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IRON AND STEEL INDUSTRY PARTICULATE EMISSIONS: SOURCE CATEGORY REPORT

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Prepared by

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Research Triangle Park NC 27711

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ABSTRACT

This report includes a Source Category Report for the Iron and Steel Industry and an update of Section 7.5, Iron and Steel Production, of AP-42. The revised section contains both total particulate emission factors and particle size data.

Particle size data were collected, reviewed, analyzed, and ranked in terms of data reliability. A description of all data sources evaluated and their assigned rating is presented. Process descriptions and information on emissions and controls are summarized for each process.

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SECTION 1

INTRODUCTION

The primary purpose of this program was to provide a Source Category Report including a summary of the best available inhalable particulate emissions data ($\leq$10 μm) representative of the iron and steel industry. A second objective was to revise Section 7.5 of AP-42, entitled Iron and Steel Production, and incorporate particle size distribution data. The current section was last updated with total particulate emission factors in May 1983.

Both controlled and uncontrolled total particulate and size specific emission factors are presented in this report. The uncontrolled emission factors represent levels that would occur if emission control devices (baghouse, scrubber, etc.) were bypassed. It is recognized that emission collection systems may have an effect on the type and amount of emissions generated, by affecting the gas velocity and composition in the vicinity of the emission source. However, the effect is generally not quantifiable and it is assumed that the collected "bypass" emissions accurately represent the emissions generated in the absence of a collection system. Size-specific emission factors are generally based on the results of cascade impactor sampling conducted simultaneously with total particulate sampling procedures at the inlet or outlet to a control device.

The above objectives were accomplished by conducting an intensive search of all emissions data sources. Data were collected from the following sources:

- Computerized literature searches through New England Research Application Center (NERAC);
- State and federal regulatory personnel;
- Industry personnel;
- GCA/Technology Division files compiled during related iron and steel work;
- Other EPA contractors;
- AP-42 steel industry background file at OAQPS; and
- Fine Particle Emission Information System (FPEIS).

All available particulate emissions data were reviewed, analyzed, summarized, and ranked according to the reliability criteria provided in the April 1980 report, entitled "Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections".[1] The data were rated according to the following criteria:

- A = Tests performed by a sound methodology and reported in enough detail for adequate validation. These tests are not necessarily EPA reference method tests, although such reference methods are used as a guide.

- B = Tests that are performed by a generally sound methodology but lack enough documentation for adequate validation.

- C = Tests that are based on an unproven methodology or lack a significant amount of documentation.

- D = Tests that are based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

The information considered in rating the test data includes source operating parameters, sampling procedures, data variability, and calculating procedures. The data are not specifically downgraded due to age, providing that an acceptable test method was used. Acceptable test methods include EPA Method 5 or an equivalent method for total particulate, and cascade impactor for particle size. Particle size data obtained using the SORI Inhalable Particulate dual-cyclone sampler were downgraded to a C rating because of limited experience with this method. Particle size data obtained by Source Assessment Sampling System (SASS) were downgraded to a D rating because of the limited data (only four cutpoints) obtained with this method.

After ranking the data, emission factors were calculated using the highest quality data available. If possible, only A-rated test data were used in the emission factor calculation. B-rated data were included with the A-rated data only if the latter were so limited as to not represent a reasonable sample of the source type. If no A- or B-rated data were available, C- and D-rated data were combined to provide an "order-of-magnitude" emission factor. In no case were A- or B-rated data combined with C- or D-rated data. The following ratings were applied to each emission factor:

- A = Excellent--Developed from A-rated test data taken from many randomly chosen facilities in the industry population. The source category is specific enough to minimize variability within the source category population.

- B = Above Average--Developed only from A-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. As with the A rating, the source category is specific enough to minimize variability within the source category population.

- C = Average--Developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. As with the A rating, the source category is specific enogugh to minimize variability within the source category population.

- D = Below Average--The emission factor was developed from A- and B-rated test data, and there may be reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor are footnoted in the emission factor table.

- E = Poor--The emission factor was developed from C- and D-rated test data, and there may be reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of these factors are always footnoted.

Process data, control system descriptions, and operating data were obtained, evaluated, summarized, and presented as general background information. It was not the objective of this program to provide detailed engineering analyses, product specifications, or detailed evaluations of trends in the industry.

This report was structured according to information presented in "The Outline for Source Category Reports" which was included in the technical directive for this program. Duplication of information between Section 5, the AP-42 section, and Sections 1 through 4 of the report was necessary in order that the proposed Section 5 could stand alone once inserted into AP-42.

No environmental measurements were conducted during this program, therefore, no separate QA section is contained in this report. The quality of the existing data has been evaluated as described above.

SECTION 2

IRON AND STEEL INDUSTRY PROCESS BACKGROUND INFORMATION

SINTER PLANT

Process Description

Sinter plants perform the function of agglomerating undersized iron-bearing materials to make them suitable for blast furnace feedstock. It is necessary to agglomerate dusts and undersized fractions of raw materials in order to prevent their being immediately blown out the furnace top when charged. The agglomerated sinter also serves to maintain a favorable burden porosity.

A secondary function of the sinter plant is to provide all or part of the

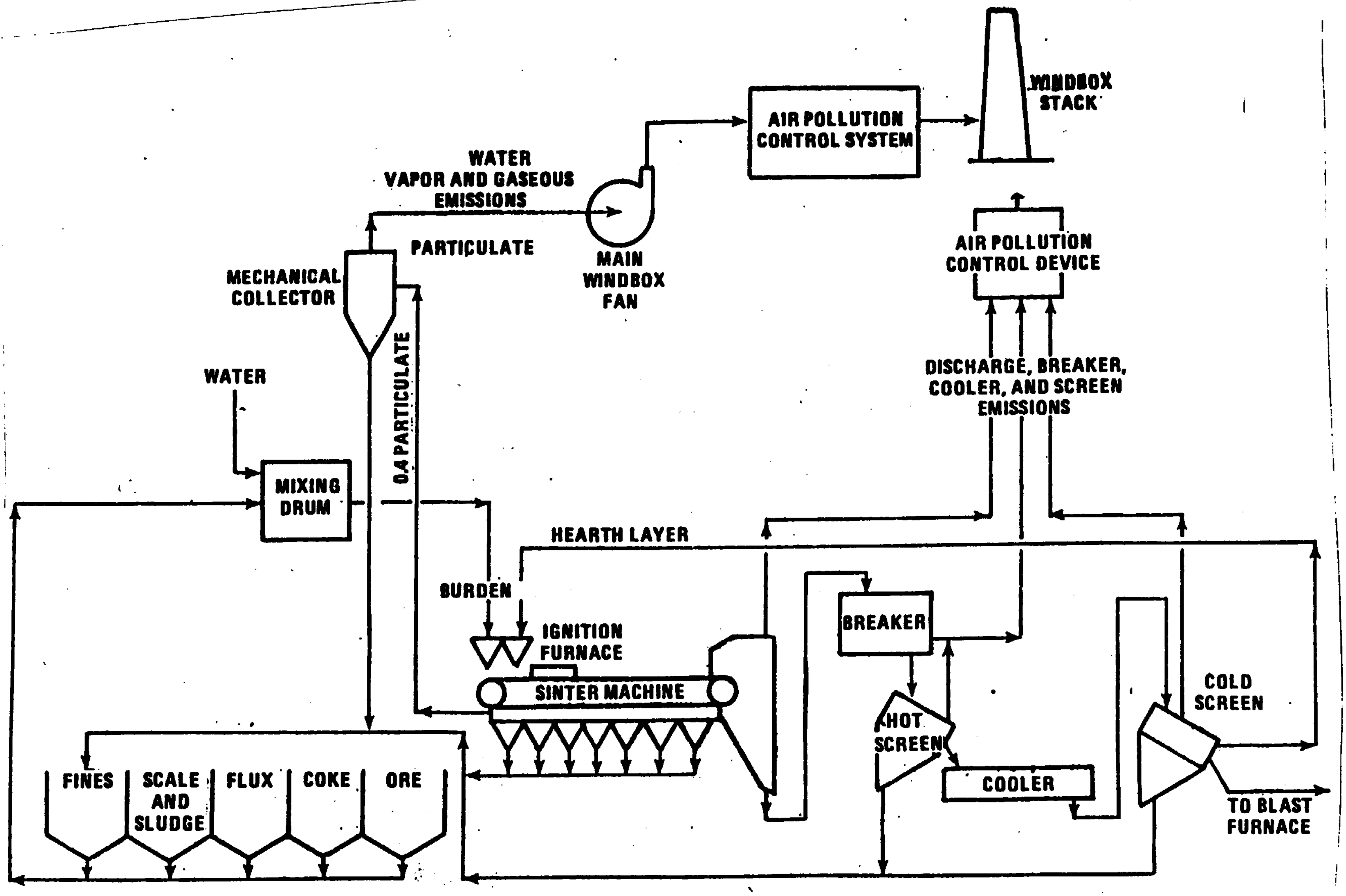

Figure 1. Typical sinter plant flow diagram.[3]

Raw materials in the desired proportions are withdrawn from storage bins and conveyed to a pug-mill or balling drum mixer where enough water is added to cause the material to form small pellets. This material is fed onto the grate. At the head of the grate a gas- or oil-fired combustion hood is located over the bed. The mix is ignited while under the hood. Combustion continues down through the bed of material as the grate travels along the windbox. The combustion zone can be thought of as a standing wave starting at the surface of the bed under the ignition hood and sloping down through the bed until it reaches the bottom or burnthrough point near the end of the strand. Temperatures in the sinter combustion zone range from 2400 to 2700° (1300 to 1480°C).

At the end of the strand the sinter falls off as the pallets return to the ignition end of the strand. The sinter is screened on hot screens, crushed in a sinter breaker, and then conveyed to a sinter cooler. The cooler is usually a circular or straight line moving bed. As much as 5 lb of air per lb of sinter may be required for cooling.[2] The sinter is screened after exiting the cooler at "cold screens". Undersized screening material is returned to the strand. In some plants a portion of the returns may be used to produce the hearth layer on the strand. A hearth layer consists of larger size sinter that holds the burden from falling through openings in the pallets.

Emission Generation

The most significant source of emissions from sintering operations is the windbox exhaust. The windbox exhaust stream contains entrained fine particulate from the bed, and also volatilized and partially pyrolyzed hydrocarbons, carbon monoxide, nitrogen, and sulfur oxides. A factor which affects windbox particulate emissions is the fineness (particle size) of the burden. Very fine materials such as BOF dust increase the mass and proportion of small particles in both windbox and material handling emissions. Improper proportioning or mixing can cause incomplete sintering which allows more of the burden to be drawn through the grates. Improper maintenance of the grate bars will cause increased emissions by allowing mix to fall through. Holes may form in the bed allowing uneven and greater air volumes to enter the windbox and control system. The use of a hearth layer composed of sinter returns will protect the grates from deterioration and help maintain lower emissions. The air conveying system must be carefully maintained due to the abrasive nature of sinter fines. Excessive infiltration caused by holes in the ductwork may decrease the efficiency of the windbox control system.[3]

Mill scale, blast furnace sludge, and coke breeze contribute to hydrocarbon emissions. The oil content of each of these components is responsible for the hydrocarbon emissions.[3]

Emission Controls

Windbox emissions may be controlled by cyclones, electrostatic precipitators, scrubbers, or baghouses. Most plants use cyclones as pretreatment to remove large particulate from the gas stream to reduce fan wear. The majority of plants use either dry ESPs or scrubbers for windbox emission control. Baghouses are not commonly used because of potential problems with filter blinding caused by vapor condensation and hydrocarbon deposits.

ESP control efficiency is adversely affected by high sinter dust resistivity resulting from production of sinter with a high flux content; i.e., superfluxed. The trend in the industry toward low basicity, superfluxed sinter, has caused an increase in emissions from ESPs.[3] High basicity sinter produces a dust of resistivity greater than 2 x 10^{10} ohm-cm which cannot be efficiently collected in an ESP.

High pressure drop venturi and steam scrubbers have been shown to effectively control windbox emissions. In addition to control of particulate, scrubbers also reduce emissions of hydrocarbons, fluorides, and sulfur dioxide.[3]

Baghouses are the most common method of controlling material handling emissions. Sinter coolers are often not controlled and usually show no visible emissions if effective screening has been provided previously.[3]

BLAST FURNACE

Process Description

Blast furnaces are used to produce pig iron from iron-bearing raw materials, primarily iron ore. The blast furnace produces a high carbon iron which is converted to steel in basic oxygen furnaces or open hearth furnaces.

The blast furnace is a large steel shell with a refractory lining, usually 100 ft or more in height. The trend in the industry is toward the construction of fewer, more efficient furnaces to replace older, small ones. Input materials (including coke, flux, and iron-bearing material) are charged to the furnace top and descend slowly through the furnace. Blast air is supplied through water-cooled tuyeres near the base and rises rapidly up through the burden. The blast air, preheated to temperatures between 1000° to 2000°F, supplies oxygen to fuel the burning coke in the burden. At some furnaces, liquid fuels are injected with the blast air to increase the melting process. The pressure of the blast air controls the rate of burden descent. A diagram of a blast furnace appears in Figure 2.

In the furnace, coke acts as both a fuel and a source of carbon to reduce iron oxides to metallic iron. The coke burns to produce carbon monoxide in the lower sections of the furnace where the hot blast air enters. As the carbon monoxide rises in the furnace, it reduces the oxides of iron. The most accelerated reduction of the burden occurs in the lower part of the furnace called the bosh. This is where the blast air enters. In the bosh, the intense heat completes the melting process and allows iron and slag to drip down into a pool in the furnace hearth area.

Blast furnace charging is accomplished semicontinuously by a skip car. The skip car is loaded with a weighed charge of the desired composition in the stockhouse where coke, limestone, and a variety of iron-bearing materials and

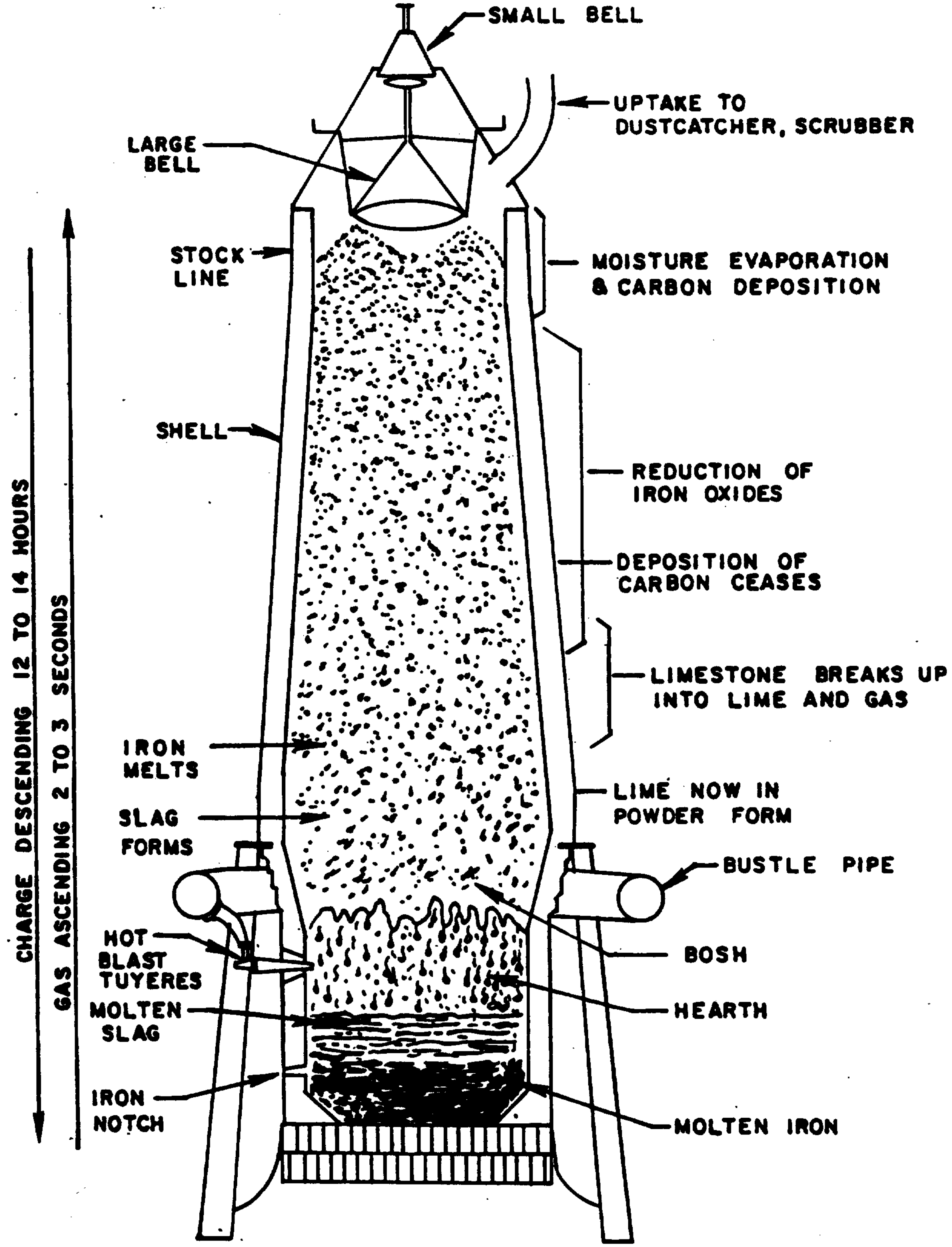

Figure 2. Blast furnace cross section.[4]

sometimes a sinter are kept in bins. The skip car is hoisted to the top of the furnace and dumped on the first bell (see Figure 2). The first bell opens and the charge falls onto the second bell. The first bell closes before the second bell opens to drop the charge into the furnace. The double bell closure system allows material to be added witout reducing the furnace pressure and prevents the direct escape of large quantities of gas to the atmosphere.

Molten iron and slag accumulate continuously in the hearth and are removed periodically. A taphole is drilled through the clay plug in the iron notch located at the base of the hearth to remove hot metal. During the ensuing casting process, hot metal flows out of the furnace and collects in the iron trough. About half way through a cast, slag is discharged from the furnace with the iron. A dam at the trough end with an opening at its base allows separation of the iron from the slag which floats on the surface of the molten pool. The iron flows from under the dam into runners which lead into refractory lined ladles. The ladles are transported by rail to iron casting or steelmaking facilities. The floating slag flows over a slag dam, located on the side of the trough, and into a separate runner system leading to a slag pit adjacent to the casthouse, or into slag pots which are hauled to a remote slag pit. At the end of the cast, a "mudgun" is moved into position in front of the notch to inject a clay mixture into the taphole. The casting operation is normally initiated every 2 to 4 hours and lasts approximately 1 hour, although this typical schedule may vary at different plants. On large modern blast furnaces with multiple tapholes, casting may be conducted on a more frequent basis.

The production of 1 ton of iron requires about 1.7 tons of ore or other iron-bearing material, 0.5 to 0.65 ton of coke or other fuel, 0.25 ton of limestone or dolomite, and 1.8 to 2 tons of air. Byproducts produced along with the production of 1.0 ton of iron will be: 0.2 to 0.4 ton of slag, 0.05 ton or less of flue dust, and 2.5 to 3.5 tons of blast furnace gas.[2] Blast furnace gas has a useful caloric value due to its high concentration of carbon monoxide and hydrogen. Gas leaves the furnace through offtakes at the top of the furnace above the burden level. The blast furnace gas exiting the furnace is commonly cleaned by cyclones and venturi scrubbers. The cleaned gas is used as fuel for various other steel mill processes, in addition to recycling back to the blast furnace. A portion of the gas (18 to 30 percent)[2,4] is used to preheat the blast air in large stoves located next to the furnace. These steel-shelled stoves are usually 120 feet tall and 26 to 28 feet in diameter with a regenerative brick checker work inside. Typically, three stoves serve a single blast furnace.

The base and lower part of a blast furnace is enclosed by a casthouse. The casthouse floor slopes downward from just below the iron notch, to the iron ladles and slag pit or slag pots located around the perimeter of the structure, or underneath the floor. In terms of particulate emissions, the casthouse is the major source associated with blast furnace operations. Emissions created during the casting operation rise and escape the casthouse from both the roof monitor and the furnace shell area around the furnace. Many casthouses have open side walls which allow additional escape of emissions depending on the degree of cross winds.

Emission Generation

A major source of emissions generated from casting operations is the notch area and the iron trough. The iron runners and the slag runners also produce emissions; however, these are usually less severe. Emissions from the ladles and slag pots are also considerable if located inside the casthouse area. The particulate emissions result from both the interaction of hot metal and slag with air forming iron oxides, and from the cooling of hot iron forming light graphite flakes called "kish". Since the molten iron from the furnace contains approxiately 4 percent carbon, and the solubility of carbon in iron decreases with temperature, carbon therefore precipitates from the hot metal. Kish is generally a large size particle and tends to settle inside the casthouse.

Prior to the flow of hot metal, emissions are generated when opening the taphole by drilling through the clay plug. The drilling operation generally lasts 2 to 10 minutes. Occasionally, if drilling is unsuccessful, it is necessary to burn through the taphole with an oxygen lance, which results in heavy red-brown colored emissions.

The amount of emissions generated during casting is related to the degree of turbulence created by the flow of hot metal. The stream of hot metal from the 1- to 3-inch taphole may be only a small steady flow, or it may extend 20 feet or more depending primarily on the furnace pressure and the condition of the taphole. Emissions typically increase at the end of the cast when the level of molten material in the hearth lowers to a point where the hot blast air can exit from the taphole creating spray of hot metal and slag. Additionally, when the taphole is being plugged with a clay mixture, heavy black emissions may result. The level of plugging emissions is generally related to the pressure of slag/air exiting the taphole and the percent of volatile compounds in the plugging material.

Other emissions sources associated with the casting operation include fumes from slag pots that may be located outside the casthouse proper, or from slag pits adjacent to the casthouse. Cooling of slag in the pit with water produces much steam which entrains particulte matter. Also, water in the pit may react with sulfur in the slag to form H_2S.

Atmospheric emissions from the furnace top gas are not usually significant. The offgas is used for fuel and is, therefore, cleaned by two to three emission control systems in series. This is commonly referred to as Pipeline Efficiency. The average particulate concentration of cleaned blast furnace gas is 0.05 gr/dscf.[2] Newer scrubber designs are capable of providing even better particulate control.[4] Combustion emissions from burning cleaned gas in the multiple stoves are discharged through a single combustion stack adjacent to the furnace or stove.

Emissions generated during furnace pressure surges, referred to as "slips", occur occasionally depending on the smoothness of burden descent. Blast furnace gas offtakes are fitted with pressure relief valves to prevent damage to the furnace shell or associated equipment during sudden surges in furnace top pressure. Sudden surges result when the burden becomes hung up and then releases; the sudden descent displaces gas which creates a high localized pressure. The pressure causes the relief valves to open and a large plume of dense emissions to escape from the top of the furnace. Slips are indicative of uneven furnace operation--a situation furnace operators strive to avoid. Recent trends toward more uniform, higher quality blast furnace raw materials have substantially reduced the incidence of slips in the industry.

Other fugitive emissions related to blast furnace operations include the furnace raw material handling systems for coke, sinter, and limestone. Withdrawal of materials from bins and weighing generate some minor emissions in the stockhouse. The bleeding of gas from the space between two bells, after the second bell closes, releases some particulate and carbon monoxide laden gas. Also, if the bell valve seals deteriorate, the quantity of emissions will increase.

Emission Controls

Recently a variety of techniques for controlling emissions from new casthouses and for retrofitting older casthouses have been applied. Several shops have experimented with and installed total casthouse evacuation, partial casthouse evacuation, local hoods, runner evacuation, or passive emission suppression systems. Baghouses are used to clean collected gas for all collection techniques.

The first type of casthouse emission control system to be used in North America was the total casthouse evacuation concept applied to four casthouses during the 1970s. The casthouses were completely enclosed and evacuated with large volumes of air exhausted to a baghouse. Flow rates ranged from 300,000 to 400,000 scfm, creating 1.1 to 2.0 casthouse air changes per minute. The total evacuation concept involves relatively large capital and energy cost.

A variation of total evacuation system is partial evacuation. This approach collects casting emissions through large canopy hoods located in the roof trusses, above the notch and trough areas. This option also requires some sealing of the casthouse structure to reduce crossdrafts from carrying emissions away from the hoods. Four furnaces in the U.S. are controlled by partial evacuation systems.

Another evacuation technique uses local hoods positioned over each emission area, venting to a common baghouse. Local hoods generally have the advantage of requiring less airflow than either total or partial evacuation systems. Due to space limitations, it may be difficult to fit hoods and ductwork into existing casthouses. Also, there may be problems of interference with equipment operation, especially drill, mudgun, and crane movement. Two new blast furnaces recently built in the U.S. were designed with a combination of local hoods and evacuated runner covers to control casting emissions.

The current trend in retrofit casthouse controls is towards passive emission suppression systems which have been installed by a number of steel companies. The technique attempts to prevent the generation of emissions at their source by limiting contact between hot metal and the air. No transport or treatment of exhaust gas is involved. It has been demonstrated that this system can lead to increased hot metal yields and improved casthouse working conditions.[5]

Retrofitting a suppression system may involve installation of additional crane or monorail systems depending on the existing capacities. Emission reduction by modifying process operations and work practices has been demonstrated by many companies, mostly in conjunction with suppression systems. Reducing taphole angle and diameter has been shown to reduce iron trough turbulence and thus reduce emission generation. Additionally, companies have tried to limit the amount of volatile material in the runner, trough, and taphole materials. Maintaining hot iron ladles (torpedo cars) is also considered a means of reducing emissions.[4]

The prevention of emissions from furnace slips is related to furnace maintenance and operation. This source can be reduced by careful burden selection, preparation, and process monitoring. Blast furnace operators are becoming more aware of these factors because they are closely related to improved efficiency and productivity of the furnace, in addition to reducing emissions.

BASIC OXYGEN FURNACE

Process Description

The basic oxygen furnace is the primary method of producing steel in the United States. According to 1981 statistical data, 60.6 percent or 73 million tons of raw steel were produced by this process.* Table 1 is a listing of facilities employing bsic oxygen furnaces along with their capacity and emission control systems.[6]

In the basic oxygen furnace process, scrap and molten pig iron are refined to steel using high purity oxygen in a refractory lined steel vessel. Reaction of the oxygen with the hot iron oxidizes carbon and silicon in the iron and removes these impurities while providing heat for melting the scrap.

The two major basic oxygen furnace variations are conventional, top-blown furnaces (called BOFs in this report) and the more recently-developed Quelle Basic Oxygen Process or Q-BOP. In the conventional design, oxygen is injected through a water-cooled lance positioned at the mouth of the vessel and above the molten metal surface. In the Q-BOP design, oxygen is introduced through tuyeres in the bottom of the furnace. In bottom-blown furnaces, when oxygen is not being used, nitrogen must be blown through the tuyeres to prevent clogging.

A typical facility consists of two or three furnaces. The furnaces are arranged in a row with each furnace mounted so it can rotate on a horizontal axis to allow charging, metallurgical sampling, tapping, and slagging.

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*World Steel Industry Data Handbook, McGraw Hill.

TABLE 1. BASIC OXYGEN FURNACE LOCATIONS, DESIGN CAPACITY, HOOD DESIGN, AND AIR POLLUTION CONTROL DEVICE[6]

Company	Location	Furnaces		Capacity	Hood Design/Air Pollution Control		
		Number	Size-Mg (tons)	MM Mg/yr MM(tons/yr)	Open Hood/ Precipitator	Open Hood/ Scrubber	Closed Hood/ Scrubber
Bethlehem Steel Corp.[a]	Lackawanna, NY	3	270(300)	4.5(5.0)		X	
Republic Steel Corp.[a]	Buffalo, NY	2	129(130)	0.9(1.0)		X	
Alan Wood Steel Co.[a]	Conshocken, PA	2	135(150)	1.8(2.0)	X		
Allegheny Ludlum Steel Co.[a]	Natrona, PA	2	75(80)	0.4(0.5)		X	
Bethlehem Steel Corp.	Sparrows Pt., MD	2	195(215)	2.7(3.0)		X	
Bethlehem Steel Corp.	Bethlehem, PA	2	240(270)	3.1(3.5)	X		
Crucible, Inc.[a]	Midland, PA	2	95(105)	0.9(1.0)		X	
Jones & Laughlin Steel Corp.	Aliquippa, PA	3	170(190)	6.0(6.7)	X		
Weirton Steel Corp.	Weirton, W. VA	2	350(390)	5.2(5.8)		X	
Sharon Steel Corp.	Farrell, PA	3[b]	135(150)	1.4(1.6)		X	
U.S. Steel Corp.	Duquesne, PA	2	195(215)	2.2(2.5)		X	
U.S. Steel Corp.	Braddock, PA	2	210(230)	2.2(2.5)		X	
Wheeling-Pittsburgh Steel Corp.	Monessen, PA	2	180(200)	1.4(1.6)	X		
Armco Steel Corp.	Ashland, KY	2	165(180)	1.8(2.0)	X		
Republic Steel Corp.	Gadsden, AL	2	165(180)	1.3(1.5)	X		
U.S. Steel Corp.	Fairfield, AL	3[c]	180(200)	3.2(3.5)			X
Armco Steel Corp.	Middletown, OH	2	190(210)	2.0(2.3)			X
Bethlehem Steel Co.	Burns Harbor, IN	2	270(300)	4.0(4.5)		X	
Bethlehem Steel Co.	Burns Harbor, IN	1	270(300)	0.9(1.0)			X
Rouge Steel Co.	Dearborn, MI	2	225(250)	3.4(3.8)	X		
Inland Steel Co.	East Chicago, IL	2	230(255)	6.0(6.7)		X	
Inland Steel Co.	East Chicago, IL	2	190(210)	6.0(6.7)			X
Interlake, Inc.	Chicago, IL	2	70(75)	0.9(1.0)	X		

(continued)

TABLE 1 (continued)

Company	Location	Furnaces		Capacity	Hood Design/Air Pollution Control		
		Number	Size-Mg (tons)	MM Mg/yr MM(tons/yr)	Open Hood/ Precipitator	Open Hood/ Scrubber	Closed Hood/ Scrubber
Jones & Laughlin Steel Corp.	Cleveland, OH	2	205(225)	2.7(3.0)	X		
McLouth Steel Corp.	Trenton, MI	5	100(110)	2.5(2.8)		X	
National Steel Corp.	Ecorse, MI	2	270(300)	5.2(5.8)	X		
National Steel Corp.	Ecorse, MI	2	215(235)	5.2(5.8)	X		
National Steel Corp.	Granite City, IL	2	215(235)	2.2(2.5)	X		
Republic Steel Corp.	Warren, OH	2	170(190)	1.9(2.2)	X		
Republic Steel Corp.	Cleveland, OH	2	220(245)	3.3(3.7)			X
Republic Steel Corp.	So. Chicago, IL	2[c]	180(200)	2.0(2.3)			X
U.S. Steel Corp.	Gary, IN	3	195(215)	7.2(8.0)	X		
U.S. Steel Corp.	Gary, IN	3[c]	180(200)	7.2(8.0)			X
U.S. Steel Corp.[a]	So. Chicago, IL	3	180(200)	2.7(3.0)		X	
U.S. Steel Corp.	Lorain, OH	2	205(225)	2.7(3.0)			X
Wheeling-Pittsburgh Steel Corp.	Steubenville, OH	2	260(285)	2.6(2.9)		X	
Wisconsin Steel[a]	So. Chicago, IL	2	110(120)	1.0(1.2)	X		
J&L Steel Co.	East Chicago, IL	2	255(280)	2.7(3.0)	X		
CF&I Steel Corp.[a]	Pueblo, CO	2	110(120)	1.2(1.4)	X		
Kaiser Steel Corp.[a]	Fontana, CA	3	110(120)	1.6(1.8)	X		
Kaiser Steel Corp.[a]	Fontana, CA	2	205(225)	2.1(2.4)			X

Notes:

[a] Known shutdowns (permanent)

[b] This facility consists of one standard top-blown BOF and two Kaldo Process BOFs, the latter vessels being inclined and rotating during the oxygen blow. The Kaldo units have been virtually supplanted by the standard fixed unit.

[c] Q-BOP installation.

Production and maintenance requirements dictate how many furnaces are operated simultaneously. For simultaneous operation, production cycles are staggered so each furnace can share the same scrap charge equipment, and hot metal and tapping ladle cranes.

The raw materials for basic oxygen steelmaking are molten pig iron, scrap steel, alloy additives, fluxes, and oxygen. Pig iron is provided by the blast furnace and delivered to the furnace shop in railcar ladles. It is then transferred into charging ladles that can be maneuvered by the overhead charging crane. Steel scrap may provide up to approximately 35 percent of the metallic charge. Many types of steel scrap are used, including relatively clean steel mill scrap and purchased bundles. Dirtier scrap may include oil coated turnings and stamping scraps, compacted automobiles, or recycled machinery. A variety of alloy additives such as aluminum, boron, tungsten nickel, etc. are added to the hot metal bath depending on scrap type, hot metal composition, and desired final steel chemistry. Fluxes are added to react with impurities in the metal and remove them by forming a floating slag. Alloys and fluxes may be added through a chute positioned above the furnace, or added while the furnace is in a turned-down position during temperature and chemistry measurement. In Q-BOP furnaces, powdered fluxes are injected through the tuyeres.

The basic oxygen furnace cycle consists of distinct operations that occur in the following order; scrap charge, hot metal charge, oxygen blowing, turndown, reblow (if necessary), tapping, slagging, and teeming. Each sequence is described below.

Initially, the furnace is rotated toward the charging aisle to facilitate charging. Scrap is first dumped into the furnace by either a hydraulically or crane operated bucket. The scrap charge usually lasts less than a minute. Then, hot metal is added to the vessel from an extended spout ladle positioned and poured by an overhead crane. In Q-BOP operation, nitrogen is blown through the tuyeres during hot metal addition to prevent clogging. One or two ladles of iron are usually necessary to complete the charge. The hot metal pour may last from less than half a minute to over 4 minutes.

Upon completion of the hot metal charge, the furnace is turned to the upright position and the lance lowered for the start of the oxygen blow. A prescribed weight of flux is added to the furnace through a flux chute in the hood. Oxygen is blown onto the surface of the metal at high velocities under a pressure that is normally held between 140 and 180 lb per square inch.[2] The amount of oxygen varies somewhat depending on the quality of the scrap and the desired final steel chemistry, but the amount usually approximates 2000 scf per ton of steel produced.[7] The start of the oxygen blow in a Q-BOP furnace occurs when the nitrogen flow through the tuyeres is switched to oxygen. For either type of furnace, the refining period normally lasts about 20 minutes. At a point about halfway through the blow, the oxidation reactions reach their maximum intensity. Increased turbulence and splashing of the bath, commonly termed "slopping", often causes some of the bath to spill over the mouth of the furnace and increases emission rates.

Upon completion of the oxygen blow, the furnace is turned down toward the charge aisle and tested for temperature and chemistry. If the metal is not within specifications, the furnace is returned to the upright position and a short reblow of oxygen is initiated. This reblow is also used if the metal has cooled. It may also be necessary to add fluxes or rock the furnace to cool the metal. Several reblows or temperature adjustments may be necessary before tapping. However, the goal is to avoid reblows and to limit the need for a reblow to an average of less than one heat out of three.

Tapping is accomplished by rotating the furnace toward the tapping aisle. The metal is poured through a taphole in the side of the furnace and into a teeming ladle positioned below the furnace. During tapping, alloy additions are added to the teeming ladle.

After the completion of the tap, the furnace is rotated towards the charging aisle and slag is dumped into a slag pot. The furnace is then returned to the charge position for the start of the next heat. The heat cycle (charge to tap) usually lasts about 45 minutes. The tapping ladle is transported by overhead crane to the teeming areas where the steel is poured into ingots or transported to a continuous caster.

Emission Generation

Emissions from the basic oxygen furnace are divided into two categories, primary and secondary. Primary emissions refer to any emissions generated while the furnace is in an upright position. Emissions escaping capture by the primary exhaust hood during the oxygen blow would be considered primary fugitive emissions. Secondary emissions refer to any emissions generated while the furnace is tilted; i.e., charging, turndowns, tapping, and slagging.

The paticulate emissions generated during oxygen blow consist of oxides of iron and impurities such as CaO and SiO_2. Primary emissions are currently controlled at all BOF and Q-BOP shops. All Q-BOPs and some BOFs use a closed hood system which reduces inlet gas volumes; the remaining BOFs use an open hood located farther above the mouth of the vessel. Compared to open hood systems, the gases in closed hood systems are hotter and contain higher percentages of carbon monoxide. The lack of excess air also permits only partial oxidation of iron, thus, the particulate in closed hood systems is composed mainly of iron oxide, FeO (magnetite), and small amounts of metallic iron. The higher FeO content in closed systems has been reported to be responsible for a larger particle size distribution compared to open hoods.

Slopping emissions frequently occur during the oxygen blow. These emissions are caused by surges in gas evolution which exceed the collection capabilities of the control system. Slopping occurs most often around the midpoint of the blow.

During scrap charging, a short duration emission is produced when the scrap enters the hot vessel. Emissions from hot metal charging are more intense and of longer duration than from scrap charge. These emissions are one of the most significant of the nonrefining secondary emissions. The quality of scrap charged affects the quantity of emissions. Clean, high quality scrap generally produces only light emissions, while scrap containing significant amounts of oil or other combustible material usually produces a large cloud of dense smoke. This plume consists mainly of iron oxide particulate and kish evolved from the hot pig iron as it cools upon contact with the much cooler scrap. Dust loadings of 0.4 to 0.5 gr/scf in an air volume of 100,000 scfm have been reported.[8] Hot metal charge emissions from Q-BOPs tend to be more severe than those from conventional BOFs due to the increased turbulence in the vessel caused by blowing nitrogen through the tuyeres.

Emission Controls

The control of emissions from the basic oxygen furnace is divided between primary and secondary categories. Table 2 shows the current distribution of primary emission controls used by the American steel industry. Although 70 percent of all operating furnaces use the open hood design, newer furnaces tend to be the closed hood design. The closed hood system consists of a retractable water-cooled skirt which fits close to the mouth of the furnace when positioned upright. Open hoods, or combustion hoods, are fixed in a stationary position a few feet above the mouth of the furnace.

TABLE 2. DISTRIBUTION OF PRIMARY CONTROL SYSTEMS FOR BOFs AND Q-BOPs IN THE U.S.

Number of furnaces			
Open hood, scrubber	Open hood, ESP	Closed hood, scrubber (BOF)	Closed hood, scrubber (Q-BOP)
22	36	11	9

Closed hoods have the advantage of reducing air inflow thus requiring treatment of much lower volumes of gas. Gas flow may be only 20 to 25 percent that of open hood systems, resulting in an almost 50 percent energy savings. Due to the explosion potential, electrostatic precipitators are not used on closed hood systems; gas cleaning is accomplished by venturi scrubbers with a pressure drop of at least 60 inches H_2O. Closed hood systems also allow a potential energy recovery of 0.44×10^6 Btu per ton of raw steel produced by the combustion of carbon monoxide in the treated gas.

ESPs are the predominant gas cleaner used in conjunction with open hood systems. Both ESPs and high pressure venturi scrubbers have been shown to be capable of complying with the New Source Performance Standard level of 50 mg/dscm (0.022 gr/dscf).[6]

As discussed earlier, secondary emissions include all furnace emissions occuring while the furnace is in a tilted position. Currently, 57 percent of the operating basic oxygen furnace vessels in the United States employ secondary emissions control. The techniques employed consist of one or more of the following techniques; complete furnace enclosures with or without charge side and tap side interior hoods, partial furnace enclosures, local hoods, deflector mechanisms to direct fumes toward the primary hood in open hood systems, and careful operating maintenance procedures using the existing primary hood.

Furnace enclosures were developed in Germany and first introduced in this country with the Q-BOP furnaces. There are two types of furnace enclosures: complete and partial enclosure. Complete enclosures are sometimes referred to as doghouses. Charging is accomplished through sliding doors at the front of the furnace. Partial furnace enclosures are three-sided enclosures, generally open on the charging side of the furnace. Furnace enclosures may rely on the primary control system to capture secondary emissions or may have charge side and/or tap side hoods to collect these emissions. Secondary emissions may be ducted to the primary control device or to a separate secondary control device. Dampers in the systems are adjusted to maintain optimum flow during all heat cycle operations and to divide flow between multiple furnaces using a common gas cleaner.

Local and canopy hoods have been employed in conjunction with a variety of furnace enclosure systems. Canopy hoods have the problem of needing to handle very large volumes of air. Emissions may escape capture by canopy hood systems due to possible shop cross drafts. Baghouses may be used to treat the cooler secondary emissions captured by local or canopy hoods.

In 1974, a United States patent was issued for a device called the "Gaw Damper" which facilitates emission capture during hot metal charging. The Gaw Damper is a plate which slides across the open face of the primary hood to close off approximately 70 to 80 percent of the face area. This increases in-draft velocity in the hood area closest to the mouth of the furnace and increases hood capture. Only two shops currently make use of the Gaw Damper concept.

Tapping emissions have been controlled at a variety of shops by the primary control device with the addition of tapside enclosures. The design of these systems differs, however, they essentially consist of an extension of the primary hood toward the tapping aisle which directs emissions into the primary hood.

Secondary control strategies have been developed which require no equipment installation or modification. These techniques depend on careful operation of the process and modification of some operating procedures. Charging emissions have been reduced by the use of only clean scrap, the use of an extended spout on the charging ladle, skillful furnace and crane manipulation, slow pouring, and limited furnace tilt to increase capture by the primary hood. This technique has been used with and without a Gaw Damper to reduce hot metal charging emissions.

OPEN HEARTH FURNACE

Process Description

The open hearth furnace process was once the industry workhorse. However, in the past 25 years, the basic oxygen process and electric furnace technology have replaced the cost and manpower-intensive open hearth. As of 1982 there were only seven operable open hearth shops left in the U.S., responsible for approximately 10 percent of all steel produced.

The open hearth furnace is a shallow refractory lined basin in which scrap and molten iron are combined for melting and refining to steel. The input material typically consists of 50 percent scrap and 50 percent molten iron; however, the furnaces are capable of handling 100 percent scrap or 100 percent molten iron. The open hearth shop is constructed so that a number of individual furnaces are arranged side by side along the length of the shop. A shop may consist of as many as 12 individual furnaces. The average size of an individual furnace heat is about 200 tons.

Currently, all open hearths are the basic slag variety. The open hearth furnace is capable of operating with a variety of materials including light and heavy grades of scrap, sinter, solid pig iron, molten pig iron, and iron ore in various proportions. The charging of solid materials is accomplished by inserting buckets through doors in the front of the furnace and dumping them with the charging machine. There are many variations in open hearth operating procedures dictated by the composition of charge materials and desired product grade. Reference 2 discusses open hearth design and operation in detail.

Heat for the process is provided by burners fired with natural gas, oil, tar or pitch, and sometimes coke oven or blast furnace gas. In recent years, open hearth furnaces have been retrofitted with oxygen lances to provide an additional, more direct heat source to speed up refining operation. Oxygen is blown through lance(s) extending through the furnace roof at rates of approximately 300 to 1000 cu. ft/ton of steel.[2,8]

The burners, air intakes and exhaust passages are provided on both ends of the furnace. The furnace operates on a regenerative principle where the intake and exhaust sides are switched periodically. The exhaust gas flows through a brick checkerwork which retains heat until the exhaust gas flow direction is reversed. After the flow reversal, the warm checkerwork on the inlet side warms intake combustion air prior to firing on the opposing burner.

The heat generated by the flame and oxygen melt and oxidize the scrap into solution with the molten iron from the blast furnace. Fluxing agents are added to combine with impurities and form a slag layer on top of the molten bath. At a point 1 to 3 hours after the start of the heat, when the scrap has been sufficiently heated or in some cases melted and oxidized, molten blast furnace iron is added to the furnace. The hot metal is poured from a ladle into a movable spout which is positioned at a charging door in the front of the furnace. The furnace then undergoes several phases of the process referred to as ore boil, lime boil, and working period which require an additional 6 to 7 hours.[2]

When the heat is finished, the furnace is tapped into a ladle which is then used to pour steel into ingots. Tapping is accomplished by placing a small explosive charge on the taphole located at the base of the furnace working volume on the back side of the furnace. Alternatively, the taphole may be opened by burning with oxygen.

Emission Generation

The primary emissions generated by an open hearth process are the combustion and reaction gases drawn off the furnace. The quantity and composition of these emissions vary considerably during the heat.[8] The fact that many furnaces, each at different stages in the heat cycle, are normally ducted to a single control device tends to smooth out variations in final exhaust gas. Some of the large particulates settle out in the slag pockets which act as settling chambers before the gas enters the regenerative checkerwork passages. Additional settling occurs in the checkerwork and the passages eventually become clogged and must be cleaned. The exhaust gas passes through a waste heat boiler prior to entering a common duct leading to pollution control device(s).

The use of oxygen lancing produces significantly higher concentrations of dust and fume emissions than the old conventional operation. The quality and quantity of scrap charged also affects emissions. Particulates produced from the open hearth furnace have been reported to be up to 90 percent iron oxide (Fe_2O_3). During the lime boil (more than one-third of the heat), the percentage of iron oxide may be less. When large amounts of scrap are charged, zinc oxides may be significant during the early stage of the heat. The exhaust gases also contain sulfur oxides, nitrogen oxides, and fluorides. 8

Emission Controls

Primary emissions from currently existing open hearth shops are controlled by either electrostatic precipitators or scrubbers. Precipitators are the more common control device. Furnaces may be ducted to an individual control device or they may be manifolded such that several devices control emissions from all furnaces in the shop.

A few shops have installed capture systems to collect secondary emissions from hot metal transfer operations. These systems use either a baghouse or an electrostatic precipitator for emission control.

ELECTRIC ARC FURNACE

Process Description

The electric arc furnace (EAF) is used to produce steels with a wide range of composition including carbon alloy and stainless steel grades. Electric arc furnaces produced 27,882,000 tons of steel in 1977, accounting for 22 percent of total U.S. steel production. Various factors have contributed to the increased use of electric arc furnaces for steel production. These factors include increasing blast furnace energy costs, larger supplies of steel scrap, growing use of specialty steels, mini-steel plants that use EAFs exclusively, and development of new steel melting technology.[9]

Electric arc furnaces are cylindrical, refractory-lined vessels. They range in size from a diameter of about 7 feet with a hot metal capacity of about 3 tons to a diameter of 38 feet with a metal capacity of 400 tons.[9] A sectional view of an electric arc furnace is shown in Figure 3. Three cylindrical solid graphite electrodes, suspended from above the shell, extend down through ports in the furnace roof. The electrodes conduct the electric current needed for melting and refining. The furnace structure is mounted on toothed rockers and rails to permit forward and backward rocking of the furnace. Most furnaces are designed to tilt 75° backward for deslagging and 45° forward for tapping. There are mechanisms to position electrodes, to remove the roof for top charging, and to operate the doors of the furnace enclosure.

Openings for tapping, slagging, and working the charge and a side door are provided in the furnace shell structure. The side door, which is used as an aid in refining the charge and patching the walls, is sometimes omitted to reduce heat losses and air infiltration. Instead, covered ports may be provided to facilitate patching, oxygen blowing, and for lime and carbon injection lances.

The raw materials for electric arc furnace steelmaking are scrap, ferroalloys, and fluxes. The charge material is transported to the furnace by loading it into drop bottom charge buckets, ranging in capacity from about 100 to 400 cubic feet. The bucket is moved by overhead cranes. The two charging methods for EAFs are top charging and door charging. Top charging is by far the most common technique. The electrodes and roof are moved away and the scrap material is placed in the furnace by drop-bottom buckets. Since the furnace bottom undergoes a shock when materials are charged to it, the buckets are loaded with a layer of light scrap on the bottom to provide some cushioning for the larger pieces of scrap. Door charging sometimes is used to charge heavy scrap metal. The door is removed and the electrodes are raised as high as possible to prevent breakage. A bin-type bucket with a side chute is used to pour in the scrap. After the scrap charge, fluxes and alloys are added according to a schedule. The type and quantity of alloys charged are dependent on the composition of scrap and of the desired product.

A few plants are designed for hot metal charging. Hot metal would normally be charged after the scrap has been heated. The charge is melted by lowering the electrodes and applying electric current. The lowering mechanism is constructed to allow the electrodes to bore into the cold scrap as needed. The voltage is increased shortly after the electrodes begin to penetrate the charge in order to speed the melting rate. The charge is melted from radiation and the resistance heating generated by the arc between the electrodes.

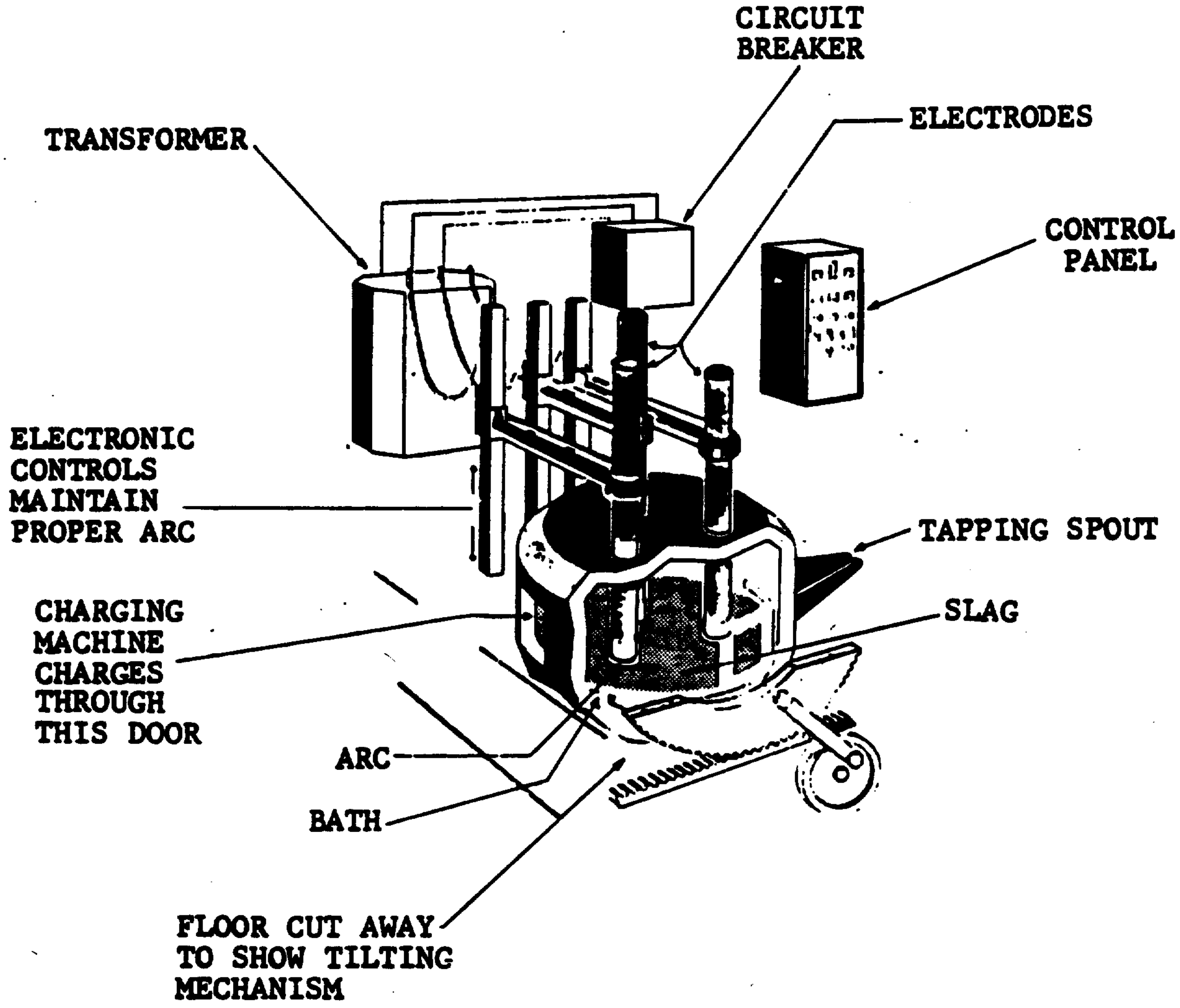

Figure 3. Sectional view of an electric arc furnace.[10]

When the molten metal has reached the desired composition, the power is shut off, the electrodes are raised above the furnace vessel, ~~and the steel is tapped by~~ tilting the furnace. The slag may be tapped before, with, or after the product. The product steel is tapped into teeming ladles. The liquid steel is sometimes further refined by adding alloys to the ladle prior to teeming into the molds.

Oxygen is sometimes injected into the melt via a lance to reduce carbon in the metal. The amount of oxygen injected depends on the carbon and oxygen content of the raw materials.

Emission Generation

Emissions from the furnace occur during charging, melting, oxygen-blowing, and tapping operations. Fugitive dust emissions are generated by scrap and raw material unloading, storage, and transfer activities.

Initial charging of scrap produces emissions of oil, grease, or other organics present in the charge. Emissions increase if the scrap metal is heavily contaminated with foreign matter. The process of charging additional scrap during a heat, called back charging, causes substantial emissions due to the reaction between the cold scrap and the molten bath. Charging emissions are not usually collected by the furnace evacuation system because the cover is removed during this operation, but are often captured by canopy hoods or other techniques.

The greatest emissions occur during the early melting portion of the furnace cycle. These emisisons may be effectively captured by a furnace roof evacuation system. However, some fumes escape through the electrode ports. Occasionally, oxygen blown into the furnce during refining greatly increases the amount of emissions generated. Lime addition by crane may also cause increased furnace emissions. The quantity and type of particulate emissions generated during melting are affected by scrap cleanliness, amount of alloy additives, and degree of refining. The production of carbon steel in electric arc furnaces usually generates much greater emissons than does the production of alloy steel.

Emission Controls

A variety of systems have been developed to control emissions from electric arc furnaces. These include direct shell evacuation through a fourth hole in the furnace cover, total building evacuation, canopy hoods, and local hoods.

The use of direct shell evacuation requires the least amount of exhaust gas handling capacity. These systems cannot capture charging emissions from top charged furnaces and a secondary control system is usually required. Side draft hoods can be constructed to control emissions from a covered furnace such that a draft around the edges and/or through the electrode ports is created. Such hoods must be movable so the electrodes and furnace cover can be moved during charging. Local hoods may also be employed in the tapping area to capture tapping emissions.

Canopy hoods are used to capture either all furnace emissions or to capture only fugitives which escape a direct furnace evacuation system. Leaks, tapping, and charging emissions can be controlled by several canopy hoods which may be divided and dampered so that the section above the emission source can receive maximum evacuation. Total building evacuation is also used to capture all furnace emissions or in conjunction with a direct furnace evacuation system to capture charging, tapping, and fugitive emissions. Furnace enclosures ducted to a control device have also been employed to control emissions from tapping, charging, melting, and refining.

Almost all EAFs use baghouses to clean furnace emissions. In shops with both furnace evacuation and fugitive collection systems, the systems may be ducted to separate control devices.

HOT METAL DESULFURIZATION

Process Description

Over the last decade, hot metal desulfurization has become increasingly popular among both large and small steel producers. Desulfurization has traditionally been accomplished in the blast furnace by operational adjustments and better control of charge materials. However, many plants have recently switched to external desulfurization in order to increase blast furnace yields and still meet low sulfur specifications of high quality steels. This is accomplished by reducing the coke and limestone added in the blast furnace burden, thereby allowing more iron-bearing materials to be charged. External desulfurization also makes practical the use of lower quality coking coals, containing higher sulfur contents, within coke batteries.[9]

A variety of processes have been developed for the desulfurization of blast furnace iron. Additional processes have been developed for desulfurizing steel produced in electric arc furnaces and basic oxygen furnaces after tapping. Iron desulfurization is performed either in torpedo ladles at a station enroute to the steel refining shop or in the transfer ladle inside the refining shop.

The basic process consists of injecting reagents into the hot metal via a lance. The reagents combine with sulfur in the iron and form a floating slag which can be skimmed off. Reagents that are commonly used are powdered calcium carbide (CaC_2) and limestone ($CaCO_3$), powdered magnesium and limestone, and salt-coated magnesium granules. Powdered reagents are injected into the ladle through a lance with high pressure nitrogen. The desulfurization process usually lasts from 5 to 30 minutes,[11,12] depending on the quantity of sulfur requiring removal.

Emission Generation and Control

The injection, and subsequent reaction, of desulfurizing reagents with the hot metal (iron) creates significant amounts of fume. The degree of emission generation depends on the amount of reagent used, the period and rate of injection, and the hot metal temperature. The duration of the desulfurization is determined by the iron sulfur content and the desired percent reduction for use in the steel refining process.

Splash shields may be placed over the mouth of the ladle to prevent metal from splashing out of the ladle. Emissions from the desulfurization process are controlled by collection hoods located above or alongside the mouth of the furnace; i.e., stationary, retractable canopy, or side draft hoods, respectively. The most commmon gas cleaning device used for controlling desulfurization fumes is a baghouse.

SECTION 3

IRON AND STEEL PRODUCTION EMISSION FACTORS

TOTAL AND SIZE SPECIFIC PARTICULATE EMISSION FACTORS

Emission factors for total and size-specific particulate for the iron and steel industries have been generated from information available in the May 1983 update of AP-42, in addition to several other recent reports. Additions to the May 1983 AP-42 particulate emission factor data base include information pertaining to uncontrolled casthouse emissions from blast furnaces with local evacuation, controlled and uncontrolled hot metal desulfurization, baghouse-controlled BOF charging, and baghouse-controlled BOF tapping.* All additions were based on reports that included total and size-fractionated particulate emission information with adequate production data to allow calculation of emission factors.

Total particulate emission factors are presented in Table 3. Particle size distributions for controlled and uncontrolled emissions are presented in tabular form in Table 4 and graphically in Figures 4 through 6. The data presented herein are considered typical for each source category. However, the particle size distribution of emissions from different sources within a particular source category is expected to vary as total mass emissions from similar processes vary. Emission variability may result from subtle or gross differences in design, operating conditions, feedstocks, control device performance, and maintenance programs. Care should be taken when using the particle size distributions presented herein, and emission factors in general.

DATA REVIEW AND TEST RATING

All available sources of data were reviewed for the compilation of source category particle size distributions. Only sources of data which reported the results of actual measurements of particle size distributions obtained by aerodynamic techniques were considered. These data were primarily stack test reports containing cyclone or impactor measurements. When a secondary data source was discovered, an attempt was made to obtain the primary source on which it was based.

All acceptable sources were extensively reviewed and analyzed. The data were ranked using an A-D grading system based on data quality and reliability according to the criteria described in Section 1. The reports reviewed were

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*The term "BOF" in this report refers to only top-blown, conventional basic oxygen furnaces, not including Q-BOPs.

TABLE 3. PARTICULATE EMISSION FACTORS FOR IRON AND STEEL MILLS[a]

Source	Units	Emission factors	Emission factor rating	Size data
Sintering				
Windbox emissions	kg/Mg (lb/T) finished sinter			
Uncontrolled				
Leaving grate		5.56 (11.1)	B	Yes
After coarse particulate removal		4.35 (8.7)	A	
Controlled by dry ESP		0.8 (1.6)	B	
Controlled by wet ESP		0.085 (0.17)	B	Yes
Controlled by venturi scrubber		0.235 (0.47)	B	Yes
Controlled by cyclone		0.5 (1.0)	B	Yes
Sinter discharge (breaker and hot screens)	kg/Mg (lb/T) finished sinter			
Uncontrolled		3.4 (6.8)	B	
Controlled by baghouse		0.05 (0.1)	B	Yes
Controlled by venturi scrubber		0.295 (0.59)	A	
Windbox and discharge	kg/Mg (lb/T) finished sinter			
Controlled by baghouse		0.15 (0.3)	A	
Blast Furnaces				
Slips	kg/Mg (lb/T)/slip	39.5 (87.0)	D	
Uncontrolled casthouse emissions	kg/Mg (lb/T) hot metal			
Roof Monitor[b]		0.3 (0.6)	B	Yes

(continued)

TABLE 3 (continued)

Source	Units	Emission factors	Emission factor rating	Size data
Furnaces with local evacuation[c]		0.65 (1.3)	B	Yes
Taphole and trough only (not runners)		0.15 (0.3)	B	
Hot Metal Desulfurization Emissions				
Uncontrolled		0.55[d] (1.09)	D	Yes
Controlled by baghouse		0.0045 (0.009)	D	Yes
Basic Oxygen Furnaces				
BOF melting and refining	kg/Mg (lb/T) steel			
Uncontrolled		14.25 (28.5)	B	
Controlled by open hood vented to:				
ESP		0.065 (0.13)	A	
Scrubber		0.045 (0.09)	B	
Controlled by closed hood vented to:				
Scrubber		0.0034 (0.0068)	A	Yes
BOF Charging	kg/Mg (lb/T) hot metal			
At source		0.3 (0.6)	D	
At building monitor		0.071 (0.142)	B	
Controlled by baghouse		0.0003 (0.0006)	D	Yes
BOF Tapping	kg/Mg (lb/T) steel			
At source		0.46 (0.92)	D	
At building monitor		0.145 (0.29)	B	
Controlled by baghouse		0.0013 (0.0026)	D	Yes

(continued)

TABLE 3 (continued)

Source	Units	Emission factors		Emission factor rating	Size data
BOF metal transfer	kg/Mg (lb/T) hot metal				
At source		0.095	(0.19)	A	
At building monitor		0.028	(0.056)	B	
BOF monitor (all sources)	kg/Mg (lb/T) steel	0.25	(0.5)	B	
Q-BOP melting and refining	kg/Mg (lb/T) steel				
Controlled by scrubber		0.028	(0.056)	B	Yes
Electric Arc Furnaces					
Melting and refining	kg/Mg (lb/T) steel				
Uncontrolled					
Carbon steel		19.0	(38.0)	C	Yes
Charging, tapping and slagging	kg/Mg (lb/T) steel				
Uncontrolled emissions escaping monitor		0.7	(1.4)	C	
Melting, refining, charging, tapping and slagging	kg/Mg (lb/T) steel				
Uncontrolled					
Alloy steel		5.65	(11.3)	A	
Carbon steel		25.0	(50.0)	C	
Controlled by:[e]					
Building evacuation to baghouse for alloy steel		0.15	(0.3)	A	
Direct shell evacuation (plus charging hood) vented to common baghouse for carbon steel		0.0215	(0.043)	E	Yes

(continued)

TABLE 3 (continued)

Source	Units	Emission factors	Emission factor rating	Size data
Open Hearth Furnaces				
Melting and refining	kg/Mg (lb/T) steel			
Uncontrolled		10.55 (21.1)	D	Yes
Controlled by ESP		0.14 (0.28)	D	Yes
Roof monitor emissions		0.084 (0.168)	C	
Teeming				
Leaded steel	kg/Mg (lb/T) steel			
Uncontrolled (as measured at the source)		0.405 (0.81)	A	
Controlled by side-draft hood vented to baghouse)		0.0019 (0.0038)	A	
Unleaded steel				
Uncontrolled (as measured at the source)		0.035 (0.07)	A	
Controlled by side-draft hood vented to baghouse		0.0008 (0.0016)	A	
Machine Scarfing				
Uncontrolled	kg/Mg (lb/T) metal through scarfer	0.05 (0.1)	B	
Controlled by ESP		0.0115 (0.023)	A	
Miscellaneous Combustion Sources[f]				
Boilers, soaking pits and slab reheat furnaces	kg/10^9 J ($lb/10^6$ Btu)			
Blast furnace gas[g]		0.015 (0.035)	D	
Coke oven gas[g]		0.0052 (0.012)	D	

TABLE 3 (continued)

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[a] Reference 13, except as noted.

[b] Typical of older furnaces with no controls, or for canopy hoods or total casthouse evacuation.

[c] Typical of the large, new technology furnaces with local hoods and covered, evacuated runners. Emissions are higher than without capture systems because emissions are concentrated or not diluted by the outside environment.

[d] Emission factor of 1.09 lb/ton represents one torpedo car; 2.53 lb/ton for two torpedo cars, and 2.74 lb/ton for three torpedo cars.

[e] Building evacuation collects all process emissions while direct shell evacuation collects only melting and refining emissions.

[f] For fuels such as coal, fuel oil, and natural gas, use the emission factors presented in Chapter 1 of this document. The rating for these fuels in boilers is A, and in soaking pits and slab reheat furnaces is D.

[g] Emission factor based on methane content and cleaned particulate loading.

TABLE 4. SIZE SPECIFIC EMISSION FACTORS

Source	Emission factor rating (A-E)	Particle[+] size (micrometers)	Cumulative mass % less than stated size	Cumulative mass emission factor kg/Mg alloy	(lb/ton alloy)
Sintering					
Windbox emissions					
Uncontrolled					
Leaving grate	D	0.5	4 [a]	0.22	(0.44)
		1.0	4	0.22	(0.44)
		2.5	5	0.28	(0.56)
		5.0	9	0.50	(1.00)
		10	15	0.83	(1.67)
		15	20 [b]	1.11	(2.22)
		*	100	5.56	(11.1)
Controlled by wet ESP	C	0.5	18 [a]	0.015	(0.03)
		1.0	25	0.021	(0.04)
		2.5	33	0.028	(0.06)
		5.0	48	0.041	(0.08)
		10	59 [a]	0.050	(0.10)
		15	69	0.059	(0.12)
		*	100	0.085	(0.17)
Controlled by venturi scrubber	C	0.5	55	0.129	(0.26)
		1.0	75	0.176	(0.35)
		2.5	89	0.209	(0.42)
		5.0	93	0.219	(0.44)
		10	96	0.226	(0.45)
		15	98	0.230	(0.46)
		*	100	0.235	(0.47)
Controlled by cyclone[c]	C	0.5	25 [b]	0.13	(0.25)
		1.0	37 [a]	0.19	(0.37)
		2.5	52	0.26	(0.52)
		5.0	64	0.32	(0.64)
		10	74	0.37	(0.74)
		15	80	0.40	(0.80)
		*	100	0.5	(1.0)
Controlled by baghouse	D	0.5	3	0.005	(0.009)
		1.0	9	0.014	(0.027)
		2.5	27	0.041	(0.081)
		5.0	47	0.071	(0.141)
		10	69	0.104	(0.207)
		15	79	0.119	(0.237)
		*	100	0.150	(0.30)

(continued)

TABLE 4 (continued)

Source	Emission factor rating (A-E)	Particle[+] size (micrometers)	Cumulative mass % less than stated size	Cumulative mass emission factor kg/Mg alloy	(lb/ton alloy)
Sinter Discharge (breaker and hot screens) controlled by baghouse	C	0.5	2 [b]	0.001	(0.002)
		1.0	4	0.002	(0.004)
		2.5	11	0.006	(0.011)
		5.0	20	0.010	(0.020)
		10	32 [b]	0.016	(0.032)
		15	42 [b]	0.021	(0.042)
		*	100	0.05	(0.1)
Blast Furnaces					
Uncontrolled casthouse emissions					
Roof monitor[d] Total or partial evacuation	C	0.5	4	0.01	(0.02)
		1.0	15	0.05	(0.09)
		2.5	23	0.07	(0.14)
		5.0	35	0.11	(0.21)
		10	51	0.15	(0.31)
		15	61	0.18	(0.37)
		*	100	0.3	(0.6)
Furnace with local evacuation[e]	C	0.5	7 [b]	0.04	(0.09)
		1.0	9	0.06	(0.12)
		2.5	15	0.10	(0.20)
		5.0	20	0.13	(0.26)
		10	24	0.16	(0.31)
		15	26	0.17	(0.34)
		*	100	0.65	(1.3)
Hot Metal Desulfurization Uncontrolled	E	0.5	N/A		
		1.0	2 [b]	0.01	(0.02)
		2.5	11	0.06	(0.12)
		5.0	19	0.10	(0.22)
		10	19	0.10	(0.22)
		15	21	0.12	(0.23)
		*	100	0.55	(1.09)

(continued)

TABLE 4 (continued)

Source	Emission factor rating (A-E)	Particle$^+$ size (micro- meters)	Cumulative mass % less than stated size	Cumulative mas emission facto	
				kg/Mg alloy	(lb/ton alloy
Hot Metal Desulfurization					
Controlled baghouse	D	0.5	8	0.0004	(0.000
		1.0	18	0.0008	(0.001
		2.5	42	0.0019	(0.003
		5.0	62	0.0028	(0.005
		10	74	0.0033	(0.006
		15	78	0.0035	(0.007
		*	100	0.0045	(0.009
Basic Oxygen Furnaces					
BOF melting and refining					
Controlled by closed hood and vented to:					
Scrubber:	C	0.5	34	0.0012	(0.002
		1.0	55	0.0019	(0.003
		2.5	65	0.0022	(0.004
		5.0	66	0.0022	(0.004
		10	67	0.0023	(0.004
		15	72^b	0.0024	(0.004
		*	100	0.0034	(0.006
BOF Charging					
At source^g	E	0.5	8^b	0.02	(0.05)
		1.0	12	0.04	(0.07)
		2.5	22	0.07	(0.13)
		5.0	35	0.10	(0.21)
		10	46	0.14	(0.28)
		15	56	0.17	(0.34)
		*	100	0.3	(0.6)
BOF Charging					
Controlled by baghouse	D	0.5	3	$7.5x10^{-6}$	(1.5x10
		1.0	10	$3.0x10^{-5}$	(6.0x10
		2.5	22	$6.6x10^{-5}$	(0.000
		5.0	31	$9.3x10^{-5}$	(0.000
		10	45	0.0001	(0.000
		15	60	0.0002	(0.000
		*	100	0.0003	(0.000

(continued)

TABLE 4 (continued)

Source	Emission factor rating (A-E)	Particle[+] size (micrometers)	Cumulative mass % less than stated size	Cumulative mass emission factor	
				kg/Mg alloy	(lb/ton alloy)
BOF Tapping At source[g]	E	0.5	N/A	N/A	(N/A)
		1.0	11	0.05	(0.10)
		2.5	37	0.17	(0.34)
		5.0	43	0.20	(0.40)
		10	45	0.21	(0.41)
		15	50	0.23	(0.46)
		*	100	0.46	(0.92)
BOF Tapping Controlled by baghouse	D	0.5	4	5.210^{-5}	(0.0001)
		1.0	7	0.0001	(0.0002)
		2.5	16	0.0002	(0.0004)
		5.0	22	0.0003	(0.0006)
		10	30	0.0004	(0.0008)
		15	40	0.0005	(0.0010)
		*	100	0.0013	(0.0026)
Q-BOP melting and refining Controlled by Scrubber:	D	0.5	45	0.013	(0.025)
		1.0	52	0.015	(0.029)
		2.5	56	0.016	(0.031)
		5.0	58	0.016	(0.032)
		10	68[b]	0.019	(0.038)
		15	85[b]	0.024	(0.048)
		*	100	0.028	(0.056)
Electric Arc Furnaces					
Melting and refining Uncontrolled Carbon Steel[h]	D	0.5	8	1.52	(3.04)
		1.0	23	4.37	(8.74)
		2.5	43	8.17	(16.34)
		5.0	53	10.07	(20.14)
		10	58	11.02	(22.04)
		15	61	11.59	(23.18)
		*	100	19.0	(38.0)

(continued)

TABLE 4 (continued)

Source	Emission factor rating (A-E)	Particle[+] size (micrometers)	Cumulative mass % less than stated size	Cumulative mass emission factor kg/Mg alloy	(lb/ton alloy)
Electric Arc Furnaces					
Melting, refining, charging, tapping and slagging					
Controlled by:					
Direct shell evacuation (plus charging hood) vented to common baghouse for carbon steel[i]	E	0.5	74 [b]	0.0159	(0.0318
		1.0	74	0.0159	(0.0318
		2.5	74	0.0159	(0.0318
		5.0	74	0.0159	(0.0318
		10	76	0.0163	(0.0327
		15	80	0.0172	(0.0344
		*	100	0.0215	(0.043)
Open Hearth Furnaces					
Melting and refining					
Uncontrolled	E	0.5	1 [a]	0.11	(0.21)
		1.0	21	2.22	(4.43)
		2.5	60	6.33	(12.66)
		5.0	79	8.33	(16.67)
		10	83	8.76	(17.51)
		15	85 [b]	8.97	(17.94)
		*	100	10.55	(21.1)
Controlled by ESP[j]	E	0.5	10 [b]	0.014	(0.028)
		1.0	21	0.03	(0.06)
		2.5	39	0.05	(0.10)
		5.0	47	0.07	(0.13)
		10	53 [a]	0.07	(0.15)
		15	56 [b]	0.08	(0.16)
		*	100	0.14	(0.28)

(continued)

TABLE 4 (continued)

N/A - Unable to extrapolate due to insufficient data and/or curve exceeds limits.

[+] Particle aerodynamic diameter based on task group on lung dynamics definition (particle density = 1 g/cm^3).

[*] Total particulate based on Method-5 total catch. See Table 7.5-1.

[a] Interpolated data used to develop size distribution.

[b] Extrapolated, using engineering estimates.

[c] This is average of various efficiency cyclones.

[d] Total casthouse evacuation control system.

[e] Evacuated runner covers and local hood over taphole, typical of new state-of-the-art blast furnace technology.

[f] Torpedo ladle desulfurization with CaC_2 and $CaCO_3$.

[g] Doghouse type furnace enclosure using front and back sliding doors, totally enclosing the furnace; emissions vented to hoods.

[h] Full cycle emissions captured by canopy and side draft hoods.

[i] Information on control system not available.

[j] May not be representative - test outlet size distribution was larger than inlet - may indicate reentrainment problem.

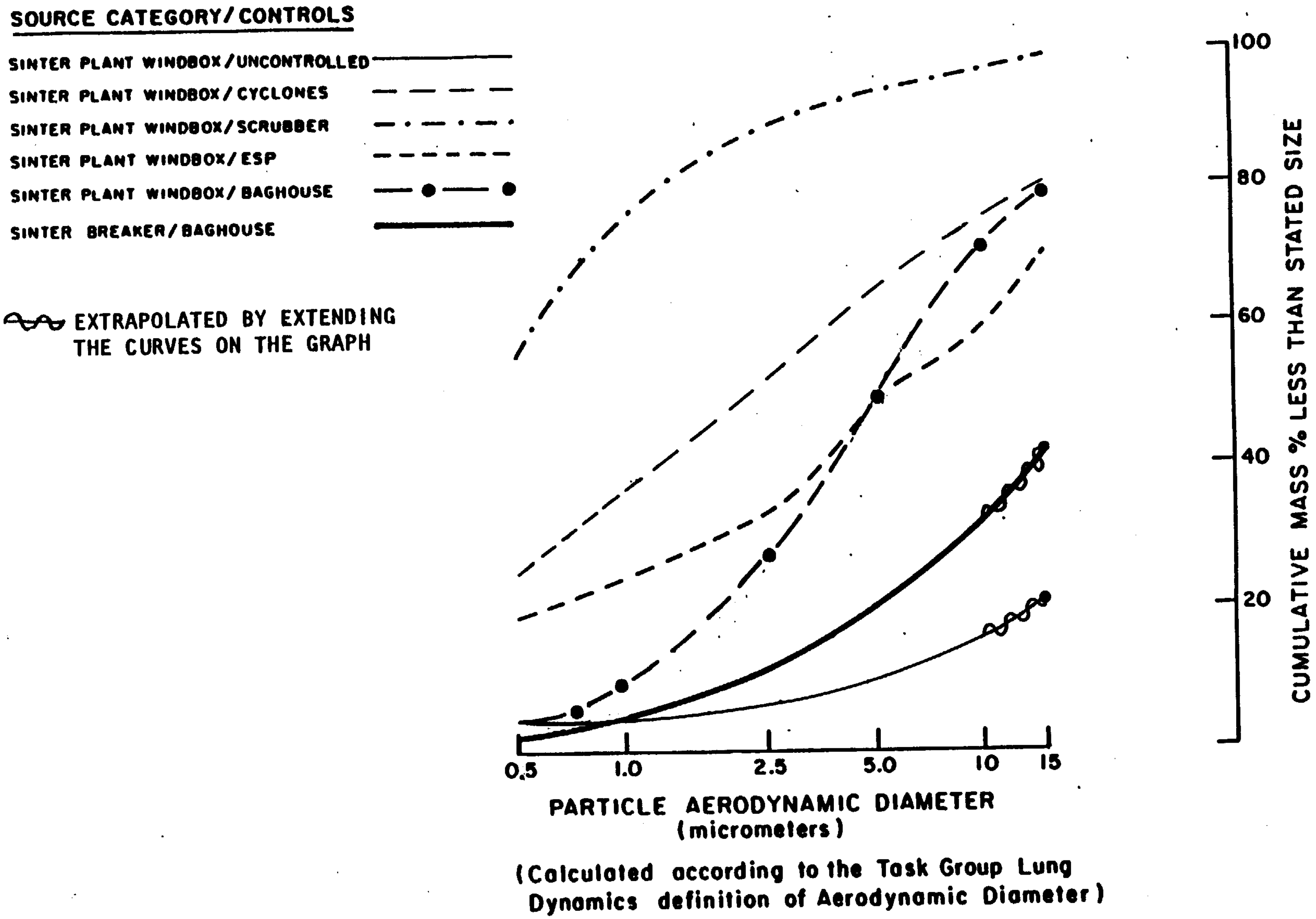
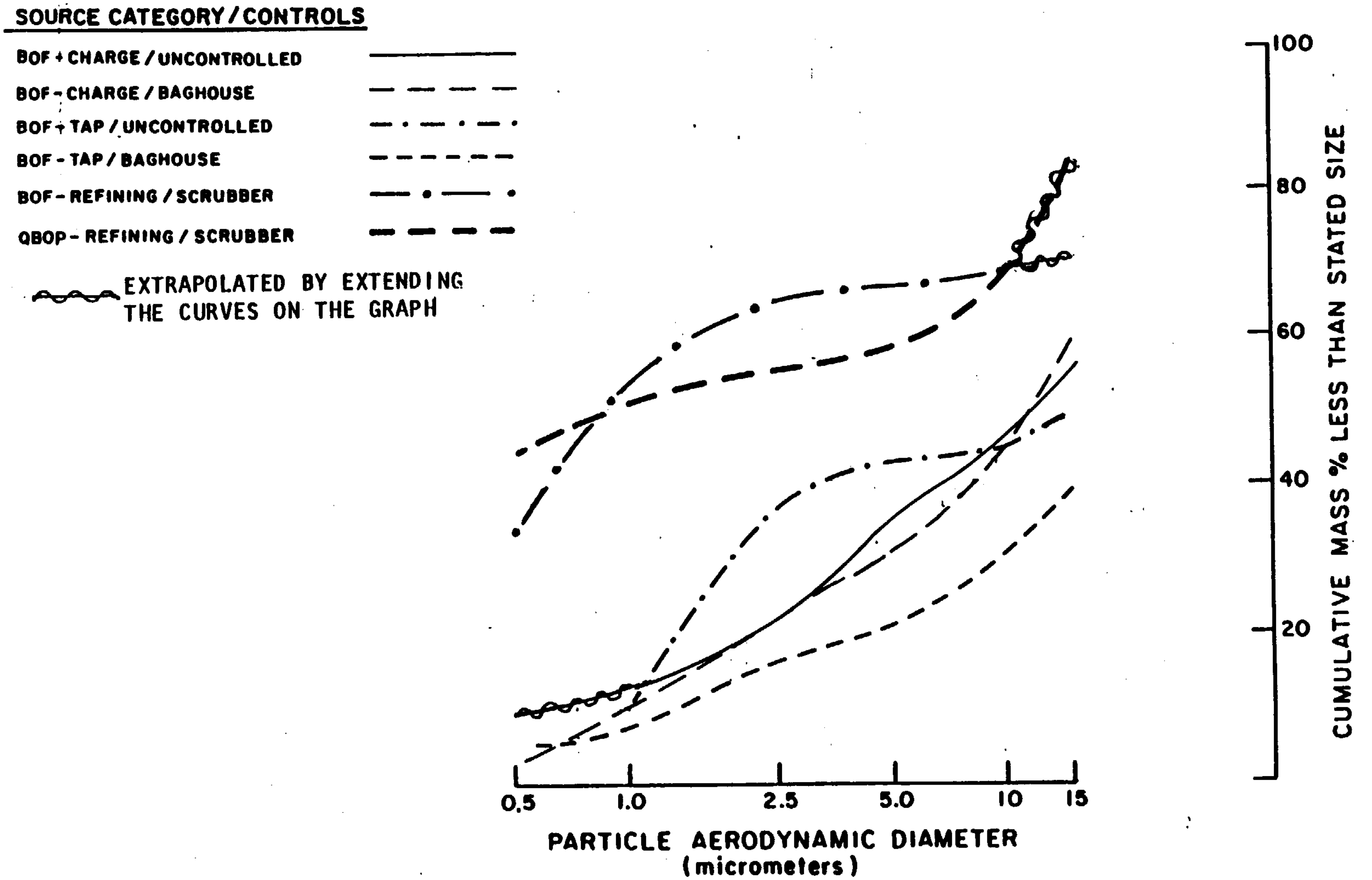
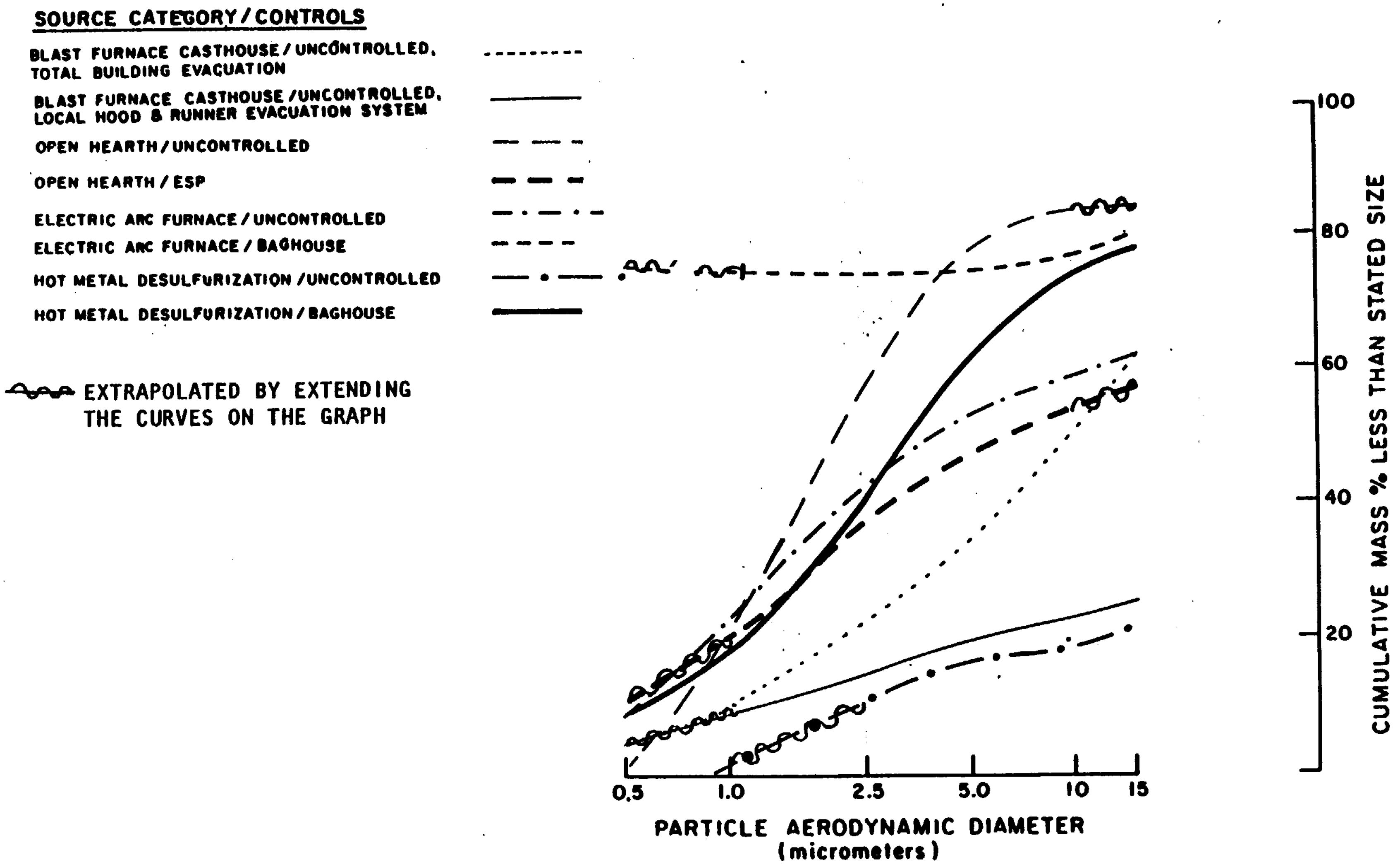


Figure 4. Particle size distribution of sinter plant emissions.



(Calculated according to the Task Group Lung Dynamics definition of Aerodynamic Diameter)

Figure 5. Particle size distribution of basic oxygen furnace emissions.



(Calculated according to the Task Group Lung Dynamics definition of Aerodynamic Diameter)

Figure 6. Particle size distribution of blast furnace, open hearth, electric

TABLE 5. SOURCE TEST REPORTS REVIEWED

Process	Control device	Test #	Ref #	Rated	Comments
Sinter Plant Windbox	none	1	14	B	
	none	2	15	D	Test on slip stream
	cyclones	3	16	D	Optical method
	cyclones	4	17	D	Fine Particle Emission Information System
	cyclones	5	18	C	
	cyclones	6	19	B	
	cyclones	7	20	B	
	venturi scrubber	8	20	B	
	venturi scrubber	9	21	A	
	ESP	10	14	B	
	ESP	11	19	B	
	baghouse	12	22	B	
Sinter Breaker	baghouse	13	19	A	
Blast Furnace Casthouse	none	14	23	A	Uncontrolled emissions total casthouse evacuation casting and non casting
	none	15	24	A	Uncontrolled emissions casting only - evacuated runners and hoods
	none	16	25	D	High volume samplers above crane
BOF - Charge	none	17	26	D	Source Assessment Sampling System
	none	18	27	D	Source Assessment Sampling System
	none	19	28	C	Dual Cyclone
	baghouse	20	28	B	
- Tap	none	21	26	D	Source Assessment Sampling System
	none	22	28	C	Dual Cyclone
	baghouse	23	28	B	
- Refining	venturi scrubber	24	29	A	Closed hood system
	venturi scrubber	25	30	D	Fugitives from canopy
QBOP - Hot Metal Charge	none	26	31	D	SASS disregard probe rise
	none	27	26	D	
- Cycle emissions	high energy scrubber	28	32	B	
Open Hearth	scrubber	29	33	B	INLET tests only-considered uncontrolled data
	ESP	30	17	D	INLET tests only-considered uncontrolled data
	ESP	31	17	D	
Electric Arc Furnace	none	32	34	B	
	none	33	35	C	
	none	34	36	D	
	baghouse	35	36	D	
Hot Metal Desulfurization	none	36	37	B/C	
	baghouse	37	37	B	

rated and grouped according to process type. Table 5 lists the test data reviewed and rating assigned. In cases where a single test report presented data on two processes, or controlled and uncontrolled emission data on the same process, each was considered separately.

SINTER PLANTS - WINDBOX

Uncontrolled Emissions

Test No. 1[14] was performed at the CF&I sinter plant in Pueblo, Colorado by EPA during June 1975. Windbox emissions were measured before the multiclones at the inlet to the ESP. The sampling point was within 2 diameters of an upstream flow disturbance. Five Brinks impactor runs were conducted. One of the five impactor runs was determined to be invalid. The data shown presents the average of the four valid runs. Data from the four good runs were closely grouped, indicating a consistent particle size distribution. The test report [14] describes the sinter plant and presents process information, however, some relevant data such as calibrations and sample calculations were missing. The data were rated B.

Test No. 2[15] was performed at the U.S. Steel Corporation, Saxonburg, PA plant by Cottrell Env. Sciences. Windbox emissions were measured in a slip stream at the inlet to a pilot plant ESP. Six Andersen Impactor runs were conducted. The results were rated D due to possible unrepresentativeness of the slip stream tested and poor documentation.

Controlled by Cyclones

Test No. 3[16] was performed at the U.S. Steel Corporation, Saxonburg, PA plant by Pennsylvania Dept. of Environmental Resources during January 1971. Sintering emissions were measured with one test at the outlet of the multiclones. The test report did not detail the process conditions or sampling procedure. Particle size was determined by an optical counting method. No discussions of the test method or consideration of optical versus aerodynamic diameter was presented. The results of Test No. 3 were rated D.

Test No. 4[17] was obtained from EPA's Fine Particulate Emission Information System (FPEIS) (test series No. 232). It contained information on a sinter plant controlled by cyclones followed by a baghouse. One impactor run was conducted at the baghouse inlet (cyclone outlet). The data were rated D due to lack of background information.

Test No. 5[18] was conducted at the Jones & Laughlin Steel Co., Cleveland sinter plant by WFI Sciences Co. during February 1975. Andersen Impactors were used to measure particle size distribution on three days during which process conditions were varied. Size measurements were poorly documented and changing process conditions may have created uncharacteristic emissions. The data were rated C.

Test No. 6[19] was performed at Bethlehem Steel Corporation, Bethlehem Plant during May and June of 1975 by York Research Corp. Windbox emissions from the No. 3 and No. 4 sinter lines were measured at the No. 2 ESP inlet duct down stream of the multiclone precollectors. The test program appeared adequate and well documented in the test report. Although only four inlet Brinks impactor runs were conducted, these data showed good consistency of measured particle size distribution. The report lacked instrument calibration data and some inconsistencies were found in the presentation of the data. Based on the above information, the data from the four inlet runs were rated B.

Test No. 7[20] was performed at the National Steel Corporation, Granite City Steel Division, sinter plant by York Research Corp. during May 1975. The windbox emissions were sampled between the cyclone collectors and the venturi scrubber. Three valid Brinks impactor runs were performed and the results showed a moderate amount of scatter, possibly indicating inconsistent size distribution or stratification within the duct. The report lacks calibration and run sheets, a diagram of sampling facilities and detailed process description. Insufficient documentation and a sampling location less than two diameters from a flow disturbance in a rectangular duct contributed to a rating of B for these data.

Controlled by Scrubber

Test No. 8[20] was performed at National Steel Corporation, Granite City Division, sinter plant by York Research Corp. during May 1975. Outlet sampling was conducted at the venturi scrubber outlet. These three runs were performed with Andersen impactors and the measured size distributions were consistent. The report lacked background information and process data. The data were rated B.

Test No. 9[21] was performed at Bethlehem Steel Corp. Sparrows Point Plant No.7 sinter strand by GCA/Technology Division during November 1979. Six Andersen impactor runs were conducted at the Venturi scrubber outlet. The data showed a considerable amount of scatter. The test program was well documented and no major problems were uncovered with the methodology or location. The process was observed during the testing. The data were rated A.

Controlled by ESP

Test No. 10[14] was performed at the CF&I sinter plant in Pueblo, Colorado by EPA during June 1975. Windbox emissions were controlled by an ESP. The sampling position was 1.5 diameters from an upstream flow disturbance. No major problems were uncovered; however, the size distributions from the three Brinks impactor runs were not consistent. The data were rated B.

Test No. 11[19] was performed at Bethlehem Steel Corporation, Bethlehem Plant during May and June of 1975 by York Research Corp. Controlled windbox emissions were measured at the outlet of the ESP which serves the No. 3 and number 4 sinter strands. The outlet sampling was conducted at a large rectangular duct (6 ft x 17 ft) and the sampling point was 1.0 diameter equivalent upstream from a disturbance and 0.68 diameter equivalents downstream from the opening to the atmosphere. Five Andersen impactor runs were conducted. The program was well documented in the report. The data were rated B due to the poor sampling location.

Controlled by Baghouse

Test No. 12[22] was performed at the Kaiser Steel Corporation sinter plant in Fontana, California. Emissions were measured at the outlet of the baghouse which controls the windbox. The sampling location was greater than 2 diameters from flow disturbances. Four Andersen impactor runs were made. Some background information including isokinetic sampling rates were not reported. The test was rated B. Results from simultaneous EPA Method 5 particulate testing by a subcontractor are contained in a report that could not be located. The report that was available provided insufficient emission and production information for calculating particulate emission factors; therefore, none were developed.

SINTER PLANTS - DISCHARGE END

Controlled by Baghouse

Test No. 13[19] was performed at Bethlehem Steel Corporation, Bethlehem Plant during May and June 1975 by York Research Corp. Four Andersen impactor runs were conducted at the outlet of the baghouse which controls emissions from the numbers 1-4 sinter strands. The testing appeared adequate and the program was well documented in the report. The results were rated A.

BLAST FURNACES

Uncontrolled Emissions

Test No. 14[23] was performed at the DOFASCO No. 3 blast furnace casthouse by GCA/Technology Division during November 1980. Casthouse emissions were controlled by a 400,000 acfm total casthouse evacuation system ducted to a baghouse. Sampling was conducted in the ductwork at the inlet to the baghouse. Twelve Andersen impactor runs were conducted during casting and eight were conducted during noncasting operations. The size distributions determined by the individual runs were relatively consistent. No problems were identified during the review of the test. The test report is well documented and includes a process description and operating data. The data were rated A.

Test No. 15[24] was performed at BSC Sparrows Point Plant, L-blast furnace by GCA/Technology Division during April 1981. The L-blast furnace is one of the largest blast furnaces in the world. The furnace has four tapholes. Testing was performed only during single taphole casting. Emissions from the cast were collected by a local hood above the iron notch, and evacuated runner covers which interconnect with close fitting hoods over the iron pool, tilting runner, and slag spoon. The fifteen Andersen impactor runs were performed at the inlet to the baghouse control device. The particle size distributions measured by the individual impactor runs varied considerably. The test was well documented and included control device and process information as well as operating conditions during the test. The test was rated A. However, the control system was expected to capture greater amounts of particulate because the evacuated runner covers can entrain large particulate that would normally settle in the casthouse.

Test No. 16[25] was conducted at the U.S. Steel Corporation, Fairless Hills plant by Betz, Converse and Murdoch Inc. during February 1980. Blast furnace casthouse emissions were measured and particle size distribution determined by the use of hi-vol samplers equipped with Sierra Instruments cascade impactor heads set up above the crane way. Eighteen runs were performed. The report lacked calibration data, sample calculations, and discussion of the errors involved with the methodology. The data were rated D.

BASIC OXYGEN FURNACES

BOF Tapping and Charging--Uncontrolled

Test Nos. 17 and 21[26] were performed at the Republic Steel Corporation, Cleveland, BOF Shop by Acurex Corp. during June 1979. Hot metal charging and tapping emissions were both sampled at the inlet to the ESP control system. Three SASS runs were performed for each operation. The data presented were rated D due to the low reliability of SASS testing results.

Test No. 18[27] was performed on charging emissions at the Kaiser Steel, Fontana, California BOF shop. The test report was unclear about the organization performing the tests, or dates of testing. The particle size distribution was developed from one SASS run which lasted 24 minutes and covered 24 hot metal charges. Only one of the two charging emission ducts was sampled. The report lacks significant amounts of background data. Due to the low reliability of a SASS test, the data in this report were rated D.

Test Nos. 19 and 22[28] were performed by Acurex Corporation at the Kaiser Steel BOF shop during April 1980. The two vessels are each controlled by full enclosures. Emissions from hot metal charging and tapping operations were sampled in the rectangular ductwork near the secondary control system off-take header. Uncontrolled emissions were measured with the SoRI Inhalable Particulate dual-cyclone sampler. Twelve charging tests and six tapping tests were performed. Details of the sampling procedure and conditions were not discussed in the test report. The sampler operated at a reported 135 percent isokinetic for charging and 156 percent isokinetic for tapping. The data necessary to verify the cyclone cutpoints were not presented. For these reasons, and because of limited experience with the dual cyclone sampler, the results were rated C.

BOF Tapping and Charging--Controlled by Baghouse

Tests Nos. 20 and 23 were performed by Acurex Corporation under the same program mentioned above. Three Method 5 and three impactor runs were made during tapping and charging operations (12 runs total). The outlets to 2 of the 12 baghouse compartments were sampled. The report did not present detailed documentation or background data. The results were rated B.

BOF Refining--Controlled by Scrubber

Test No. 24[29] measured controlled emissions at the outlet of the scrubber controlling Armco Steel's Middletown BOF No. 16. The control system is the closed hood limited combustion type. The testing was performed by PEDCo Environmental Inc. during July 1980. Sampling was done only during the oxygen blow segment of the heat. Eight Andersen impactor runs were made. Of these, six were at normal production levels and two were at intermediate production levels. The data for intermediate levels indicated that fewer fine particles were present in the emissions. The size distribution presented herein was calculated by averaging only the runs made concurrent with normal production rates. The six individual runs showed a moderate amount of variation in particle size. The test program was well documented in the report and no major problems were detected during the review. The data were rated A.

Test No. 25[30] was performed at CF&I, Pueblo, Colorado BOF shop by Seton, Johnson and Odell, Inc. during December 1975. The test program measured fugitive emissions escaping roof level canopy hoods with hi-vols set up above the crane way. One hi-vol was set up with a Sierra Instruments High Volume cascade impactor, three runs were made of which two covered the entire cycle. One problem documented in the report was that the backup filter was found under microscopic investigation to contain larger particles than any of the other stages. This observation cast doubt on the accuracy of the results. The report also lacked a complete description of the test method and analytical procedure. The data were rated D.

Q-BOP Hot Metal Charge--Uncontrolled

Test No. 26[31] was conducted at the Republic Steel Corporation Q-BOP shop in Chicago, Illinois by Acurex during March 1978. The test sampled only hot metal charge emissions which were captured by the doghouse control device. The SASS test program consisted of a single 8.8 minute run which covered eight hot metal charges. The size distribution was determined by plotting the percent mass less than each cyclone cutpoint. The probe and cyclone rinses were not included in the percent calculations. Due to the short duration of the test run and the poor accuracy of the SASS methodology for size distribution measurements the data were rated D.

Test No. 27[26] was performed at the RSC, Chicago Q-BOP by Acurex Corp. during May 1978. The test consisted of three SASS runs which sampled hot metal charging and tapping emissions. The emissions measured were those captured by the doghouse secondary emissions control system. The size distribution was determined from the cyclone catches excluding the probe and cyclone rinses. The test data were rated D since SASS methods were used.

Q-BOP Refining Cycle--Controlled by Scrubber

Test No. 28[32] was performed at the U.S. Steel Fairfield, Alabama Q-BOP shop in May 1982 by GCA/Technology Division. Emissions from the refining cycle were captured by a close fitting suppressed combustion hood and a doghouse type enclosure. The stack of the scrubber control system was tested with four Method-5 runs and eight Andersen impactor runs. The tests were in accordance with I.P. protocol. Process conditions were observed during testing and summarized. The testing and analysis effort was well documented in the report. The particle size results showed considerable scatter between runs, therefore the data were rated B.

OPEN HEARTHS

Uncontrolled

Test No. 29[33] was performed by Southern Research Institute at the Lone Star Steel open hearth shop. Twenty-six Brinks impactor runs were performed on the inlet to the scrubber. The size distribution measured by each run showed moderate variability which is expected due to changing process conditions. The open hearths tested employed oxygen lancing. The test report lacked a significant amount of background data including details of the sampling and analysis procedures and process information. The data were plotted and the desired size ranges determined graphically. The data were rated B.

Test No. 30[17] was obtained from FPEIS (test series No. 233). One SASS run was performed at the inlet to an ESP controlling open hearth furnace emissions. The FPEIS file contains minimal documentation of the test. The data was rated D.

Controlled by ESP

Test No. 31[17] was taken from the same FPEIS file (test series No. 233) mentioned above. The test consisted of a single SASS run performed at the ESP outlet. The test program and process conditions were poorly documented. The test indicated a larger particle size distribution (more large particles) present at the outlet of the ESP than at the inlet. This may indicate the source has a reentrainment problem in the control device, but more likely indicates a poor test. The data was rated D.

ELECTRIC ARC FURNACES

Uncontrolled

Test No. 32[34] was performed at Marathon LeTourneau Co. electric arc furnace in Longview, Texas by GCA/Technology Division during June 1976. Emissions from the electric arc furnace were captured by a canopy hood during charging and tapping and by side draft hoods during melting. The fumes were ducted to a baghouse. Twenty-four runs were made at the inlet to the baghouse with University of Washington impactors. The test was well documented in the report except there were no sample calculations or calibration sheets. The furnace was reported to be producing low alloy steel during the test. The particle size distributions were observed to vary with the cycle operations. The data were rated B.

Test No. 33[35] was performed at Bethlehem Steel Corporation in Seattle, WA. The electric arc furnace emissions were sampled at the inlet to an electrostatic spray scrubber by University of Washington personnel. Twenty-seven runs were made with University of Washington cascade impactors.

The test report lacked significant amounts of background data, procedures documentation, and process description. The particle size data were presented on 27 separate graphs. The data were rated C.

Test No. 34[36] was performed at an undisclosed facility. The data were obtained from FPEIS (test series No. 306). The electric arc furnace emissions were sampled at the inlet to a baghouse. The data consisted of five impactor runs. The results showed much variation between runs. The report lacked significant amounts of test documentation and facility description. The test was rated D.

Controlled by Baghouse

Test No. 35[36] was performed at the same undisclosed facility as the uncontrolled emissions testing reported above. The data was also obtained from FPEIS test series No. 306. The test consisted of two impactor runs performed at the outlet of the baghouse. One run was made during meltdown and one during deslagging and chemistry adjustment. The FPEIS file lacked background information and test documentation. The test was rated D.

HOT METAL DESULFURIZATION

Uncontrolled

Test No. 36[37] was performed by Acurex Corporation on the hot metal desulfurization process at the Kaiser Steel Facility in Fontana, California during May 1980. Desulfurization was conducted in torpedo type ladles by injection of calcium carbide (CaC_2) and calcium carbonate ($CaCO_3$). Tests were conducted at the inlet to a baghouse. Testing consisted of nine simultaneous Method 5 and SORI dual cyclone inhalable particulate sampler runs. The sampling location was a rectangular ductwork transition section located less than 1 equivalent diameter from flow disturbances. Process data was collected and reported. Data from this test series was rated B for total particulate, and C for particle size (limited experience with this test method).

Controlled by Baghouse

Test No. 37 was performed at the same facility as Test No. 36, at the outlet to the baghouse. Testing consisted of three simultaneous Method 5 and Andersen Impactor runs. Two of the six baghouse stacks were tested at a location 1.5 diameters downstream from the baghouse and 1 diameter upstream from the stack exit. The test data was rated B.

TOTAL PARTICULATE EMISSION FACTOR DETERMINATIONS

Controlled and uncontrolled particulate emission factors from iron and steel processes presented in this report are the same as those presented in the May 1983 update of Section 7.5 of AP-42 with the addition of the source categories listed in this section. The development of these additional factors is presented in the following subsections.

Blast Furnace Casthouse with Local Evacuation--Uncontrolled

An emission factor for uncontrolled emissions from a casthouse operation was generated from a single A rated test series (No. 15). A total of 8 Method 5 and 15 Andersen impactor runs were performed at the inlet to a baghouse control device. The emission factor was rated D because it was generated from a single source. The control system from this particular blast furnace is expected to capture greater amounts of particulate because the evacuated runner covers can entrain large particulate that would normally settle in the casthouse.

Hot Metal Desulfurization--Uncontrolled

An emission factor for uncontrolled emissions from a hot metal desulfurization process was generated from a single B rated test series (No. 36). Testing consisted of nine simultaneous Method 5 and SORI dual cyclone inhalable particulate sampler runs. Data from this test series was rated B; the emission factor was rated D since it was developed from a single source.

Hot Metal Desulfurization--Controlled by Baghouse

An emission factor for baghouse controlled emissions from a hot metal desulfurization process was generated from a single B rated test series (No. 37). Testing consisted of three simultaneous Method 5 and Andersen impactor runs. Data from this test series was rated B; the emission factor was rated D.

BOF Charging and Tapping--Controlled by Baghouse

An emission factor for baghouse-controlled emissions from a tapping process for a BOF shop was calculated from two testing programs (Nos. 20 and 23). Three Method 5 tests and three impactor runs were performed during each process operation. The results from these testing series was rated B; the emission factor was rated D.

SIZE SPECIFIC EMISSION FACTOR DETERMINATION

Size specific emission data were presented in Table 4 in this report in the uniform format of size ranges 0.5, 1.0, 2.5, 5.0, 10 and 15 microns aerodynamic equivalent diameter. Most test reports did not list results in terms of percent less than these desired sizes. In those cases where the data were not presented in the desired size range format, the preferred method of obtaining results was interpolating from a graph of percent mass less than stated particle size. In cases where the individual runs were presented graphically, the values for the specific size ranges were read from the individual graphs and averaged arithmetically. In some cases where all runs were presented on a single graph, the average was determined graphically. In cases where only stage cutpoint and mass data were presented, the desired particle size information was acquired by arithmetically calculating percent mass less than the cutpoint and plotting the data on a log-probability graph to visually interpolate the specific size ranges.

All particle diameters contained in this report are aerodynamic diameters based on an assumed particle density of 1 g/cc. Some test reports presented data based on particle sizes calculated using a measured particle density. In these cases the data was converted to unit density aerodynamic diameter using an appropriate conversion factor (square root of density).

The size distributions for some source categories were developed from two or more test series. When test series were combined the respective particle size distributions were averaged weighting the data in direct proportion to the number of runs comprising the individual test series average. The source category size distributions were ranked on an A-E scale which is different from the A-D test series rating scale. The rating criteria for both scales are described in Section 1.

The size distribution calculated for each category is contained in tabular form along with its rating in Table 3. This data was previously presented graphically in Figures 4 through 6. A summary of the test series incorporated into each category size distribution and its assigned rating follows. Size specific emission factors were calculated by multiplying the cumulative mass percent less than the stated particle size times the total particulate emission factor.

Sinter Plant--Windbox Emissions

The size distribution for uncontrolled sinter plant windbox emissions was developed from a single B rated test series (No. 1). Size specific emission factors were calculated from this data and B rated total particulate emission factor data. The size specific emission factor was rated D because it was generated from a single source of B rating.

The size distribution for windbox emissions controlled by cyclones was calculated as a weighted average of two B rated test series (tests No. 6 and 7). Size specific emission factors were calculated from this data and B rated total particulate emission factor data. The size specific emission factor was rated C because it was generated from B rated test data.

The size distribution for scrubber controlled emissions was developed from the weighted average of test series No. 8 and No. 9, rated B and A, respectively. Size specific emission factors were calculated from this data and B rated total particulate emission factor data. The size specific emission factor was rated C because it was generated from A and B rated test data.

The size distribution for ESP controlled windbox emissions was calculated as a weighted average of two B rated test series (tests No. 10 and 11). Size specific emission factors were calculated from this data and B rated total particulate emission factor data. The size specific emission factor was rated C because it was generated from B rated test data.

Sinter Discharge End Emissions--Controlled by Baghouse

The size distribution for baghouse controlled emissions from a sinter discharge end (breaker) was developed from a single A rated test series (test No. 13). Size specific emission factors were calculated from this data and B rated total particulate emission factor data. The size specific emission factor was rated C because it was generated from a single source of A rated test data.

Blast Furnace Casthouse Emissions--Uncontrolled

Total Evacuation System--

The uncontrolled particle size distribution for the total evacuation control system option was based on a single A rated test series (test No. 14). It should be used for uncontrolled casthouses and casthouses using total or partial casthouse evacuation control technology. Size specific emission factors were calculated from this data and B rated total particulate emission factor data. The size specific emission factor was rated C because it was generated from a single source of A rated test data.

Evacuated Local Hood System--

The particle size distribution for uncontrolled emissions conveyed through the local hood and runner cover casthouse control system was based on a single A rated test series (test No. 15). It should be used to calculate uncontrolled emissions from the large, new technology, multiple taphole blast furnaces of recent construction with similar control systems. Size specific emission factors were calculated from this data and B rated total particulate emission factor data. The size specific emission factor was rated C because it was generated from a single source of A rated test data.

Hot Metal Desulfurization Emissions--Uncontrolled

The particle size distribution of uncontrolled emissions from hot metal desulfurization was based on a single C rated test series (test No. 36). Size specific emission factors were calculated from this data and D rated total particulate emission factor data. The size specific emission factor was rated E because it was generated from a single source of C rated data.

Hot Metal Desulfurization Emissions--Controlled by Baghouse

The particle size distribution of emissions from hot metal desulfurization controlled by a baghouse was based on a single B rated test series (test No. 37). Size specific emission factors were calculated from this data and D rated total particulate emission factor data. The size specific emission factor was rated D because it was generated from a single source of B rating.

BOF Tapping and Charging Emissions--Uncontrolled

The size distribution of uncontrolled hot metal charging emissions was calculated from the run weighted average of two D rated test series (tests No. 17, 18) and one C rated test series (test No. 19). Size specific emission factors were calculated from this data and D rated total particulate emission factor data. The size specific emission factor was rated E because it was generated from C and D rated test data.

The size distribution of uncontrolled tapping emissions was calculated from the run weighted average of one D rated test series (test No. 21) and one C rated series (test No. 22). Size specific emission factors were calculated from this data and D rated total particulate emission factor data. The size specific emission factor was rated E because it was generated from C and D rated test data.

BOF Tapping and Charging Emissions-Controlled by Baghouse

The size distribution for BOF charging and tapping emissions controlled by a baghouse were each developed from a single B rated test series. (test Nos. 20 and 23, respectively). Size specific emission factors were calculated from this data and B rated total particulate emission factor data. The size specific emission factor was rated D because it was generated from a single source of B rating.

BOF Refining Emissions Controlled by Scrubber

The size distribution for BOF refining (O_2 blow) emissions controlled by a high energy scrubber was developed from a single A rated test series (test No. 24). The distribution was rated B. Size specific emission factors were calculated from this data and A rated total particulate emission factor data. The size specific emission factor was rated C because it was generated from a single source of A rated test data.

Q-BOP Refining Cycle Emissions-Controlled by Scrubber

The size distribution for Q-BOP refining (principally O_2 blow) emissions captured by a close fitting hood and a "doghouse" enclosure and controlled by a high energy venturi scrubber were developed from a single B rated test series (test No. 28). Size specific emission factors were calculated from this data and B rated total particulate emission factor data. The size specific emission factor was rated D because it was generated from a single source of B rating.

Open Hearth-Uncontrolled Emissions

The Open Hearth refining cycle particle size distribution was calculated from the weighted average of one B rated test consisting of 26 impactor runs (test No. 29) and a D rated test consisting of a single SASS run (test No. 30). Size specific emission factors were calculated from this data and D rated total particulate emission factor data. The size specific emission factor was rated E because it was generated from B and D rated test data.

Open Hearth Emissions Controlled by ESP

The size distribution for open hearth emissions controlled by an ESP was developed from a single D rated test series (test No. 31) consisting of a single SASS run. Inlet, outlet results indicated there may be a reentrainment problem with the ESP and the results may therefore be biased toward a larger than representative particle size distribution. Size specific emission factors were calculated from this data and D rated total particulate emission factor data. The size specific emission factor was rated E because it was generated from a single source of D rated test data.

Electric Arc Furnace-Uncontrolled Emissions

The particle size distribution for uncontrolled electric arc furnace emissions was based on a single B rated test series (test No. 32). Size specific emission factors were calculated from this data and C rated total particulate emission factor data. The size specific emission factor was rated D because it was generated from a single source of B rating.

Electric Arc Furnace-Baghouse Controlled Emissions

The particle size distribution for baghouse controlled electric arc furnace emissions was based on a single D rated test series (test No. 35). The data came from FPEIS and lacked control system details. Size specific emission factors were calculated from this data and E rated total particulate emission factor data. The size specific emission factor was rated E because it was generated from a single source of D rated test data.

SECTION 4

CHEMICAL CHARACTERIZATION

BLAST FURNACE CASTHOUSE EMISSIONS

Particulate emissions from blast furnace casthouses have been reported to consist of approximately 75 percent iron oxides with small percentages of manganese, silicon oxides, and sulfates.[38] Table 6 contains the elemental analysis of 15 samples of blast furnace casthouse particulate collected on glass fiber filters. The analysis was performed by spark source mass spectrometry. However, limitations of the method prevented analysis for carbon (C), sulfur (S), nitrogen (N), oxygen (O), chlorine (Cl), iron (Fe), fluorine (F) and nickel (Ni). It also does not account for iron oxide or sulfate.

BASIC OXYGEN PROCESS EMISSIONS

Table 7 contains information on the chemical composition of open and closed hood basic oxygen furnaces emissions.[6] A Level 1* analysis of collected particulate was performed on emissions generated during hot metal charging to conventional BOFs and Q-BOPs. The concentrations of selected inorganics in the fume are presented in Table 8. Analysis of organic compounds in the fume indicated that BOF emissions contained 86 mg/Nm^3 and Q-BOP emissions 64.1 mg/Nm^3. The usefulness of this data is limited due to the expected dependence of organic emissions on scrap cleanliness, a parameter which is hard to quantify.

HOT METAL DESULFURIZATION EMISSIONS

The results of a Level 1 assessment of emissions from a calcium carbide-limestone hot metal desulfurization process are presented in Table 9. It was reported that organic emissions averaged 2.4 mg/m^3.

SINTER PLANT EMISSIONS

The results of an inorganic analysis of sinter plant windbox dust is presented in Table 10. The sample was collected using Level 1 source assessment techniques and analyzed using Spark Source Mass Spectroscopy.

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*U.S. Environmental Protection Agency, IERL-RTP Procedures Manual. Level I Environmental Assessment, 2nd Edition. EPA-600/7-78-201.

TABLE 6. ANALYSIS OF BLAST FURNACE BAGHOUSE SAMPLE (RESULTS IN $\mu g/g$)[4]

Element	Concentration
Pb	2,100
Ce	0.42
La	0.17
Ba	36
Te	1.3
Sb	8.2
Sn	1.6
Cd	25
Ag	1.1
Mo	580
Nb	25
Zr	36
Sr	110
Rb	245
Br	<360
Se	<240
Ga	230
Zn	3,800
Cu	940
Co	1,360
Fe	470,000
Mn	49,000
Cr	1,100
V	200
Ti	1,500
Sc	460
Ca	87,000
K	140,000
Cl	2,700
P	2,400
Si	52,000
Al	760
Mg	8,700
Na	39,000

TABLE 7. COMPARISON OF PARTICULATE COMPOSITION FROM OPEN AND CLOSED HOOD BASIC OXYGEN FURNACE EMISSION COLLECTION SYSTEMS[a], [6]

Component	Open hood collection process (weight, percent)	Closed hood collection process (weight, percent)
Fe total	59	75
Fe metal	--	10
Fe as FeO	1.6	63
Fe as Fe_3O_4, Fe_2O_3[b]	57.4	2
CaO	2	2
SiO_2	1	1

[a] Partial analysis is given in each case.

[b] Calculated by difference.

TABLE 8. SELECTED INORGANICS IN BOF AND Q-BOP FUME[39]

Element	BOF Concentration in gas[a]	Q-BOP Concentration in gas[a]
Aluminum	MC	0.43
Antimony	0.006	<0.001
Arsenic	≤0.05	<0.02
Barium	>0.11	0.02
Bismuth	0.003	<0.0007
Cadmium	0.077	0.002
Calcium	MC	64
Chromium	0.84	0.26
Copper	0.18	0.1
Iron	>2.7	85.3
Lead	>0.02	0.41
Magnesium	>0.55	2.3
Manganese	>0.11	3.8
Mercury	0.0008	>0.0031
Nickel	0.31	0.18
Phosphorous	MC	0.53
Selenium	0.087	<0.033
Silicon	>1.1	4.2
Strontium	0.016	<0.056
Sulfur	>0.06	7.9
Zinc	MC	0.14

[a] Concentrations in mg/Nm^3

MC - major component

TABLE 9. TOTAL ELEMENTAL COMPOSITION IN HOT METAL DESULFURIZATION GAS, BEFORE EMISSION CONTROL[11]

Element	Concentration µg/Nm^3	Element	Concentration µg/Nm^3	Element	Concentration µg/Nm^3	Element	Concentration µg/Nm^3
Uranium	6	Terbium	0.6	Ruthenium		Vanadium	40
Thorium	12	Gadolinium	1	Molybdenum	19	Titanium	1100
Bismuth		Europium	0.6	Niobium	6	Scandium	13
Lead	131	Samarium	5	Zirconium	50	Calcium	a
Thallium		Neodymium	6	Yttrium	25	Potassium	a
Mercury	0.3	Praseodymium	6	Strontium	1300	Chlorine	810
Gold		Cerium	50	Rubidium	70	Sulfur	a
Platinum		Lanthanum	50	Bromine	30	Phosphorus	1400
Iridium		Barium	875	Selenium	≤ 4	Silicon	a
Osmium		Cesium	1	Arsenic	170	Aluminum	a
Rhenium		Iodine	1	Germanium	2	Magnesium	a
Tungsten		Tellurium	≤ 1	Gallium	5	Sodium	a
Tantalum		Antimony	30	Zinc	a	Fluorine	1300
Hafnium		Tin	3	Copper	160	Oxygen	NR
Lutetium		Indium		Nickel	50	Nitrogen	NR
Ytterbium		Cadmium		Cobalt	6	Carbon	NR
Thulium		Silver	120	Iron	a	Boron	3
Erbium		Palladium		Manganese	>3700	Beryllium	<0.6
Holmium		Rhodium		Chromium	600	Lithium	4
Dysprosium	2					Hydrogen	NR

[a]Major component of one sample.

NR - Not Reported

All elements not detected 0.6 µg/Nm^3.

TABLE 10. TOTAL INORGANICS, SINTER PLANT NO. 3 SPARK SOURCE MASS SPECTROSCOPY DATA[40]

Element	Health MATE value or range mg/m^3	At source mass/volume mg/m^3 or μg/l	Element	Health MATE value or range mg/m^3	At source mass/volume mg/m^3 or μg/l	Element	Health MATE value or range mg/m^3	At source mass/volume mg/m^3 or μg/l
Copper	0.2	1.48	Cerium	37	0.006	Uranium	0.009	<0.0009
Nickel	0.015	0.038	Lanthanum	110	0.001	Thorium	0.42	<0.004
Cobalt	0.050	0.0047	Barium	0.5	0.049	Bismuth		0.0017
Iron	0.7 - 9.0	45.4	Cesium	82	0.0011	Lead	0.150	0.657
Manganese	5.0	7.93	Iodine		0.013	Thallium		0.0062
Chromium	0.001	0.075	Tellurium		0.0022	Mercury		
Vanadium	0.5	0.017	Antimony	0.5	0.012	Gold		
Titanium	6.0	0.233	Tin	10	0.0045	Platinum		
Scandium			Indium			Iridium		
Calcium	16.0	32.2	Cadmium	0.010	0.0042	Osmium		
Potassium	2.0	5.77	Silver			Rhenium		
Chlorine			Palladium			Tungsten		0.005
Sulphur	1.0 - 440	15.16	Rhedium			Tantalum		
Phosphorus	0.1 - 1.0	3.08	Ruthenium			Hafnium		
Silicon	10	0.791	Molybdenum	5.0	0.0058	Lutecium		
Aluminum	5.2 - 10	10.81	Niobium	22	0.00084	Ytterbium		
Magnesium	6 - 10	2.54	Zirconium	5.0	0.0049	Thulium		
Sodium	2 - 53	Major	Yttrium	1.0	0.0021	Erbium		
Fluorine			Strontium	3.1	0.037	Holmium		
Oxygen			Rhubidium	120	0.064	Dysprosium		
Nitrogen			Bromine	10	0.034	Terbium		
Carbon			Selenium	0.2	<0.0056	Gadolinium		
Boron	3 - 10	0.117	Arsenic	0.002	0.0226	Europium		
Beryllium	0.002	0.0006	Germanium	0.56	0.0029	Samarium		
Lithium	0.022	0.006	Gallium	0.50	0.0032	Neodymium		0.0014
Hydrogen			Zinc	4.0	1.20	Praseodymium	51	0.00015

SECTION 5

PROPOSED AP-42 SECTION

7.5 IRON AND STEEL PRODUCTION

7.5.1 Process Description[1-3]

The production of steel at an integrated iron and steel plant is accomplished using several interrelated processes. The major operations are: (1) coke production, (2) sinter production, (3) iron production, (4) iron preparation, (5) steel production, (6) semifinished product preparation, (7) finished product preparation, (8) heat and electricity supply, and (9) handling and transport of raw, intermediate and waste materials. The interrelation of these operations is depicted in a general flow diagram of the iron and steel industry in Figure 7.5-1. Coke production is discussed in detail in Section 7.2 of this publication, and more information on the handling and transport of materials is found in Chapter 11.

7.5.1.1 Sinter Production - 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. The raw materials are sometimes mixed with water to provide a cohesive matrix, and then placed on a continuous, travelling grate called the sinter strand. A burner hood, at the beginning of the sinter strand ignites the coke in the mixture, after which the combustion is self supporting and it provides sufficient heat, 1300 to 1480°C (2400 to 2700°F), to cause surface melting and agglomeration of the mix. On the underside of the sinter strand is a series of windboxes that draw combusted air down through the material bed into a common duct leading to a gas cleaning device. The fused sinter is discharged at the end of the sinter strand, where it is crushed and screened. Undersize sinter is recycled to the mixing mill and back to the strand. The remaining sinter product is cooled in open air or in a circular cooler with water sprays or mechanical fans. The cooled sinter is crushed and screened for a final time, then the fines are recycled, and the product is sent to be charged to the blast furnaces. Generally, 2.5 tons of raw materials, including water and fuel, are required to produce one ton of product sinter.

7.5.1.2 Iron Production - Iron is produced in blast funaces by the reduction of iron bearing materials with a hot gas. The large, refractory lined furnace is charged through its top with iron as ore, pellets, and/or sinter; flux as limestone, dolomite and sinter; and coke for fuel. Iron oxides, coke and fluxes react with the blast air to form molten reduced iron, carbon monoxide and slag. The molten iron and slag collect in the hearth at the base of the furnace. The byproduct gas is collected through offtakes located at the top of the furnace and is recovered for use as fuel.

The production of one ton of iron requires 1.4 tons of ore or other iron bearing material; 0.5 to 0.65 tons of coke; 0.25 tons of limestone or dolomite; and 1.8 to 2 tons of air. Byproducts consist of 0.2 to 0.4 tons of slag, and 2.5 to 3.5 tons of blast furnace gas containing up to 100 lbs of dust.

The molten iron and slag are removed, or cast, from the furnace periodically. The casting process begins with drilling a hole, called the taphole, into the clay filled iron notch at the base of the hearth. During casting, molten iron flows into runners that lead to transport ladles. Slag also flows

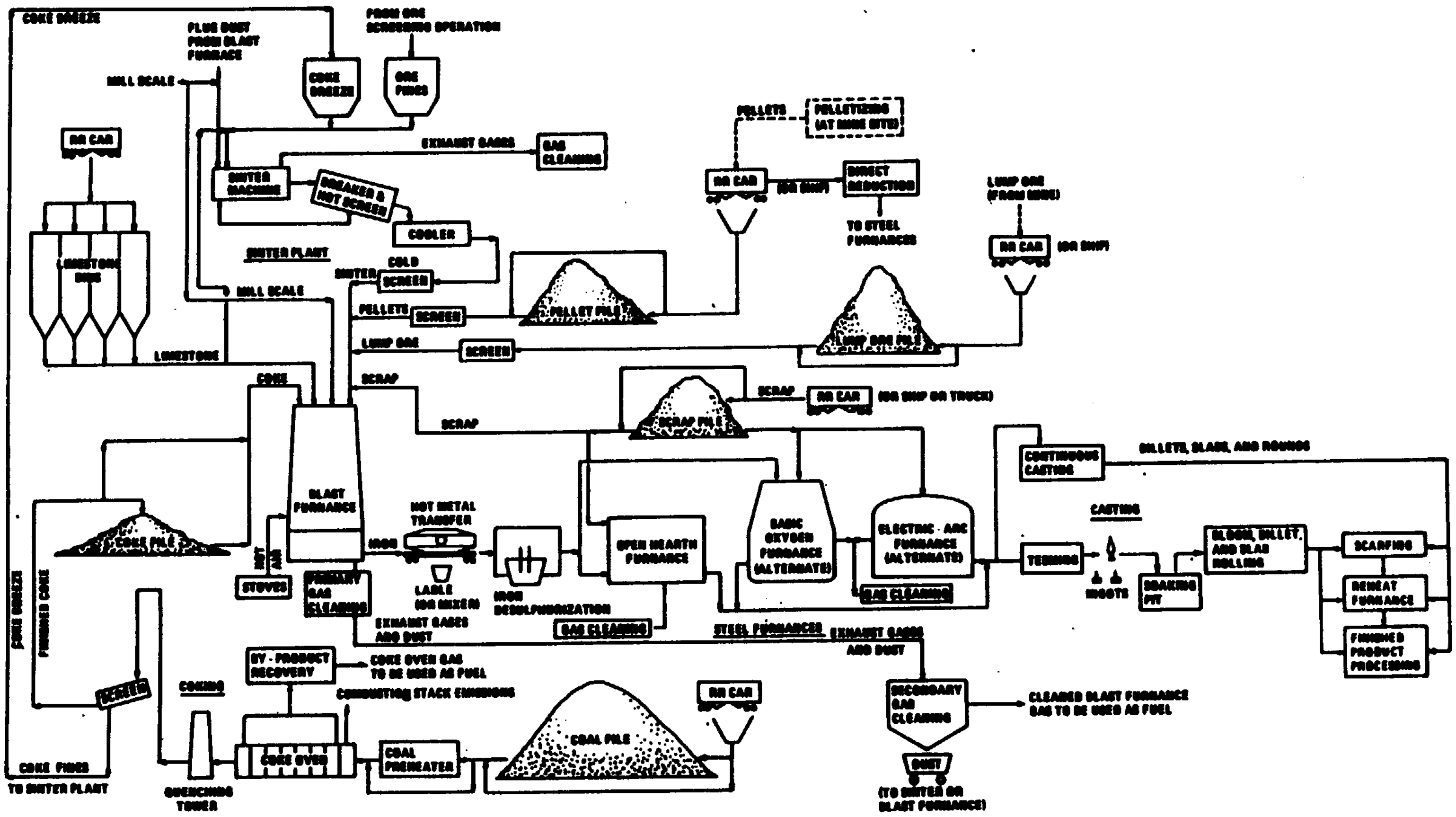

Figure 7.5-1. General flow diagram for the iron and steel industry.

from the furnace, and is directed through separate runners to a slag pit adjacent to the casthouse, or into slag pots for transport to a remote slag pit. At the conclusion of the cast, the taphole is replugged with clay. The area around the base of the furnace, including all iron and slag runners, is enclosed by a casthouse. The blast furnace byproduct gas, which is collected from the furnace top, contains carbon monoxide and particulate. Because of its high carbon monoxide content, this blast furnace gas has a low heating value, about 2790 to 3350 joules per liter (75 to 90 BTU/ft^3) and is used as a fuel within the steel plant. Before it can be efficiently oxidized, however, the gas must be cleaned of particulate. Initially, the gases pass through a settling chamber or dry cyclone to remove about 60 percent of the particulate. Next, the gases undergo a one or two stage cleaning operation. The primary cleaner is normally a wet scrubber, which removes about 90 percent of the remaining particulate. The secondary cleaner is a high energy wet scrubber (usually a venturi) or an electrostatic precipitator, either of which can remove up to 90 percent of the particulate that eludes the primary cleaner. Together these control devices provide a clean fuel of less than 0.05 grams per cubic meter (0.02 gr/ft^3). A portion of this gas is fired in the blast furnace stoves to preheat the blast air, and the rest is used in other plant operations.

7.5.1.3 Iron Preparation Hot Metal Desulfurization - Sulfur in the molten iron is sometimes reduced before charging into the steelmaking furnace by adding reagents. The reaction forms a floating slag which can be skimmed off. Desulfurization may be performed in the hot metal transfer (torpedo) car at a location between the blast furnace and basic oxygen furnace (BOF), or it may be done in the hot metal transfer (torpedo) ladle at a station inside the BOF shop.

The most common reagents are powdered calcium carbide (CaC_2) and calcium carbonate ($CaCO_3$) or salt coated magnesium granules. Powdered reagents are injected into the metal through a lance with high pressure nitrogen. The process duration varies with the injection rate, hot metal chemistry, and desired final sulfur content, and is in the range of 5 to 30 minutes.

7.5.1.4 Steelmaking Processes Basic Oxygen Furnaces - In the basic oxygen process (BOP), molten iron from a blast furance and iron scrap are refined in a furnace by lancing (or injecting) high purity oxygen. The input material is typically 70 percent molten metal and 30 percent scrap metal. The oxygen reacts with carbon and other impurities to remove them from the metal. The reactions are exothermic, i. e., no external heat source is necessary to melt the scrap and to raise the temperature of the metal to the desired range for tapping. The large quantities of carbon monoxide (CO) produced by the reactions in the BOF can be controlled by combustion at the mouth of the furnace and then vented to gas cleaning devices, as with open hoods, or combustion can be suppressed at the furnace mouth, as with closed hoods. BOP steelmaking is conducted in large (up to 400 ton capacity) refractory-lined pear-shaped furnaces. There are two major variations of the process. Conventional BOFs have oxygen blown into the top of the furnace through a water cooled lance. In the newer, Quelle Basic Oxygen process (Q-BOP), oxygen is injected through tuyeres located in the bottom of the furnace. A typical BOF cycle consists of the scrap charge, hot metal charge, oxygen blow (refining) period, testing for temperature and chemical composition of the steel, alloy additions and reblows (if necessary), tapping, and slagging. The full furnace cycle typically ranges from 25 to 45 minutes.

7.5.1.5 Steelmaking Process-Electric Arc Furnace - Electric arc furnaces (EAF) are used to produce carbon and alloy steels. The input material to an EAF is typically 100 percent scrap. Cylindrical, refractory lined EAFs are equipped with carbon electrodes to be raised or lowered through the furnace roof. With electrodes retracted, the furnace roof can be rotated aside to permit the charge of scrap steel by overhead crane. Alloying agents and fluxing materials usually are added through the doors on the side of the furnace. Electric current of the opposite polarity electrodes generates heat between the electrodes and through the scrap. After melting and refining periods, the slag and steel are poured from the furnace by tilting.

The production of steel in an EAF is a batch process. Cycles, or "heats", range from about 1 1/2 to 5 hours to produce carbon steel and from 5 to 10 hours or more to produce alloy steel. Scrap steel is charged to begin a cycle, and alloying agents and slag materials are added for refining. Stages of each cycle normally are charging and melting operations, refining (which usually includes oxygen blowing), and tapping.

7.5.1.6 Steelmaking Process-Open Hearth Furnaces - The open hearth furnace (OHF) is a shallow, refractory-lined basin in which scrap and molten iron are melted and refined into steel. Scrap is charged to the furnace through doors in the furnace front. Hot metal from the blast furnace is added by pouring from a ladle through a trough positioned in the door. The mixture of scrap and hot metal can vary from all scrap to all hot metal, but a half and half mixture is most common. Melting heat is provided by gas burners above and at the side of the furnace. Refining is accomplished by the oxidation of carbon in the metal and the formation of a limestone slag to remove impurities. Most furnaces are equipped with oxygen lances to speed up melting and refining. The steel product is tapped by opening a hole in the base of the furnace with an explosive charge. The open hearth steelmaking process with oxygen lancing normally requires from 4 to 10 hours for each heat.

7.5.1.7 Semifinished Product Preparation - After the steel has been tapped, the molten metal is teemed (poured) into ingots which are later heated and formed into other shapes, such as blooms, billets, or slabs. The molten steel may bypass this entire process and go directly to a continuous casting operation. Whatever the production technique, the blooms, billets, or slabs undergo a surface preparation step, scarfing, which removes surface defects before shaping or rolling. Scarfing can be performed by a machine applying jets of oxygen to the surface of hot semifinished steel, or by hand (with torches) on cold or slightly heated semifinished steel.

7.5.2 Emissions and Controls

7.5.2.1 Sinter - Emissions from sinter plants are generated from raw material handling, windbox exhaust, discharge end (associated sinter crushers and hot screens), cooler, and cold screen. The windbox exhaust is the primary source of particulate emissions, mainly iron oxides, sulfur oxides, carbonaceous compounds, aliphatic hydrocarbons, and chlorides. At the discharge end, emissions are mainly iron and calcium oxides. Sinter strand windbox emissions commonly are controlled by cyclone cleaners followed by a dry or wet ESP, high pressure drop wet scrubber, or baghouse. Crusher and hot screen emissions, usually controlled by hooding and a baghouse or scrubber, are the next largest emissions source. Emissions are also generated from other material handling operations. At some sinter plants, these emissions are captured and vented to a baghouse.

7.5.2.2 Blast Furnace - The primary source of blast furnace emissions is the casting operation. Particulate emissions are generated when the molten iron and slag contact air above their surface. Casting emissions also are generated by drilling and plugging the taphole. The occasional use of an oxygen lance to open a clogged taphole can cause heavy emissions. During the casting operation, iron oxides, magnesium oxide and carbonaceous compounds are generated as particulate. Casting emissions at existing blast furnaces are controlled by evacuation through retrofitted capture hoods to a gas cleaner, or by suppression techniques. Emissions controlled by hoods and an evacuation system are usually vented to a baghouse. The basic concept of suppression techniques is to prevent the formation of pollutants by excluding ambient air contact with the molten surfaces. New furnaces have been constructed with evacuated runner cover systems and local hooding ducted to a baghouse.

Another potential source of emissions is the blast furnace top. Minor emissions may occur during charging from imperfect bell seals in the double bell system. Occasionally, a cavity may form in the blast fuernace charge, causing a collapse of part of the burden (charge) above it. The resulting pressure surge in the furnace opens a relief valve to the atmosphere to prevent damage to the furnace by the high pressure created and is referred to as a "slip".

7.5.2.3 Hot Metal Desulfurization - Emissions during the hot metal desulfurization process are created by both the reaction of the reagents injected into the metal and the turbulence during injection. The pollutants emitted are mostly iron oxides, calcium oxides and oxides of the compound injected. The sulfur reacts with the reagents and is skimmed off as slag. The emissions generated from desulfurization may be collected by a hood positioned over the ladle and vented to a baghouse.

7.5.2.4 Steelmaking - The most significant emissions from the BOF process occur during the oxygen blow period. The predominant compounds emitted are iron oxides, although heavy metals and fluorides are usually present. Charging emissions will vary with the quality and quantity of scrap metal charged to the furnace and with the pour rate. Tapping emissions include iron oxides, sulfur oxides, and other metallic oxides, depending on the grade of scrap used. Hot metal transfer emissions are mostly iron oxides.

BOFs are equipped with a primary hood capture system located directly over the open mouth of the furnaces to control emissions during oxygen blow periods. Two types of capture systems are used to collect exhaust gas as it leaves the furnace mouth: closed hood (also known as an off gas, or O. G., system) or open, combustion type hood. A closed hood fits snugly against the furnace mouth, ducting all particulate and carbon monoxide to a wet scrubber gas cleaner. Carbon monoxide is flared at the scrubber outlet stack. The open hood design allows dilution air to be drawn into the hood, thus combusting the carbon monoxide in the hood system. Charging and tapping emissions are controlled by a variety of evacuation systems and operating practices. Charging hoods, tapside enclosures, and full furnace enclosures are used in the industry to capture these emissions and send them to either the primary hood gas cleaner or a second gas cleaner.

7.5.2.5 Steelmaking-Electric Arc Furnace - The operations which generate emissions during the electric arc furnace steelmaking process are melting and refining, charging scrap, tapping steel, and dumping slag. Iron oxide is the predominant constituent of the particulate emitted during melting. During refining, the primary particulate compound emitted is calcium oxide from the slag. Emissions from charging scrap are difficult to quantify, because they depend on the grade of scrap utilized. Scrap emissions usually contain iron and other metallic oxides from alloys in the scrap metal. Iron oxides and oxides from the fluxes are the primary constituents of the slag emissions. During tapping, iron oxide is the major particulate compound emitted.

Emission control techniques involve an emission capture system and a gas cleaning system. Five emission capture systems used in the industry are fourth hold (direct shell) evacuation, side draft hood, combination hood, canopy hood, and furnace enclosures. Direct shell evacuation consists of ductwork attached to a separate or fourth hole in the furnace roof which draws emissions to a gas cleaner. The fourth hole system works only when the furnace is upright with the roof in place. Side draft hoods collect furnace off gases from around the electrode holes and the work doors after the gases leave the furnace. The combination hood incorporates elements from the side draft and fourth hole ventilation systems. Emissions are collected both from the fourth hole and around the electrodes. An air gap in the ducting introduces secondary air for combustion of CO in the exhaust gas. The combination hood requires careful regulation of furnace interval pressure. The canopy hood is the least efficient of the four ventilation systems, but it does capture emissions during charging and tapping. Many new electric arc furnaces incorporate the canopy hood with one of the other three systems. The full furnace enclosure completely surrounds the furnace and evacuates furnace emissions through hooding in the top of the enclosure.

7.5.2.6 Steelmaking-Open Hearth Furnace - Particulate emissions from an open hearth furnace vary considerably during the process. The use of oxygen lancing increases emissions of dust and fume. During the melting and refining cycle, exhaust gas drawn from the furnace passes through a slag pocket and a regenerative checker chamber, where some of the particulate settles out. The emissions, mostly iron oxides, are then ducted to either an ESP or a wet scrubber. Other furance-related process operations which produce fugitive emissions inside the shop include transfer and charging of hot metal, charging of scrap, tapping steel and slag dumping. These emissions are usually uncontrolled.

7.5.2.7 Semifinished Product Preparation - During this activity, emissions are produced when molten steel is poured (teemed) into ingot molds, and when semifinished steel is machine or manually scarfed to remove surface defects. Pollutants emitted are iron and other oxides (FeO, Fe_2O_3, SiO_2, CaO, MgO).

Teeming emissions are rarely controlled. Machine scarfing operations generally use as ESP or water spray chamber for control. Most hand scarfing operations are uncontrolled.

7.5.2.8 Miscellaneous Combustion - Every iron and steel plant operation requires energy in the form of heat or electricity. Combustion sources that produce emissions on plant property are blast furnace stoves, boilers, soaking pits, and reheat furnaces. These facilities burn combinations of coal, No. 2 fuel oil, natural gas, coke oven gas, and blast furnace gas. In blast furnace stoves, clean gas from the blast furnace is burned to heat the refractory checker work, and in turn, to heat the blast air. In soaking pits, ingots are heated until the temperature distribution over the cross section of the ingots is acceptable and the surface temperature is uniform for further rolling into semifinished products (blooms, billets and slabs). In slab furnaces, a slab is heated before being rolled into finished products (plates, sheets or strips). Emissions from the combustion of natural gas, fuel oil or coal in the soaking pits or slab furnaces are estimated to be the same as those for boilers. (See Chapter 1 of this document.) Emission factor data for blast furnace gas and coke oven gas are not available and must be estimatexW There are three facts available for making the estimation. First, the gas exiting the blast furnace passes through primary and secondary cleaners and can be cleaned to less than 0.05 grams per cubic meter (0.02 gr/ft^3). Second, nearly one third of the coke oven gas is methane. Third, there are no blast furnace gas constituents that generate particulate when burned. The combustible constituent of blast furnace gas is CO, which burns clean. Based on facts one and three, the emission factor for combustion of blast furnace gas is equal to the particulate loading of that fuel, 0.05 grams per cubic meter (2.9 lb/10^6 ft^3) having an average heat value of 83 BTU/ft^3.

Emissions for combustion of coke oven gas can be estimated in the same fashion. Assume that cleaned coke oven gas has as much particulate as cleaned blast furnace gas. Since one third of the coke oven gas is methane, the main component of natural gas, it is assumed that the combustion of this methane in coke oven gas generates 0.06 grams per cubic meter (3.3 lb/10^6 ft^3) of particulate. Thus, the emission factor for the combustion of coke oven gas is the sum of the particulate loading and that generated by the methane combustion, or 0.1 grams per cubic meter (6.2 lb/10^6 ft^3) having an average heat value of 516 BTU/ft^3.

The particulate emission factors for processes in Table 7.5-1 are the result of an extensive investigation by EPA and the American Iron and Steel Institute.[3] Particle size distributions for controlled and uncontrolled emissions from specific iron and steel industry processes have been calculated and summarized from the best available data.[1] Size distributions have been used with particulate emission factors to calculate size specific factors for the sources listed in Table 7.5-1 for which data are available. Table 7.5-2 presents these size specific particulate emission factors. Particle size distributions are presented in Figures 7.5-2 to 7.5-4. Carbon monoxide emission factors are in Table 7.5-3.[6]

TABLE 7.5-1. PARTICULATE EMISSION FACTORS FOR IRON AND STEEL MILLS[a]

Source	Units	Emission Factor	Emission Factor Rating	Particle Size Data
Sintering				
Windbox	kg/Mg (lb/ton) finished sinter			
Uncontrolled				
Leaving grate		5.56 (11.1)	B	Yes
After coarse particulate removal		4.35 (8.7)	A	
Controlled by dry ESP		0.8 (1.6)	B	
Controlled by wet ESP		0.085 (0.17)	B	Yes
Controlled by venturi scrubber		0.235 (0.47)	B	Yes
Controlled by cyclone		0.5 (1.0)	B	Yes
Sinter discharge (breaker and hot screens)	kg/Mg (lb/ton) finished sinter			
Uncontrolled		3.4 (6.8)	B	
Controlled by baghouse		0.05 (0.1)	B	Yes
Controlled by venturi scrubber		0.295 (0.59)	A	
Windbox and discharge	kg/Mg (lb/ton) finished sinter			
Controlled by baghouse		0.15 (0.3)	A	
Blast furnace				
Slip	kg/Mg (lb/ton) slip	39.5 (87.0)	D	
Uncontrolled casthouse	kg/Mg (lb/ton) hot metal			
Roof Monitor[b]		0.3 (0.6)	B	Yes
Furnace with local evacuation[c]		0.65 (1.3)	B	Yes
Taphole and trough only (not runners)		0.15 (0.3)	B	
Hot metal desulfurization				
Uncontrolled[d]	kg/Mg (lb/ton) hot metal	0.55 (1.09)	D	Yes
Controlled by baghouse		0.0045 (0.009)	D	Yes
Basic oxygen furnace (BOF)				
Top blown furnace melting and refining	kg/Mg (lb/ton) steel			
Uncontrolled		14.25 (28.5)	B	
Controlled by open hood vented to:				
ESP		0.065 (0.13)	A	
Scrubber		0.045 (0.09)	B	
Controlled by closed hood vented to:				
Scrubber		0.0034 (0.0068)	A	Yes

TABLE 7.5-1 (cont.). PARTICULATE EMISSION FACTORS FOR IRON AND STEEL MILLS[a]

Source	Units	Emission Factor	Emission Factor Rating	Particle Size Data
BOF Charging	kg/Mg (lb/ton) hot metal			
At source		0.3 (0.6)	D	Yes
At building monitor		0.071 (0.142)	B	
Controlled by baghouse		0.0003 (0.0006)	B	Yes
BOF Tapping	kg/Mg (lb/ton) steel			
At source		0.46 (0.92)	D	Yes
At building monitor		0.145 (0.29)	B	
Controlled by baghouse		0.0013 (0.0026)	B	Yes
Hot metal transfer	kg/Mg (lb/ton) hot metal			
At source		0.095 (0.19)	A	
At building monitor		0.028 (0.056)	B	
BOF monitor (all sources)	kg/Mg (lb/ton) steel	0.25 (0.5)	B	
Q-BOP melting and refining	kg/Mg (lb/ton) steel			
Controlled by scrubber		0.028 (0.056)	B	Yes
Electric arc furnace				
Melting and refining	kg/Mg (lb/ton) steel			
Uncontrolled carbon steel		19.0 (38.0)	C	Yes
Charging, tapping and slagging	kg/Mg (lb/ton) steel			
Uncontrolled emissions escaping monitor		0.7 (1.4)	C	
Melting, refining, charging, tapping and slagging	kg/Mg (lb/ton) steel			
Uncontrolled				
Alloy steel		5.65 (11.3)	A	
Carbon steel		25.0 (50.0)	C	
Controlled by:[e]				
Building evacuation to baghouse for alloy steel		0.15 (0.3)	A	
Direct shell evacuation (plus charging hood) vented to common baghouse for carbon steel		0.0215 (0.043)	E	Yes

TABLE 7.5-1 (Cont.). PARTICULATE EMISSION FACTORS FOR IRON AND STEEL MILLS

Source	Units	Emission Factor		Emission Factor Rating	Partic Size Data
Open hearth furnace					
Melting and refining	kg/Mg (lb/ton) steel				
Uncontrolled		10.55	(21.1)	D	Yes
Controlled by ESP		0.14	(0.28)	D	Yes
Roof monitor		0.084	(0.168)	C	
Teeming					
Leaded steel	kg/Mg (lb/ton) steel				
Uncontrolled (measured at source)		0.405	(0.81)	A	
Controlled by side draft hood vented to baghouse		0.0019	(0.0038)	A	
Unleaded steel					
Uncontrolled (measured at source)		0.035	(0.07)	A	
Controlled by side draft hood vented to baghouse		0.0008	(0.0016)	A	
Machine scarfing					
Uncontrolled	kg/Mg (lb/ton) metal through scarfer	0.05	(0.1)	B	
Controlled by ESP		0.0115	(0.023)	A	
Miscellaneous combustion sources[f]		f	f		
Boiler, soaking pit and slab reheat	kg/10^9 J (lb/10^6 Btu)				
Blast furnace gas[g]		0.015	(0.035)	D	
Coke oven gas[g]		0.0052	(0.012)	D	

[a] Reference 3, except as noted.

[b] Typical of older furnaces with no controls, or for canopy hoods or total casthouse evacuation.

[c] Typical of large, new furnaces with local hoods and covered evaucated runners. Emissions are higher than without capture systems because they are not diluted by outside environment.

[d] Emission factor of 0.55 kg/Mg (1.09 lb/ton) represents one torpedo car; 1.26 kg/Mg (2.53 lb/ton) for two torpedo cars, and 1.37 kg/Mg (2.74 lb/ton) for three torpedo cars.

[e] Building evacuation collects all process emissions, and direct shell evacuation collects only melting and refining emissions.

[f] For various fuels, use the emission factors in Chapter 1 of this document. The emission factor rating, for these fuels in boilers is A, and in soaking pits and slab reheat furnaces is D.

[g] Based on methane content and cleaned particulate loading.

TABLE 7.5-2. SIZE SPECIFIC EMISSION FACTORS

Source	Emission Factor Rating	Particle Size µm^a	Cumulative Mass % ≤ Stated size	Cumulative mass emission factor kg/Mg	(lb/ton)
Sintering					
Windbox					
Uncontrolled					
Leaving grate	D	0.5	4^b	0.22	(0.44)
		1.0	4	0.22	(0.44)
		2.5	5	0.28	(0.56)
		5.0	9	0.50	(1.00)
		10	15	0.83	(1.67)
		15	20^c	1.11	(2.22)
		d	100	5.56	(11.1)
Controlled by wet ESP	C	0.5	18^b	0.015	(0.03)
		1.0	25	0.021	(0.04)
		2.5	33	0.028	(0.06)
		5.0	48	0.041	(0.08)
		10	59^b	0.050	(0.10)
		15	69	0.059	(0.12)
		d	100	0.085	(0.17)
Controlled by venturi scrubber	C	0.5	55	0.129	(0.26)
		1.0	75	0.176	(0.35)
		2.5	89	0.209	(0.42)
		5.0	93	0.219	(0.44)
		10	96	0.226	(0.45)
		15	98	0.230	(0.46)
		d	100	0.235	(0.47)
Controlled by cyclone^e	C	0.5	25^c	0.13	(0.25)
		1.0	37^b	0.19	(0.37)
		2.5	52	0.26	(0.52)
		5.0	64	0.32	(0.64)
		10	74	0.37	(0.74)
		15	80	0.40	(0.80)
		d	100	0.5	(1.0)
Controlled by baghouse	C	0.5	3.0	0.005	(0.009)
		1.0	9.0	0.014	(0.027)
		2.5	27.0	0.041	(0.081)
		5.0	47.0	0.071	(0.141)
		10.0	69.0	0.104	(0.207)
		15.0	79.0	0.119	(0.237)
		d	100.0	0.15	(0.3)

TABLE 7.5.2 (cont.) SIZE SPECIFIC EMISSION FACTORS

Source	Emission Factor Rating	Particle Size µm[a]	Cumulative Mass % ≤ Stated size	Cumulative mass emission factor kg/Mg (lb/ton)
Sinter discharge (breaker and hot screens) controlled by baghouse	C	0.5	2[b]	0.001 (0.002)
		1.0	4	0.002 (0.004)
		2.5	11	0.006 (0.011)
		5.0	20	0.010 (0.020)
		10	32[b]	0.016 (0.032)
		15	42[b]	0.021 (0.042)
		d	100	0.05 (0.1)
Blast furnace Uncontrolled cast-house emissions Roof monitor[f]	C	0.5	4	0.01 (0.02)
		1.0	15	0.05 (0.09)
		2.5	23	0.07 (0.14)
		5.0	35	0.11 (0.21)
		10	51	0.15 (0.31)
		15	61	0.18 (0.37)
		d	100	0.3 (0.6)
Furnace with local evacuation[g]	C	0.5	7[c]	0.04 (0.09)
		1.0	9	0.06 (0.12)
		2.5	15	0.10 (0.20)
		5.0	20	0.13 (0.26)
		10	24	0.16 (0.31)
		15	26	0.17 (0.34)
		d	100	0.65 (1.3)
Hot metal desulfurization[h] Uncontrolled	E	0.5	j	
		1.0	2[c]	0.01 (0.02)
		2.5	11	0.06 (0.12)
		5.0	19	0.10 (0.22)
		10	19	0.10 (0.22)
		15	21	0.12 (0.23)
		d	100	0.55 (1.09)
Hot metal desulfurization[h] Controlled baghouse	D	0.5	8	0.0004 (0.0007)
		1.0	18	0.0009 (0.0016)
		2.5	42	0.0019 (0.0038)
		5.0	62	0.0028 (0.0056)
		10	74	0.0033 (0.0067)
		15	78	0.0035 (0.0070)
		d	100	0.0045 (0.009)

TABLE 7.5-2 (cont.) SIZE SPECIFIC EMISSION FACTORS

Source	Emission Factor Rating	Particle Size μm[a]	Cumulative Mass % $\leq$ Stated size	Cumulative mass emission factor kg/Mg (lb/ton)
Basic oxygen furnace Top blown furnace melting and refining controlled by closed hood and vented to scrubber	C	0.5	34	0.0012 (0.0023)
		1.0	55	0.0019 (0.0037)
		2.5	65	0.0022 (0.0044)
		5.0	66	0.0022 (0.0045)
		10	67	0.0023 (0.0046)
		15	72[c]	0.0024 (0.0049)
		d	100	0.0034 (0.0068)
BOF Charging At source[k]	E	0.5	8[c]	0.02 (0.05)
		1.0	12	0.04 (0.07)
		2.5	22	0.07 (0.13)
		5.0	35	0.10 (0.21)
		10	46	0.14 (0.28)
		15	56	0.17 (0.34)
		d	100	0.3 (0.6)
Controlled by baghouse	D	0.5	3	9.0×10^{-6} 1.8×10^{-5}
		1.0	10	3.0×10^{-5} 6.0×10^{-5}
		2.5	22	6.6×10^{-5} (0.0001)
		5.0	31	9.3×10^{-5} (0.0002)
		10	45	0.0001 (0.0003)
		15	60	0.0002 (0.0004)
		d	100	0.0003 (0.0006)
BOF Tapping At source[k]	E	0.5	j	j j
		1.0	11	0.05 (0.10)
		2.5	37	0.17 (0.34)
		5.0	43	0.20 (0.40)
		10	45	0.21 (0.41)
		15	50	0.23 (0.46)
		d	100	0.46 (0.92)

TABLE 7.5-2 (cont.) SIZE SPECIFIC EMISSION FACTORS

Source	Emission Factor Rating	Particle Size m[a]	Cumulative Mass % ≤ Stated size	Cumulative mass emission factor kg/Mg (lb/ton)
BOF Tapping Controlled by baghouse	D	0.5	4	5.2×10^{-5} (0.0001)
		1.0	7	0.0001 (0.0002)
		2.5	16	0.0002 (0.0004)
		5.0	22	0.0003 (0.0006)
		10	30	0.0004 (0.0008)
		15	40	0.0005 (0.0010)
		d	100	0.0013 (0.0026)
Q-BOP melting and refining controlled by scrubber	D	0.5	45	0.013 (0.025)
		1.0	52	0.015 (0.029)
		2.5	56	0.016 (0.031)
		5.0	58	0.016 (0.032)
		10	68	0.019 (0.038)
		15	85[c]	0.024 (0.048)
		d	100	0.028 (0.056)
Electric arc furnace melting and refining carbon steel uncontrolled[m]	D	0.5	8	1.52 (3.04)
		1.0	23	4.37 (8.74)
		2.5	43	8.17 (16.34)
		5.0	53	10.07 (20.14)
		10	58	11.02 (22.04)
		15	61	11.59 (23.18)
		d	100	19.0 (38.0)
Electric arc furnace Melting, refining, charging, tapping, slagging Controlled by direct shell evacuation (plus charging hood) vented to common baghouse for carbon steel[n]	E	0.5	74[b]	0.0159 (0.0318)
		1.0	74	0.0159 (0.0318)
		2.5	74	0.0159 (0.0318)
		5.0	74	0.0159 (0.0318)
		10	76	0.0163 (0.0327)
		15	80	0.0172 (0.0344)
		d	100	0.0215 (0.043)

TABLE 7.5-2 (cont.) SIZE SPECIFIC EMISSION FACTORS

Source	Emission Factor Rating	Particle Size μm[a]	Cumulative Mass, % ≤ Stated size	Cumulative mass emission factor kg/Mg (lb/ton)
Open hearth furnace Melting and refining Uncontrolled	E	0.5	1[b]	0.11 (0.21)
		1.0	21	2.22 (4.43)
		2.5	60	6.33 (12.66)
		5.0	79	8.33 (16.67)
		10	83	8.76 (17.51)
		15	85[c]	8.97 (17.94)
		d	100	10.55 (21.1)
Open Hearth Furnaces Controlled by ESPP	E	0.5	10[b]	0.01 (0.02)
		1.0	21	0.03 (0.06)
		2.5	39	0.05 (0.10)
		5.0	47	0.07 (0.13)
		10	53[b]	0.07 (0.15)
		15	56[b]	0.08 (0.16)
		d	100	0.14 (0.28)

[a] Particle aerodynamic diameter micrometers (μm) as defined by Task Group on Lung Dynamics. (Particle density = 1 gr/cm^3).

[b] Interpolated data used to develop size distribution.

[c] Extrapolated, using engineering estimates.

[d] Total particulate based on Method 5 total catch. See Table 7.5-1.

[e] Average of various cyclone efficiencies.

[f] Total casthouse evacuation control system.

[g] Evacuation runner covers and local hood over taphole, typical of new state of the art blast furnace technology.

[h] Torpedo ladle desulfurization with CaC_2 and $CaCO_3$.

[j] Unable to extrapolate because of insufficient data and/or curve exceeding limits.

[k] Doghouse type furnace enclosure using front and back sliding doors, totally enclosing the furnace, with emissions vented to hoods.

[m] Full cycle emissions captured by canopy and side draft hoods.

[n] Information on control system not available.

[p] May not be representative. Test outlet size distribution was larger than inlet and may indicate reentrainment problem.

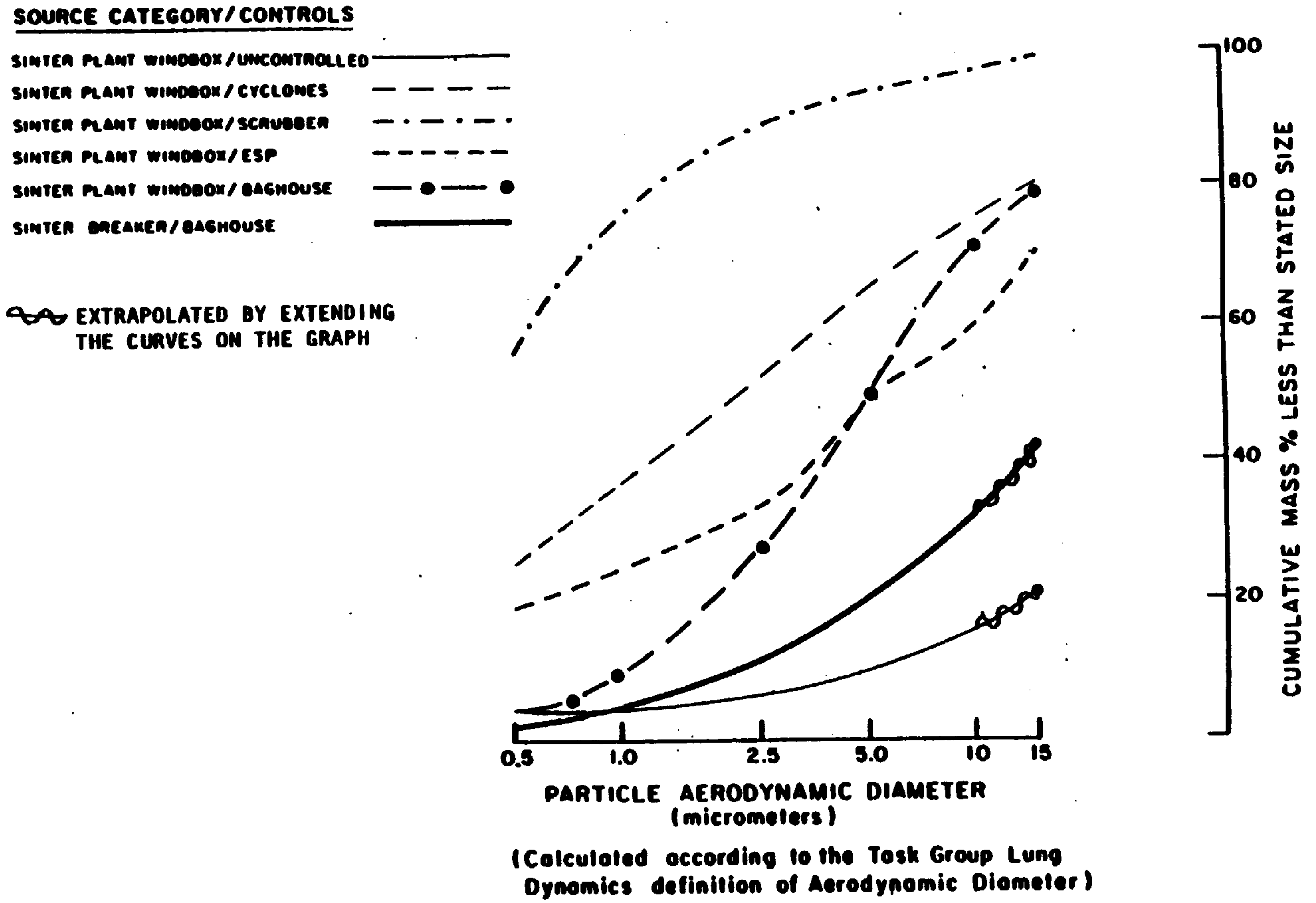

Figure 7.5-2. Particle size distribution of sinter plant emissions.

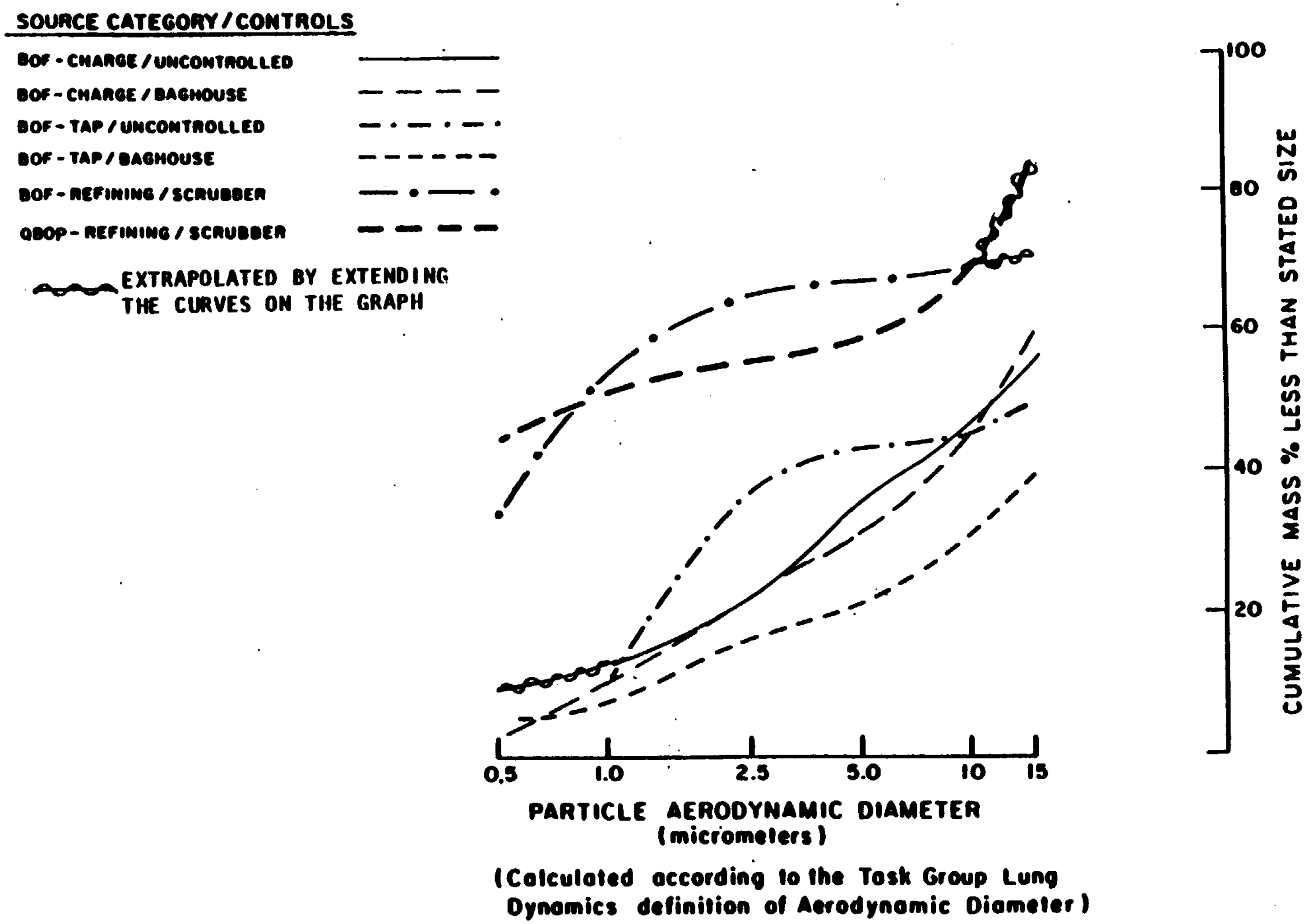

Figure 7.5-3. Particle size distribution of basic oxygen furnace emissions.

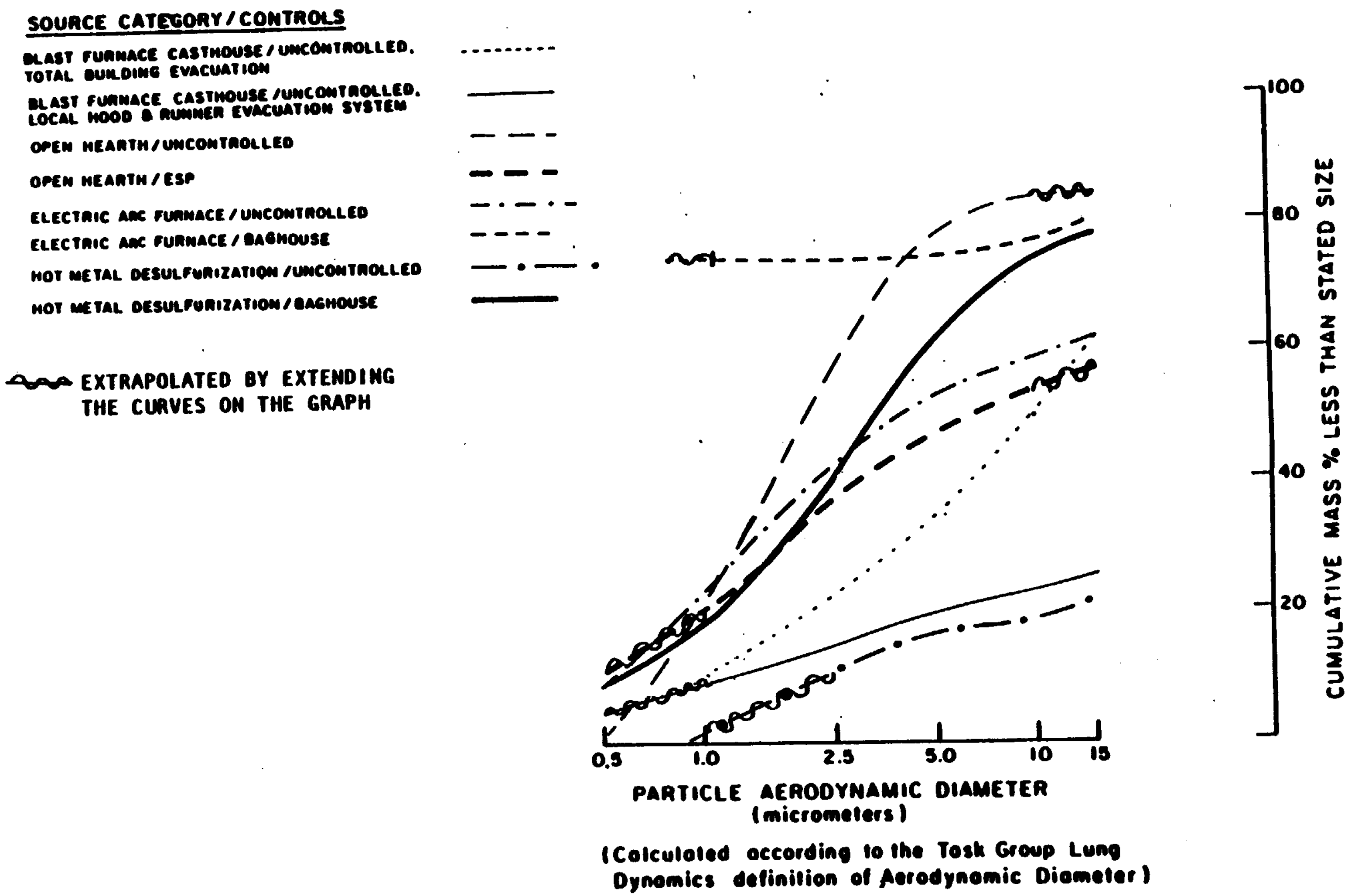

Figure 7.5-4. Particle size distribution of blast furnace, open hearth, electric arc furnace and hot metal desulfurization emissions.

TABLE 7.5-3. UNCONTROLLED CARBON MONOXIDE EMISSION FACTORS FOR IRON AND STEEL MILL[a]

EMISSION FACTOR RATING: C

Source	kg/Mg	lb/ton
Sintering windbox[b]	22	44
Basic oxygen furnace[c]	69	138
Electric arc furnace[c]	9	18

[a] Reference 6.
[b] kg/Mg (lb/ton) of finished sinter.
[c] kg/Mg (lb/ton) of finished steel.

7.5.2.9 Open Dust Sources - Like process emission sources, open dust sources contribute to the atmospheric particulate burden. Open dust sources include vehicle traffic on paved and unpaved roads, raw material handling outside of buildings and wind erosion from storage piles and exposed terrain. Vehicle traffic consists of plant personnel and visitor vehicles, plant service vehicles, and trucks handling raw materials, plant deliverables, steel products and waste materials. Raw materials are handled by clamshell buckets, bucket/ladder conveyors, rotary railroad dumps, bottom railroad dumps, front end loaders, truck dumps, and conveyor transfer stations, all of which disturb the raw material and expose fines to the wind. Even fine materials resting on flat areas or in storage piles are exposed and are subject to wind erosion. It is not unusual to have several million tons of raw materials stored at a plant and to have in the range of 10 to 100 acres of exposed area there.

Open dust source emission factors for iron and steel production are presented in Table 7.5-4. These factors were determined through source testing at various integrated iron and steel plants.

As an alternative to the single valued open dust emission factors given in Table 7.5-4, empirically derived emission factor equations are presented in Section 11.2 of this document. Each equation was developed for a source operation defined on the basis of a single dust-generating mechanism which crosses industry lines, such as vehicle traffic on unpaved roads. The predictive equation explains much of the observed variance in measured emission factors by relating emissions to parameters which characterize source conditions. These parameters may be grouped into three categories: (1) measures of source activity or energy expended (e. g., the speed and weight of a vehicle traveling on an unpaved road), (2) properties of the material being disturbed (e.g., the content of suspendible fines in the surface material on an unpaved road) and (3) climatic parameters (e.g., number of precipitation-free days per year, when emissions tend to a maximum).[4]

TABLE 7.5-4. UNCONTROLLED PARTICULATE EMISSION FACTORS FOR OPEN DUST SOURCES AT IRON AND STEEL MILLS[a]

Operation	Emissions by particle size range (aerodynamic diameter)					Units[b]	Emission Factor Rating
	≤ 30 μm	≤ 15 μm	≤ 10 μm	≤ 5 μm	≤ 2.5 μm		
Continuous drop							
Conveyor transfer station sinter[c]	13 0.026	9.0 0.018	6.5 0.013	4.2 0.0084	2.3 0.0046	g/Mg lb/ton	D D
Pile formation stacker pellet ore[c]	1.2 0.0024	0.75 0.0015	0.55 0.0011	0.32 0.00064	0.17 0.00034	g/Mg lb/ton	B B
Lump ore[c]	0.15 0.00030	0.095 0.00019	0.075 0.00015	0.040 0.000081	0.022 0.000043	g/Mg lb/ton	C C
Coal[d]	0.055 0.00011	0.034 0.000068	0.026 0.000052	0.014 0.000028	0.0075 0.000015	g/Mg lb/ton	E E
Batch drop							
Front end loader/truck[c]							
High silt slag	13 0.026	8.5 0.017	6.5 0.013	4.0 0.0080	2.3 0.0046	g/Mg lb/ton	C C
Low silt slag	4.4 0.0088	2.9 0.0058	2.2 0.0043	1.4 0.0028	0.80 0.0016	g/Mg lb/ton	C C
Vehicle travel on unpaved roads							
Light duty vehicle[d]	0.51 1.8	0.37 1.3	0.28 1.0	0.18 0.64	0.10 0.36	Kg/VKT lb/VMT	C C
Medium duty vehicle[d]	2.1 7.3	1.5 5.2	1.2 4.1	0.70 2.5	0.42 1.5	Kg/VKT lb/VMT	C C
Heavy duty vehicle[d]	3.9 14	2.7 9.7	2.1 7.6	1.4 4.8	0.76 2.7	Kg/VKT lb/VMT	B B
Vehicle travel on paved roads							
Light/heavy vehicle mix[c]	0.22 0.78	0.16 0.58	0.12 0.44	0.079 0.28	0.042 0.15	Kg/VKT lb/VMT	C C

[a] Predictive emission factor equations are generally preferred over these single values emission factors. Predictive emission factors estimates are presented in Chapter 11, Section 11.2. VKT = Vehicle kilometer traveled. VMT = Vehicle mile traveled.

[b] Units/unit of material transferred or units/unit of distance traveled.

[c] Reference 4. Interpolation to other particle sizes will be approximate.

[d] Reference 5. Interpolation to other particle sizes will be approximate.

Because the predictive equations allow for emission factor adjustment to specific source conditions, the equations should be used in place of the factors in Table 7.5-4, if emission estimates for sources in a specific iron and steel facility are needed. However, the generally higher quality ratings assigned to the equations are applicable only if (1) reliable values of correction parameters have been determined for the specific sources of interest and (2) the correction parameter values lie within the ranges tested in developing the equations. Section 11.2 lists measured properties of aggregate process materials and road surface materials in the iron and steel industry, which can be used to estimate correction parameter values for the predictive emission factor equations, in the event that site specific values are not available.

Use of mean correction parameter values from Section 11.2 reduces the quality ratings of the emission factor equation by one level.

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16. ABSTRACT

The report gives results of a study to develop particulate emission fac based on cutoff size for inhalable particles for the iron and steel industry. After viewing available information characterizing particulate emissions from iron an steel plants, the data were summarized and rated in terms of reliability. Size s cific emission factors were developed from these data for the major processes in the manufacture of iron and steel. A detailed process description was present with emphasis on factors affecting the generation of emissions. A replacement f Section 7.5 (Iron and Steel Production) of EPA report AP-42, A Compilation of Pollutant Emissions Factors, was prepared, containing the size specific emissi factors developed during this program.

17. KEY WORDS AND DOCUMENT ANALYSIS

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Iron and Steel Industry	Stationary Sources	05C, 11F
Emission	Particulate	14G
Particles	Emission Factors	
Dust		11G
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