hr
Compressed air cost	$0.25/1,000 scf
Dust disposal	$25/ton
Taxes, insurance, administration	4%
Interest rate	7%
Bag life	2 years
Capital recovery factor for bags	0.553
Control system life	20 years
Capital recovery factor for control system	0.0944

TABLE B-33. ESTIMATES OF TOTAL ANNUAL COSTS

Item	Annual cost ($/yr for 120,000 acfm)	Annual cost ($/yr for 200,000 acfm)
Operating labor	37,282	37,282
Supervisory labor	5,592	5,592
Maintenance labor	19,159	19,159
Maintenance materials	19,159	19,159
Labor overhead	48,715	48,715
Electricity	100,593	167,656
Compressed air	31,104	51,840
Bag replacement	70,416	117,362
Dust disposal	44,434	74,057
Tax, insurance, administration	141,773	220,130
Capital recovery	322,541	499,439
Total annual cost	**840,800**	**1,260,000**

B.9.2 Emission Reduction and Cost Effectiveness

Emission reductions and cost effectiveness are presented for two cases: (1) installing a baghouse on the discharge end to reduce emissions of PM from 0.02 gr/dscf (the MACT floor) to 0.01 gr/dscf and (2) installing a baghouse on the sinter cooler to reduce emissions of PM from 0.03 gr/dscf (the MACT floor) to 0.01 gr/dscf. Data from two plants showed that the HAP content of dust from the discharge end ranged from 0.3 percent[46] of PM to 1.2 percent.[47] For this estimate, use a midrange value of 0.75 percent for both the discharge end and cooler because the dust from the cooler should be similar in composition to that from the discharge end.

The PM and HAP emission reductions for the two cases are given in Table B-34. The cost effectiveness ranges from $1.2 to $2.5 million per ton of HAP reduced.

TABLE B-34. EMISSION REDUCTIONS AND COST EFFECTIVENESS

Emission point	PM emission reduction (tpy)	HAP emission reduction (tpy)	Total annual cost ($million/yr)	Cost effectiveness ($million/ton HAP)
Discharge end (120,000 acfm)	45	0.34	0.84	2.5
Cooler (200,000 acfm)	150	1.1	1.3	1.2

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16. ABSTRACT

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

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