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Particulate Emission Factors Applicable to Iron and Steel Industry

EPA-450/4-79-028

Particulate Emission Factors Applicable to the Iron and Steel Industry

by

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PREFACE

This report was prepared for the Environmental Protection Agency (Mr. Charles Masser, Project Officer) under EPA Contract No. 68-02-2814. The work was performed in the Environmental and Materials Sciences Division of Midwest Research Institute, under the supervision of Dr. Chatten Cowherd, Head, Air Quality Assessment Section. Mr. Thomas Cuscino, Jr., Project Leader, is the author of this report. He was assisted in data compilation by Mr. Mark Golembiewski and Dr. Ralph Keller. Mr. Charles Masser wrote the Introduction of this report.

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SECTION 1.0

INTRODUCTION

An intensified effort has occurred in the last 3 years to update the iron and steel industry particulate emission factors presented in AP-42 and to add, for the first time, fugitive source emission factors. The emission factors in AP-42 for the iron and steel industry are dated April 1973.[1/]

The intensified effort began in August 1975 when Gary McCutchen of the Environmental Protection Agency's (EPA's) Emission Standards and Engineering Division (ESED), Office of Air Quality Planning and Standards (OAQPS) compiled a table of particulate point and fugitive emission factors for eight generic categories of sources. By March 1976, a task force consisting of the American Iron and Steel Institute (AISI) Fugitive Emission Committee and specific EPA personnel had been formed at the request of the director of OAQPS.

In July 1976, AISI presented a compilation of particulate source test data performed at AISI member plants.[2/] This compilation and its support documentation provided significant new test data and became the focal point of discussions for the following 2 years. From late July until November 1976, Peter Westlin, Test Support Section, OAQPS, reviewed the support data and corresponded with Bill Benzer of AISI to acquire additional information necessary to evaluate the AISI compilation of test results. By mid-November, Mr. Westlin had selected a major portion of the tests presented in the AISI compilation as acceptable. The task force discussions since November 1976 centered mainly on the development of a methodology which would result in single emission factor values to represent each process stack, process fugitive, and open dust source.

It is the objective of this report to present the results of this data gathering and analysis effort. The report is divided into three major areas. First, background information will be presented related to the processes in the iron and steel industry along with a process flow chart. Second, all of the particulate source test data will be presented and summarized in chart form. Third, the methodology for selecting single source specific emission factors and the resulting particulate emission factors will be presented.

All of the particulate emission source test data that were in the possession of the EPA/AISI task force on June 1, 1979, have been included in the evaluation and emission factor development. If you, as the reader, feel you are in possession of documented source test data that would further enhance the understanding of emissions from processes within the iron and steel industry, please send a copy to the present EPA task coordinator:

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As with all average or "typical" emission factors, they are obtained from a wide range of data of varying degrees of accuracy. The reader must be cautioned not to use these emission factors indiscriminately. That is, the factor generally may not yield precise emission estimates for an individual installation. Only on-site source tests can provide data sufficiently accurate and pre cise to determine actual emissions for that source. Emission factors are most appropriate when used in diffusion models for the estimation of the impact of proposed new sources upon the ambient air quality and for community or nation-wide air pollution emission estimates.

This report represents the combined efforts of EPA and steel industry experts to establish reasonable particulate emission factors with ranges for all known stack and fugitive sources within an integrated steel mill. The EPA task coordinator wants to thank the AISI Fugitive Emission Committee, the EPA ESED, the Industrial Environmental Research Laboratory (IERL), Research Triang Park, the Enforcement Division of the EPA Regional Offices, and the EPA Divisi of Stationary Source Enforcement in Washington, D.C., for the data and review comments which resulted in this report.

SECTION 2.0

BACKGROUND

Particulate emission sources in the iron and steel industry can be generically classified as (a) process stack emission sources, (b) process fugitive emission sources, and (c) open dust sources. Process stack emissions are any emissions exhausted to the atmosphere through a stack duct, or flue. Process fugitive emissions and open dust sources are both defined as any emissions not entering the atmosphere from a duct, stack, or flue. Open dust sources traditionally have included (a) vehicular traffic on paved and unpaved roads, (b) raw material handling outside of buildings, and (c) wind erosion from storage piles and exposed terrain, while all other nonducted sources have been classified as process fugitive emissions.

Figure 1 portrays a process flow diagram for a representative integrated iron and steel plant. Industry-wide material flows are presented in Figure 2. The Appendix presents typical material quantity conversion factors useful in calculating material flows.

Table 1 shows the main sources of particulate emissions in the integrated iron and steel industry. Not all sources are listed, but those of most common interest are shown. Such sources as dry quenching, hot metal desulfurization, and argon-oxygen decarburization will not be considered, since little or no data are currently available.

2.1 BY-PRODUCT COKE OVEN PROCESS

Coking is the process of heating coal in an atmosphere of low oxygen content, i.e., destructive distillation. During this process, organic compounds in the coal break down to yield gases and a residue of relatively nonvolatile nature.

The integrated iron and steel industry produces coke using the by-product process. This process will not be found at plants which produce steel only via the electric arc furnace process. Plants producing steel via the basic oxygen furnace or open hearth furnace process will normally have a coke plant but this is not always the case since some plants have their coke brought in by rail or barge.

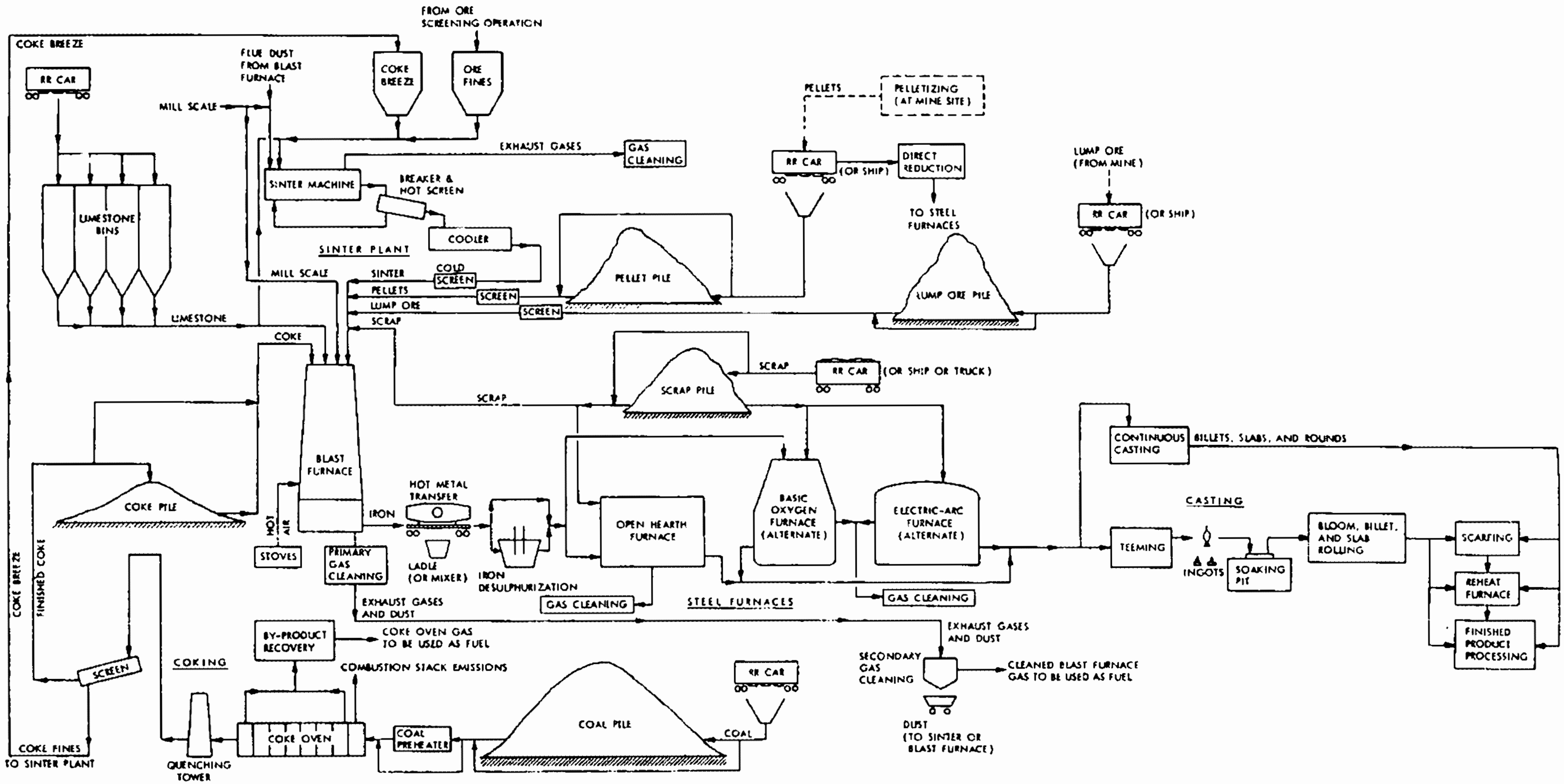

FIGURE 1 - GENERAL FLOW DIAGRAM FOR THE IRON AND STEEL INDUSTRY.

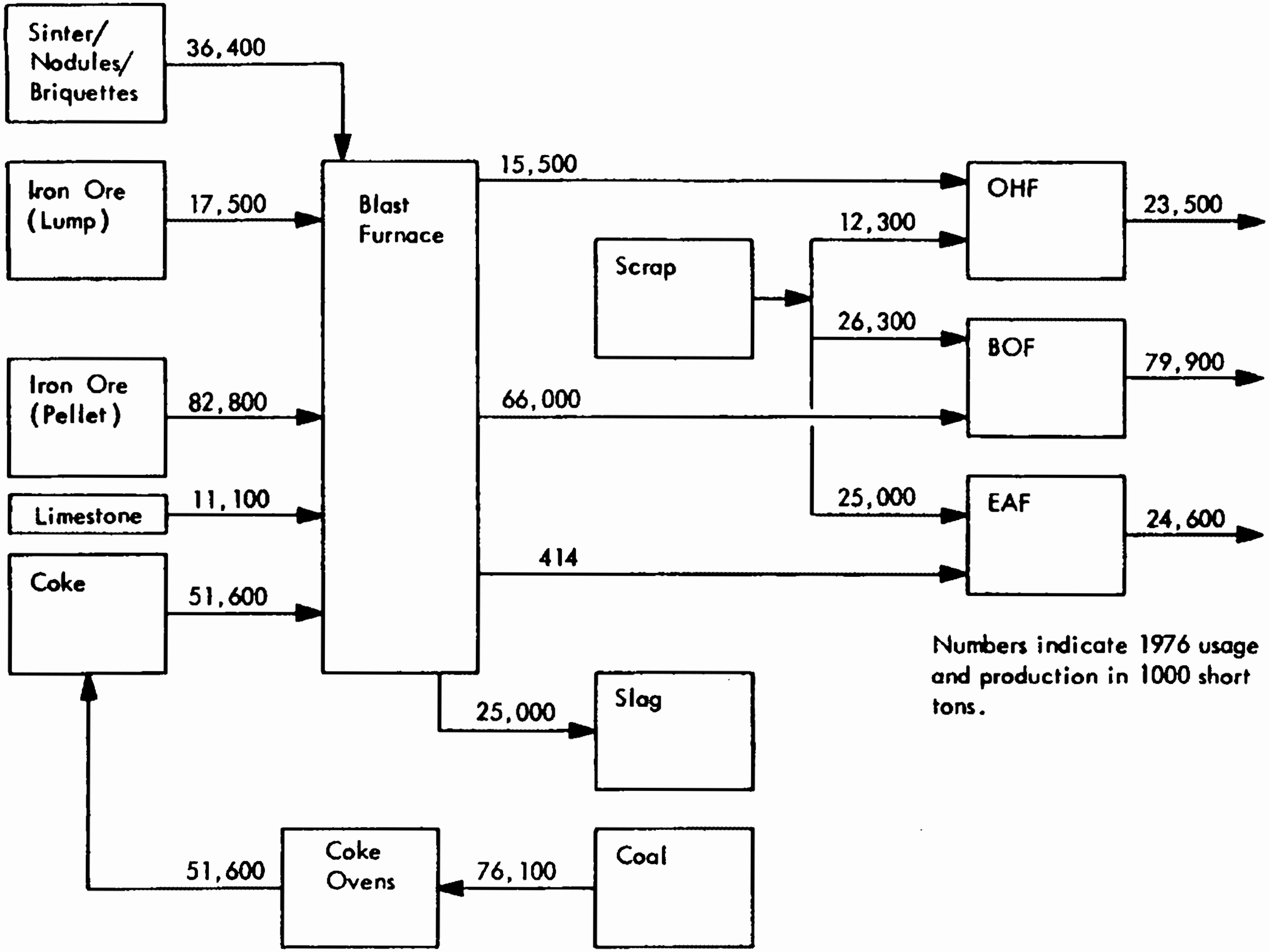

Figure 2. 1976 Iron and steel industry material flows.[3,4]

TABLE 1. PARTICULATE EMISSION SOURCES IN THE IRON AND STEEL INDUSTRY

Process equipment	Process stack and fugitive emission sources	Process associated open dust sources[a/]
I. By-product coke ovens	* Coal Preheating * Charging of coal * Oven door leaks * Coke pushing * Wet coke quenching * Oven combustion stacks * Coal Preheating * Topside Leaks	* Coal unloading from rail or barge * Coal storage pile load-in * Coal storage pile load-out * Coal storage pile wind erosion * Coal conveyor transfer stations
II. Sinter plants	* Windbox * Discharge (crusher and hot screen) * Cooler * Cold screen	* Sinter plant input pile load-in * Sinter plant input pile load-out * Sinter plant input pile wind erosion * Sinter plant input and output conveyor transfer stations
III. Blast furnaces	* Slips * Cast house monitor	* Pellet, lump iron ore, coke and flux stone unloading from rail or barge * Pellet, lump iron ore, coke and flux stone storage pile load-in * Pellet, lump iron ore, coke and flux stone storage pile load-out * Pellet, lump iron ore, coke and flux stone storage pile wind erosion * Pellet, lump iron ore, coke and flux stone conveyor transfer stations
IV. Basic oxygen furnaces (BOFs)	* Hot metal transfer to charging ladle * Scrap and hot metal charging * Steel refining and melting (scrap preheat, O_2 blowing, turndown) * Slag dumping * Steel tapping * Teeming	
V. Electric arc furnaces (EAFs)	* Scrap charging * Steel refining and melting * Slag dumping * Steel tapping * Teeming	
VI. Open hearth furnaces (OHFs)	* Hot metal transfer to charging ladle * Scrap and/or hot metal charging * Steel refining and Melting * Slag dumping and steel tapping * Teeming	
VII. Scarfers	* Hand scarfing * Machine scarfing	
VIII. Miscellaneous combustion units	* Boilers * Soaking pits * Reheat furnaces	
IX. Vehicles		* Traffic on paved and unpaved roads

a/ Wind erosion of exposed plant terrain is also a source but is not shown in the above table, since it is not associated with any particular process or piece of equipment.

The by-product process is oriented toward the recovery of the gases produced during the coking cycle. The rectangular coking ovens are grouped together in a series, alternately interspersed with heating flues, called a coke battery. Coal is charged to the ovens through ports in the top, which are then sealed. Heat is supplied to the ovens by burning some of the coke gas produced. Coking is largely accomplished at temperatures of 1100° to 1150°C (2000° to 2100°F) for a period of about 16 to 20 hr. At the end of the coking period, the coke is pushed from the oven by a ram and cooled by quenching with water or via a dry quenching process.

2.2 SINTERING PROCESS

Sintering provides a method of agglomerating the fine-sized raw materials that are input to the blast furnace. This reduces the occurrence of "bridging" in the blast furnace and the subsequent occurrence of blast furnace slips.

Sintering is the process of fusing fine iron ore, coke, fluxstone, mill scale, coke, and flue dust at temperatures between 1300° and 1480°C (2400° and 2700°F). The sinter bed is ignited on the top surface in the furnace. The combustion front is propagated as the windboxes draw air down through the bed. The fused sinter is discharged from the end of the sinter machine where it is crushed and screened. The larger material is cooled and screened again before being input to the blast furnace.

2.3 IRON MANUFACTURING PROCESS

~~Iron is produced in blast furnaces~~, which are large refractory-lined chambers into which iron in the form of natural ore, or agglomerated products such as pellets or sinter, coke, and limestone are charged and allowed to react with large amounts of hot air to produce molten iron. Slag and blast furnace gases are by-products of this operation. The production of 1 unit weight of iron requires an average charge of 1.7 unit weights of iron bearing charge, 0.55 unit weight of coke, 0.20 unit weight of limestone, and 1.9 unit weight of air. Blast furnace by-products consist of 0.3 unit weight of slag, 0.05 unit weight of flue dust, and 3.0 unit weights of gas per unit of pig iron produced. The coke used in the process is produced in by-product coke ovens. The flue dust and other iron ore fines from the process are converted into useful blast furnace charge via sintering operations.

2.4 BASIC OXYGEN FURNACES

The basic oxygen process is employed to produce steel from a furnace charge composed, on the average, of 70% molten blast furnace metal and 30% scrap metal by use of a stream of commercially pure oxygen to oxidize the impurities, principally carbon and silicon. Cycle time for the basic oxygen process ranges from 25 to 45 min.

Most of the basic oxygen furnaces (BOF) in the United States have oxygen blown through a lance in the top of the furnace. However, the Q-BOP which is growing in use, has oxygen blown through tuyeres in the bottom of the furnace.

There is much CO produced by the reactions in the furnace. This CO can be combusted at the mouth of the furnace and then vented to gas cleaning devices as is the case with the open hood, or the combustion can be suppressed at the furnace mouth as is the case with the closed hood. The term "closed hood" is actually a misnomer since the opening is large enough to allow approximately 10% theoretical air to enter at the furnace mouth. Nearly all the Q-BOPs in the United States have closed hoods and most of the new top-blown furnaces are being designed with closed hoods. Most of the furnaces installed prior to 1975 were of the open hood design.

2.5 ELECTRIC ARC FURNACES

Electric arc furnaces (EAF) are used to produce carbon, alloy, and stainless steel. All the stainless steel made in the United States in 1976 was via electric arc furnaces. Cycles range from 1-1/2 to 5 hr for carbon steel and from about 5 to 10 hr or more to produce alloy steel.

The charges to an electric arc furnace is nearly always 100% scrap. Heat is furnished to melt the scrap normally via direct-arc electrodes extending through the roof of the furnace. An oxygen lance may or may not be used to speed the melting and refining process.

2.6 OPEN HEARTH FURNACES

In the open hearth furnace (OHF), a mixture of scrap iron and steel, and hot metal (molten iron) is melted in a shallow rectangular basin, or "hearth." Burners producing a flame above the charge provide the heat necessary for melting. The mixture of scrap and hot metal can vary from 100% scrap to 100% hot metal but 50% scrap and 50% hot metal is a reasonable industry-wide average. The process may or may not be oxygen lanced and this effects the process cycle time which is approximately 8 hr or 10 hr, respectively.

2.7 SCARFING

Scarfing is a method of surface preparation of semi-finished steel. A scarfing machine removes surface defects from the steel billets, blooms, and slabs before they are shaped or rolled by applying jets of oxygen to the surface of the steel which is at orange heat thus removing a thin upper layer of the metal by rapid oxidation. Scarfing is normally performed by machine on hot semi-finished steel or by hand on cold or slightly preheated semi-finished steel.

2.8 MISCELLANEOUS COMBUSTION SOURCES

Iron and steel plants require energy in the form of heat or electricity for every plant operation. Some energy intensive operations that produce particulate emissions on plant property are boilers, soaking pits and slab furnaces burning such fuels as coal, No. 2 fuel oil, natural gas, coke oven gas, or blast furnace gas.

In soaking pits, ingots are heated such that the temperature distribution across the cross-section of the ingots is acceptable and the surface temperature uniform for further rolling into semi-finished products such as blooms, billets, and slabs. In slab furnaces, a slab is heated before being rolled into finished products such as plate, sheet, or strip.

2.9 OPEN DUST SOURCE PROCESSES

As was previously stated, open dust sources include (a) vehicular traffic on paved and unpaved roads, (b) raw material handling outside of buildings, and (c) wind erosion from storage piles and exposed terrain.

Vehicular traffic consists of plant personnel and visitor vehicles, plant service vehicles, and trucks for hauling raw materials, plant deliverables, steel products, and waste materials.

Raw material is handled by clamshell buckets, bucket-ladder conveyors, rotary railcar dumps, bottom railcar dumps, front-end loaders, truck dumps, and at conveyor transfer stations. All these activities disturb the raw materials and expose the fines to the wind.

Even fine materials resting on flat areas or in storage piles are exposed to the wind. It is not unusual to have several million tons of raw material stored at a plant nor is it unusual to have in the range of 10 to 100 acres of flat exposed area at a plant. These types of sources are subject to wind erosion.

SECTION 3.0

EMISSION FACTORS AND SUPPORT DATA

This section presents all the known particulate emission factors (EFs) applicable to iron and steel industry sources and also the details of process operation and test methodology necessary to evaluate the reliability of the EFs. A reliability rating is given to each EF based on the following scale:

Rating	Rating description
A	EF was based on a sound test methodology and all test methodology and process operation support data were presented in detail.
B	EF was based on a sound test methodology, but all test methodology and process operation support data were not presented in detail.
C	EF was based on questionable or unreported test methodology.
D	EF based on calculations and/or experienced estimate.

Some tests are listed as unrateable. This is because no emission factor was reported or able to be calculated from the reported data. An unrateable category does not indicate that the test was not performed properly but simply indicates that there was no emission factor to rate.

3.1 BY-PRODUCT COKE OVENS

Particulate emissions occur during the coking operation from the following sources: (a) charging of coal, (b) oven door leaks, (c) coke pushing, (d) coke quenching, (e) oven combustion stacks, (f) coal preheating, and (g) topside leaks. The present practice is to report EFs in pounds per ton of coal so that the various sources can be compared.

3.1.1 Coal Charging

One of the coal charging values presently included in the data base originated in a document which was very relevant for its time but is now technically outdated.[5] By estimates and by measurement techniques using greased plates to quantify deposition, a range of 0.1 to 2.4 lb/ton of coal charged was acquired. There were no supportive test details listed in the document. AP-42 presently uses 1.5 lb/ton which is an average of the EFs presented in Reference 5. This EF is given a D rating.

Measurements were also performed at Bethlehem Steel's Burns Harbor Plant. Measurements were taken before and after a scrubbing system. The uncontrolled emissions were measured as 0.52 lb/ton coal and the controlled emissions as 0.02 lb/ton coal. The uncontrolled emissions do not represent all the emissions from charging since emissions from the chuck door during leveling and from the coal hoppers after emptying were not captured by the system. Specific details of the tests are not available in the reference. This EF is given a C rating.

The most rigorous work in measuring the mass of charging emissions was performed under U.S. EPA Contract at the Pittsburgh Works of the J&L Steel Corporation.[141/] Emission factors for charging wet coal from a Wilputte larry car for uncontrolled coal charging and from a specifically designed semi-automated sequential charging car called the AISI/EPA car were determined. Mass emissions were measured with a specialized sampling train containing an in-stack probe followed by an out-of-stack heated cyclone and filter followed by a heated line connected to a condensate trap. The train was similar to a Method 5 train although the sampling flow rate and time permitted a much smaller sample volume than is recommended by Method 5. The six emission points on the Wilputte car and the three on the AISI/EPA car were each tested three to four times. Given a charging rate of 16.7 tons of coal per charge,[142/] the Wilputte car uncontrolled wet coal charging process yielded an emission factor of 0.11 lb/ton of coal while the AISI/EPA car yielded a controlled emission factor of 0.016 lb/ton of coal for sequential charging. Because of the non-isokinetic nature of the sampling, both emission factors were given a C rating.

None of the references provides definitive data, but, in the absence of such data, an average of 0.85 lb/ton coal will be used to represent uncontrolled charging emissions. This average EF is given a C rating.

3.1.2 Door Leaks

AISI submitted data for door leaks from Plant A which showed results of three coke-side shed tests performed when no pushing was occurring.[7/] If one concludes that the emissions measured must then represent door leaks, the average door leak EF on the push side of the tested battery was 0.18 lb/ton coal (range 0.14 to 0.24 lb/ton coal). These tests were conducted before the scrubber using test method WP-50. The details of the testing effort are not known. If the value of 0.18 lb/ton coal is doubled to allow for door leaks on both sides, then a value of 0.36 lb/ton coal represents the total door leakage emissions.

A similar value was found in another coke-side shed test series.[8] The results of three tests yielded an average of 0.22 lb/ton dry coal (range 0.04 to 0.41 lb/ton dry coal based on particulate captured in the front half of the sampling train). Doubling this result to allow for door leaks on both sides yields 0.44 lb/ton dry coal.

In a coke-side shed testing effort at a third plant,[9] particulate emissions sampled during the nonpushing cycle ranged from 0.20 to 0.52 lb/ton dry coal with an average over three tests of 0.36 lb/ton dry coal. These values are based on particulate collected in the front half of the sampling train. Assuming that the nonpushing emissions were mainly comprised of door leaks and allowing for leaks on the other side of the battery, the emissions from door leaks averaged 0.72 lb/ton dry coal.

A factor of 0.5 lb/ton dry coal represents the average door leak EF. Unfortunately, the percent of doors leaking is not known for these tests so that application to other batteries is difficult. This average EF is given a B rating.

3.1.3 Coke Pushing

The test data for coke pushing currently available in the data base are shown in Table 2. Average EFs and their reliabilities along with process parameters and test methodology are presented. There are five A-rated EFs, fourteen B-rated EFs and six-C-rated EFs in Table 2.

3.1.4 Coke Quenching

The test data for coke quenching currently available in the data base are shown in Table 3. Average EFs and their reliabilities along with process parameters and test methodology are presented. There are four A-rated EFs and five C-rated EFs in Table 3.

The reasons for the large differences shown in Table 3 between the A-rated quench test results at Dofasco's Hamilton, Ontario, plant and those at U.S. Steel's Lorain Works are currently the topic of much debate. There are five hypothesized independent variables which may explain the wide variation in emission factor measurements:

1. The vertical speed of the combined air and water vapor mixture,

2. The water application technique,

3. The total suspended solids in the quench water,

4. The amount of volatiles remaining in the coke, and

5. The existence and design of baffles.

TABLE 2. SUMMARY OF EMISSION FACTORS FOR COKE PUSHING OPERATIONS

Average emission factor[b/] (lb/ton coal)	E.F. reliability	Company/ location	Battery designation	Test date	Process parameters: Oven height (ft)	Tons of coke/ push[b/]	Coke quality	Emission capture system	Gas flow rate (dscfm)	Gas temp. (°F)	Test methodology: Sampling methodology	No. of runs	No. of pushes/ run	Sample time (min)	Percent isokinetic	Average measured concentration (gr/dscf)	Average emission factor (lb/ton coal)	Comments	Reference
2.0 (Total emissions from	B	Northwest Indiana	a/	12/77 and 4/78	12	a/	Green	None	175,400[c/]	232[d/] (81-534)	High-volume (43 scfm) isokinetic sampler at single pt suspended in center of plume. Used 8 in. x 10 in. glass fiber filter. Cup anemometer for velocity measurements.	39	1	a/	a/	1.44	2.0 (0.09-9.0)	Cross-sectional shape of plumes determined with 2 motion picture cameras.	10
0.7 pushing as measured	B						Clean		210,400[c/]	117 (71-167)		25	1	a/	a/	0.787	0.7 (0.05-2.0)		
1.5 directly over car)	B						Overall		186,400 (50,000 - 749,000)	191 (71-534)		64	1	a/	a/	1.18	1.5 (0.05-9.0)		
0.49	C		No. 1	10/74	20	23.5	Moderate to Green	Coke-side shed	171,000-308,000	160	Andersen in-stack impactor in duct leading to collector.	3 - during peak emissions	1-3	2-6	a/	0.145	0.49	Tests by Bethlehem Steel Corporation Research Department. Neglected probe losses.	11 pp. 7,11,27
0.68	B	Bethlehem Steel, Burns Harbor, Indiana	No. 1	11/74	20	23.5	a/	Coke-side shed	171,000-308,000	115-170	Alundum Thimble-ASTM method in duct leading to collector. No condensate trap.	2 - during peak emissions	10	20	a/	0.186	0.68	Tests by Bethlemen Environmental Quality Control Division. 10 pts sampled per run.	11 pp. 7,11,32-34
0.69[e/]-Suspended emissions 0.45 - Dustfall bucket catch from all push side operations	A C		No. 1	3/75	20	22-24	a/	Coke-side shed; 85% capture efficiency	268,000-Continuous sampling; 257,000-sampling during peak emissions	a/ 124	EPA Method 5 in duct leading to collector.	3 - continuous 3 - during peak emissions	23-25 20	288 60	a/ a/	0.054[e/] 0.19[e/]	0.69[e/]	Tests by Clayton Environmental Consultants. Suspended emission factor includes fugitive and shed captured particulate.	8 p.63 and 12 p. 3-25
0.55e/ without sprays 0.39e/ with sprays 1.4e,f/ without sprays 1.2e,f/ with sprays	A A B B		No. 1	3/76-4/76	20	23.5	a/	Coke-side shed; 85% capture	a/	a/	EPA Method 5 in duct leading to collector	4- without sprays; 15-	8	a/	a/	a/	0.55e/ Without sprays; 0.39e/ With sprays	Special tests to determine effects of water sprays as control.	13

Average emission factor[b/] (lb/ton coal)	E.F. reliability	Company/ location	Battery designation	Test date	Process parameters: Oven height (ft)	Tons of coke/ push[b/]	Coke quality	Emission capture system	Gas flow rate (dscfm)	Gas temp. (°F)	Test methodology: Sampling methodology	No. of runs	No. of pushes/ run	Sample time (min)	Percent isokinetic	Average measured concentration (gr/dscf)	Average emission factor (lb/ton coal)	Comments	Reference
0.25[e/] Suspended emissions 1.1 Dustfall bucket catch from all push side operations.	A C	Great Lakes Carbon St. Louis, Missouri	South	4/75	11	10.5	a/	Coke-side shed; 91% avg. capture efficiency	119,000-132,000	69-85	Modified EPA Method 5 in duct leading to collector.	3	10-15	192-288 pushing cycle 168-192 non-pushing cycle	99.9-102.9	0.017[e/] pushing cycle	0.25[e/] suspended 1.1 dustfall	Each sample taken at 20 pts in duct. Emission factor includes uncaptured fugitive and shed-captured particulate for pushing only.	9 - page 47 and 12 - page 3-25.
2.3[e/] Total uncontrolled emissions from pushing as measured directly over car.	A	Ford Motor Company, Steel Division Dearborn, Michigan	A	6/24/75 to 7/16/75	13	12	Avg. between green and clean.	Travelling hood fitted directly over car.	77,000-82,800	130-209	Modified EPA Method 5 in duct leading to scrubber.	9	16 or 24	16 or 24	100-108.6	1.67[e/]	2.3[e/]	Hood capture efficiency estimates ranged from 32 to 80%. Scrubber removed 99.3% of what was captured.	14 - pp. 11, 98, 182, 220
0.29	B[g/]	Company A (AISI Data)	a/	9/75-11/75	a/	11.3	a/	Coke-side shed	175,100	81	WP-50 in duct leading to collector	28	8	24	a/	0.063	0.29		15
0.26	B[g/]	Company A (AISI Data)	a/	2/76-3/76	a/	11.3	a/	Coke-side shed	168,900	113	("EPA-approved" in duct leading to collector)	4	24	a/	a/	0.060	0.26		15
0.4[e/]	C	Company B (AISI Data)	No. 3	12/73	a/	24	a/	Enclosed coke car & guide to venturi scrubbers via stationary main.	61,300	118	ASTM PTC-21 in duct leading to east and west scrubbers.	6	7-13	28-78	a/	0.16[e/]	0.4[e/]	Unclear how testing east and west scrubbers coincides with pushing process.	16 - p. 4
0.024[e/]	C	Company B (AISI Data)	No. 3	12/73	a/	24	a/	Same as above	66,500	108	ASTM PTC-21 in stacks exiting east and west scrubbers.	6	7-13	28-78	a/	0.071[e/]	0.024[e/]	Unclear how testing east and west scrubbers coincides with pushing process.	16 - p. 4
14.4[e/] Lb/push	B	CF&I Pueblo, Colorado	B, C, D	8/10/76 to 8/17/76	a/	a/	a/	a/	52,400 scfm	254	Single point sample through probe suspended in the plume. Sampled at 45-61 scfm.	12	1	14-30 sec	a/	1.852 gr/scf	14.4[e/] lb/push	Plume cross-sectional area determined photographically. Plume temperature measured at single point with a hot wire anemometer.	136

Average emission factor b/ (lb/ton coal)	E.F. reliability	Company/ location	Battery designation	Test date	Process parameters: Oven height (ft)	Process parameters: Tons of coke/ push b/	Process parameters: Coke quality	Process parameters: Emission capture system	Process parameters: Gas flow rate (dscfm)	Process parameters: Gas temp. (°F)	Test methodology: Sampling methodology	Test methodology: No. of runs	Test methodology: No. of pushes/ run	Test methodology: Sample time (min)	Test methodology: Percent isokinetic	Average measured concentration (gr/scf)	Average emission factor (lb/ton coal)	Comments	Reference
0.34e/	B	Bethlehem Steel, Burns Harbor, Indiana	No. 1	7/74	20	23.5	a/	Coke-side shed	a/	a/	EPA train with sampling at a single point	2	8-12	16-24	a/	a/	0.34e/	Emission factor represents emissions captured by shed	17
0.43e/	B	Bethlehem Steel, Burns Harbor, Indiana	No. 1	7/74	20	23.5	a/	Coke-side shed	a/	a/	EPA train with full Method 5 multipoint traverse	2	8-12	16-24	a/	a/	0.43e/	Emission factor represents emissions captured by shed	17
0.56 (front and back half of sampling train)	B	Bethlehem Steel, Burns Harbor, Indiana	No. 1	7/74	20	23.5	a/	Coke-side shed	a/	a/	Modified ASTM train with out-of-stack filter	7	8-12	16-24	a/	a/	0.56	Emission factor represents emissions captured by shed	17
0.53	B	Bethlehem Steel, Burns Harbor, Indiana	a/	a/	a/	a/	a/	Coke-side shed	a/	a/	ASTM sampling train	23	8-10	16-20	a/	a/	0.63	Emission factor represents emissions captured by shed	12 p. 3-25
0.48 - dustfall	C	Bethlehem Steel, Burns Harbor, Indiana	a/	a/	a/	a/	a/	Coke-side shed	a/	a/	a/	a/	a/	a/	NA	NA	0.48	Emission factor represents emissions settling on ground in shed	12 p. 3-25
0.32e/	B	P	Battery C	3/75	a/	a/	a/	Coke-side shed	a/	100	Method 5	2	8	24	a/	0.016	0.32e/	In stack after scrubber with scrubber off	12 p. 3-25

a/ Reference provides insufficient data or corroboration of data.
b/ Used 0.7 tons coke per ton of coal as conversion where necessary.
c/ Average for 66 tests.
d/ Average temperature for 33 tests.
e/ Based on particulate collected in front half of sampling train.
f/ Includes 1.25 lb/ton coke for tests without sprays and 1.1 lb/ton coke for tests with sprays as determined by dustfall buckets.
g/ AISI - compiled tests selected as acceptable by Peter Westlin, Test Support Section, OAQPS.

TABLE 3. SUMMARY OF EMISSION FACTORS FOR COKE QUENCHING OPERATIONS

Average emission factor (lb/ton coal)	E.F. reliability	Company/ location	Test date	Process parameters: Tower dimensions at sampling level	Tons of coal/ hr	Exhaust flow rate (dscfm)	Exhaust temp. (°F)	Gallons H_2O per quench	Test methodology: Sampling methodology	Sampling location	Sample No. of runs	Sample time/ run (min)	No. of quenches per run	Percent isokinetic	Average measured concentration (gr/dscf)	(lb/hr)	Average emission factor (lb/ton coal)	Comments	References
1.4 + 0.00018 x TDS b,e/ 1.4 d/ - clean water tests 2.6 d/ - dirty water tests	A	U.S. Steel Lorain, Ohio	8/76	Tapered, cylindrical 14 ft ID at 100 ft level	41-55	181,900	a/	6,000-12,000	High volume, 2 cfm singlepoint sampling using EPA Method 5 train with pre-cyclone.	After baffles	25	Only during quench (2 to 3 min each)	4	91.1-109.5	a/	a/	1.4 + 0.00018 x TDS b,e/	E.F. determined from best-fit line; 12 clean water tests and 13 dirty water tests.	18,19
0.7 c/	C	Bethlehem Steel Lackawanna, New York	4/74	16 ft x 16 ft	149	382,300 wet scfm	142	a/	Single point sampling using EPA Method 5 sampling train	After baffles with sprays	6	About 3 min per quench.	18	67-77	0.19 c/	101.9 c/	0.7 c/	Sampled north quench tower handling mainly Battery 9 coke ovens.	20
0.44	C	France	a/	a/	a/	a/	a/	a/	Greased disks	a/	a/	a/	a/	NA	a/	a/	a/	Estimate.	5, p. 6
0.40	C	Poland	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	Also contains emissions from coke pushing.	5, p. 19
0.25 d/	A	Dofasco Hamilton, Ontario	8/77	18 ft x 37 ft	16T coal quench	152,000-308,400	155	a/	High volume, 2 cfm sampling at 2-6 points using cyclone and heated probe in the tower and heated filter outside the tower followed by condensate trap	5 ft above baffles	9	9-14	6	92-107	0.0613 d/	3.965 d/	0.25 d/	Using normal recycle water.	21
0.21 d/	A	Dofasco Hamilton, Ontario	8/77	18 ft x 37 ft	16T coal quench	168,100-	155	a/	Same as above	5 ft above baffles	2	11-13	6	106-108	0.0655 d/	3.417 d/	0.21 d/	Using normal recycle water with baffle sprays operating.	21
0.23 d/	A	Dofasco Hamilton, Ontario	8/77	18 ft x 37 ft	16T coal quench	149,300-278,700	155	a/	Same as above	5 ft above baffles	6	6-13	3-6	81-108	0.0611 d/	3.739 d/	0.23 d/	Using once through bay water	21
0.32	C	U.S. Steel Clairton, Pa.	12/67	15 ft x 15 ft	186	391,000 wet scfm	150	4,000	Greased plate	In tower with no baffles	a/	a/	a/	NA	a/	6 lb/quench	0.32		22
0.04	C	U.S. Steel Clairton, Pa.	12/67	15 ft x 15 ft	186	391,000 wet scfm	150	4,000	Greased plate	In tower with 45-degree baffles spaced 1-1/2 to 3 in. apart. Baffles are washed once per shift with sprays.	a/	a/	a/	NA	a/	0.75 lb/quench	0.04		22

a/ Reference provides indufficient data on corroboration of data.
b/ TDS = Total dissolved solids in quench water in parts per million by mass.
c/ Unclear whether value is based on particulate collected in front half of sampling train or in front and back halves combined.
d/ Based on particulate collected in front half of sampling train.
e/ Based on particulate collected in front and back halves of sampling train.

Additional source testing is required to develop an equation relating emissions to the independent variables.

3.1.5 Coke Oven Battery Combustion Stacks

The test data for coke oven battery combustion stacks currently available in the data base are shown in Table 4. Average EFs and their reliabilities along with process parameters and test methodology are presented. There are 21 B-rated EFs, four C-rated EFs, and one unrateable EF in Table 4.

3.1.6 Coal Preheaters

Some limited data exist on emissions from Cerchar coal preheaters.[135] Uncontrolled emissions of total particulate were measured during 18 tests at one plant and ranged from 5.3-8.8 lb/ton coal with an average of 7.0 lb/ton coal. Controlled emissions of total particulate were measured during 18 tests at Venturi scrubber outlets and ranged from 0.25-1.82 lb/ton coal with an average of 0.65 lb/ton coal. The original testing reports were not available to identify the test methodology; consequently, the values are C-rated.

3.2 BLAST FURNACES

Emissions occur during the production of iron when blast furnaces slip and when emissions escape the cast house monitor.

3.2.1 Slips

Slips occur when a strata of the material charged to a blast furnace does not settle with the input material below it, thus leaving a gas-filled space between the two portions of the charge. When this unsettled strata of charge collapses, the displaced gas may cause the top gas pressure to increase above the safety limit, thus opening a counterweighted bleeder valve which is open to the atmosphere.

The only EFs available to quantify slip emissions were estimated by Battelle.[26] An EF range of 0.0046 to 0.046 lb/ton of hot metal reported by the Battelle researchers was estimated by the following method.

The amount of dust emitted per slip was estimated by assuming that the slip-induced dust loading would be 10 to 100 times the maximum normal dust loading of blast furnace off-gas, which is in the range of 7 to 30 gr/scf.[27] Therefore, 300 to 3,000 gr/scf would be contained in the slip-generated gas volume. This gas volume was quantified using the dimensions of a typical furnace (30-ft diameter) and assuming a 2-ft slip height, an actual temperature of 927°C, and an actual pressure of 2 atm absolute. The gas volume calculated via the ideal gas law was 18,200 normal liters (643 scf). The entire volume of slip-generated gas was then assumed to be released through the

TABLE 4. SUMMARY OF UNCONTROLLED EMISSION FACTORS FOR BY-PRODUCT COKE OVEN COMBUSTION STACKS

Average emission factor[a] (lb/ton coal)	E.F. relia-bility	Company/ location	Coke battery designation	Test date	Process conditions: No. of ovens	Coal charged per oven (tons)	Coal input (tons/hr)	Fuel type[b]	Stack gas flow rate (scfm)	Stack temp (°F)	Test methodology: Sampling method	No. of runs	Percent isokinetic	Average measured concentration: gr/dscf	lb/hr	Emission factor[a] (lb/ton coal)	References
0.35	B	Alabama By-Products Torrant, AL	Nos. 5 and 6 (common stack)	10/75	54	17	57.4	COG	61,900	329	EPA-5	3	d/	0.038	20.1	0.35	23
0.12	B	Armco	1	7/73	31	18.5	41.4[f]	NG	30,500	445	EPA-5/Texas	3	d/	0.019	5.1	0.12	23
0.21	B	Steel	1	4/75	33	18.5	41.4[f]	NG	31,870	499	Compliance	3	d/	0.032	8.5	0.21	
0.06	B	Houston, TX	1	11/76	34	18.5	41.4	NG	39,350	414	Method	3	d/	0.008	2.6	0.06	
0.42	B		2	11/76	15[c]	18.5	13.2	NG	8,550	431		3	d/	0.074	5.5	0.42	
0.36	B	Bethlehem	8	3/75	61[c]	d/	51.4	COG	35,890	525	State of	1	d/	0.060	18.5	0.36	23
0.42	B	Steel	8	3/75	61[c]	d/	51.8	BFG	47,380	565	Maryland	2	d/	0.053	21.6	0.42	
0.74	B	Sparrows	9	7/75	63[c]	d/	54.8	COG	33,300	560	Stack Test	3	d/	0.141	40.4	0.74	
0.18	B	Point, MD	9	6/75	63[c]	d/	56.8	BFG	51,660	527	Method	2	d/	0.024	10.3	0.18	
0.43	B		10	6/75	63[c]	d/	55.3	BFG	55,410	522		5	d/	0.050	23.8	0.43	
0.42	B		11	6/75	63[c]	d/	57.8	COG	29,330	576		3	d/	0.096	24.1	0.42	
0.90	B		12	6/75	61[c]	d/	57.1	COG	36,270	519		3	d/	0.165	51.2	0.90	
2.59[h]	B	Bethlehem Steel Johnstown, PA	17	12/75	77[c]	11.5	47.9	COG	66,300	576	Pennsylvania State Method	1	d/	0.218	124	2.59	23
0.53	B	Donner Hanna Coke Corporation Buffalo, NY	B	12/73	36	12	28.5	COG	22,860	588	EPA-5	3	d/	0.077	15.2	0.53	23
1.31	B	Kaiser Steel Fontana, CA	A	9/75-1/76	45	14	31.5	COG	38,450	425	EPA-5	47	d/	0.125	41.2	1.31	23
0.16	C		D	12/72	45	14	37.1	COG	42,500	270	Gelman filter with glass wool filter preceeding impingers	2	d/	0.016	5.8	0.16	23
0.12	C		E	12/72	45	14	37.1	BFG	56,100	360		1	d/	0.009	4.3	0.12	
0.36	B	Lone Star Steel Lone Star, TX	A & B (common stack)	2/73	77	17.3	51.9	COG	37,200	468	State of Texas with EPA train	3	d/	0.059	18.8	0.36	23
1.04	B	National Steel Granite City, IL	B	9/76	49	16.2	45.4	COG	28,170	600	EPA-5	2	d/	0.195	47.1	1.04	23

TABLE 4. (concluded)

Average emission factor[a] (lb/ton coal)	E.F. reliability	Company/ location	Coke battery designation	Test date	Process conditions: No. of ovens	Process conditions: Coal charged per oven (tons)	Process conditions: Coal input (tons/hr)	Process conditions: Fuel type[b]	Process conditions: Stack gas flow rate (scfm)	Process conditions: Stack temp (°F)	Test methodology: Sampling method	Test methodology: No. of runs	Test methodology: Percent isokinetic	Average measured concentration: gr/dscf	Average measured concentration: lb/hr	Emission factor (lb/ton coal)	References
0.67[h]	B	Shenango, Inc. Pittsburgh, PA	2 & 3 (common stack	7/76	35	19.8	72.0	COG	46,830	598	EPA-5/State of Pennsylvania	10	d/	0.131	51.8	0.67	23
0.82[g]	B[g]	U.S. Steel Fairfield, AL	3	8/75	48	15.2	45.6	COG	37,300	483	WP-50 (thimble)	3	d/	0.117	37.3	0.82	23
0.46	B	Youngstown Sheet & Tube Company Indiana Harbor, IN	4	11/76	75	18.1	71.4	COG	72,940	527	EPA-5	3	d/	0.052	12.6	0.46	23
0.7	C	Company D (AISI data)	d/	4/75	d/	d/	d/	d/	55,000	581	d/	10	d/	0.194	40.3	0.7	24
0.08	B[e]	Company A (AISI data)	No. 2	5/75	d/	d/	d/	d/	70,325	565	WP-50	4	d/	0.008	5.25	0.08	25
0.8	C[e]	Company D (AISI data)	d/	4/75	d/	d/	d/	d/	66,100	499	d/	10	d/	0.210	42.8	0.8	24
d/	d/	CF&I Pueblo, CO	D	6/78	31	d/	d/	d/	17,420	441	EPA-5	3	96.9-108.4	0.00650	0.98	d/	139

a/ "Front half" particulate only.
b/ COG: coke oven gas; BFG: blast furnace gas; NG: natural gas.
c/ Exact number of ovens in operation during testing not known.
d/ Reference provides insufficient data or corroboration of data.
e/ AISI-compiled tests selected as acceptable by Peter Westlin, Test Support Section, OAQPS.
f/ Reported as 56-60 tons of coal/hr in a 10/11/76 letter from Bill Benzer to Peter Westlin.
g/ Sample taken only during charging period.
h/ May include particulate captured in front and back halves of train.

dirty-gas bleeder valve. Thus, the quantity of dust emitted per slip would range from 27.6 to 276 lb.

Of the total of 135 blast furnaces operating in the United States in 1974 to 1975, it was assumed that 22 were "problem" furnaces which averaged 30 slips per month. The remaining 113 furnaces were assumed to average four slips per month. Therefore, the total number of slip-induced bleeder valve emissions in the United States in 1974 was 13,350. Using the 27.6 to 276 lb/slip range and the 1974 net hot metal production rate of 79.9×10^6 tons, the EFs for slip-induced emissions are found to range from 0.0046 to 0.046 lb/ton of hot metal produced. The document qualifies this as a first attempt order of magnitude calculation.

3.2.2 Cast House Monitor

The test data for cast house emissions currently available in the data base are shown in Table 5. Average EFs and their reliabilities along with process parameters and test methodology are presented. There is one A-rated EF, five B-rated EFs, and four C-rated EFs in Table 5.

3.3 SINTERING

Emissions occur at several points in the sintering process. The points of particulate generation are (a) the windbox, (b) the discharge (sinter crusher and hot screen), (c) the cooler, and (d) the cold screen. In addition to these sources, there are in-plant transfer stations which generate emissions and can be controlled by localized enclosures. All the above sources, except the cooler, are normally vented to one or two control systems.

The main problem with the EFs related to sintering compiled in Table 6 is that the sources contributing to the factor are not delineated in many cases. There are fifteen A-rated EFs in Table 6, twenty-seven B-rated EFs, eight C-rated EFs, and ten unrateable factors.

3.4 BASIC OXYGEN FURNACES

There are several sources of particulate emissions in the basic oxygen furnace steelmaking process. The emission sources are (a) emissions from the furnace mouth during refining collected by local full (open) or suppressed (closed) combustion hoods, (b) hot metal transfer to charging ladle, (c) charging scrap and hot metal, (d) dumping slag, and (e) tapping steel.

Table 7 lists EFs from several of the above sources. The roof monitor emissions are a composite of the portion of charging, tapping, slagging, and hot metal transfer emissions that escape to the atmosphere.

TABLE 5. SUMMARY OF EMISSION FACTORS FOR BLAST FURNACE CAST HOUSE OPERATIONS

Average Emission factor (lb/ton hot metal)	E.F. relia-bility	Company/ location	Furnace desig-nation	Test date	Process parameters: Tons hot metal/ cast	Process parameters: Duration of cast (min)	Process parameters: Exhaust rate (scfm)	Process parameters: Gas temp. (°F)	Process parameters: Emission capture system	Test methodology: Sampling methodology	Test methodology: No. of runs	Test methodology: Sample time/run (min)	Test methodology: Percent Iso-kinetic	Average Measured concentration (gr/scf)	Average Measured concentration (lb/hr)	Average Emission factor (lb/ton hot metal)	Comments	Reference
0.1c/	B	Bethlehem Steel, Bethlehem, Pa.	E	9/76	a/	a/	83,500	111	< 75% capture	EPA Method 5, Sampled in duct after hood and before any control device	3	30-40	a/	0.050c/	35.5c/	0.10c/	Capture efficiency based on visual observation of canopy hood collection system. EF represents only locally captured taphole and trough emissions.	28; 29, pp. 52-53
0.26c/	B				a/	a/	283,700	108	75-90% capture		3	35-65	a/	0.041c/	98.5c/	0.26c/		
0.25c/	B				a/	a/	144,100	125	80-95% capture		3	31-35	a/	0.097c/	120	0.25c/		
0.78c/	A	Dofasco, Hamilton, Ontario Canada	No. 1	8-11/76	277	37	308,300	134	100% open fan setting	EPA Method 5, Sampled in duct leading to baghouse	2	35	101	0.142c/	368c/	0.78c/	Total cast house evacuation. One test per cast.	29 p. 45, p. C-1ff
0.48c/	C		No. 1		321	32	293,600	140	70% open fan setting		2	22	106-111	0.126c/	299c/	0.48c/		
0.68c/	C		No. 1		283	36	208,100	155	40% open fan setting		2	33	111-116	0.200c/	326c/	0.68c/		
0.20c/	B	Bethlehem Steel, Johnstown, Pa.	E	10/76-11/76	180	33	289,900	82	Total cast house evacuation to baghouse	EPA-5	19	33	a/	0.029c/	60.9c/	0.20c/	One test per cast. Sampling in duct leading to baghouse.	29 p. 52,53, D-1
0.25	C	CF&I, Pueblo, Colorado	a/	a/	a/	a/	a/	a/	a/	Time lapse photography	a/	a/	a/	a/	a/	0.25	Study done by Celesco Ind. (Report No. 156).	29 p. 52
0.52	C	Dofasco, Hamilton, Ontario Canada	No. 1	8/76-11/76	a/	a/	300,000 acfm	a/	Building evacuation to baghouse	Weight of particulate captured by the baghouse							Does not include weight of emissions passed by baghouse.	29 pp. 45-46
0.31	Bb/	Bethlehem Steel, Sparrows Point, Md.	J	11/76-12/76	391	32-70	458,400-695,200	95	None	Hi-Vols suspended in bays of the roof monitor	10	32-70	a/	0.028	157	0.31		29 p. 52; 30

a/ Reference provides insufficient data or corroboration of data.

b/ AISI - compiled tests selected as acceptable by Peter Westlin, Test Support Section, OAQPS.

c/ Based on particulate collected in front half of sampling train.

Average emission factor (lb/ton sinter)	Emission factor reliability	Source	Company/ location	Test date	Process conditions: Process production rate	Process conditions: Gas flow rate (dscfm)	Process conditions: Gas temp. (°F)	Test methodology: Type of sampling device	Test methodology: Location of sampling device	Test methodology: Sampling methodology	Test methodology: Percent isokinetic	Test methodology: Sampling time per run (min)	Test methodology: Gas flow rate (dscfm)	Test methodology: No. of runs performed	Test results: Measured concentrations: Range (gr/dscf)	Test results: Measured concentrations: Avg. (gr/dscf)	Test results: Emission factors: Range (lb/ton sinter)	Test results: Emission factors: Avg. (lb/ton sinter)	Comments	Reference
10.8b/ (leaving grate)	B	Uncontrolled windbox exhaust stack	Company D (AISI data)	3/75	1,368-2,369 tons sinter/day	140,000-224,000	188-287	In stack thimble	In windbox exhaust stack	a/	a/	a/	a/	17	0.082-0.196b/	0.135	5.1-19.0b/	10.8b/		31
6.8b/	B	Uncontrolled strand discharge emissions	Company D (AISI data)	3/4-5/75	1,500-2,340 tons sinter/day	34,000	112-151	10 min tests-47 mm glass fiber filter 2 hr tests-alundum thimble	In discharge stack	10 min tests - single pt in stack 2 hr tests - 24 pt traverse	a/	4 tests-2 hr each; 11 tests-10 min each	a/	15	0.97-1.96b/ gr/acf	1.54 gr/acfb/	5.3-8.3b/	6.8b/	Tests performed after cyclone-efficiency of 79% determined by weighing cyclone catch. This efficiency used to calculate uncontrolled emissions.	32
11.8b/ (leaving grate)	B	Uncontrolled windbox exhaust stack	Company C (AISI data)	10/1/69	150 tons sinter/hr	165,000	260	Alundum thimble	In 9 ft sq duct before fan and after coarse particulate control devices.	a/	a/	a/	a/	6	0.16-0.31b/ gr/acf	0.21 gr/acf	8.8-17.4b/	11.8b/	Tests performed after inertial trap, multiclones and policeman. Efficiency of 75% determined by unspecified method. This efficiency used to calculate uncontrolled emissions.	33
1.0b/	Be/	Controlled windbox exhaust stack	Company C (AISI data)	3/70-4/70	150 tons sinter/hr	125,000-135,000 wet scfm	206	Alundum thimble	In 8 ft Ø stack, 85 ft above ground and 15 ft from top	Single point in stack	a/	a/	a/	16	0.13-0.3b/ gr/wet scf	0.21b/	0.64-1.5b/	1.0b/	Smapled after cyclones.	34
8.7b/	Ae/	Uncontrolled emissions from unspecified source (assume windbox)	Company N (AISI data)	10/75-11/75	113-132 tons sinter/hr	240,000-284,000	102-215	a/	a/	EPA Method 5	101-108	90	a/	10	0.176-1.01b/	0.47b/	3.1-18.9b/	8.7b/	Sampled at precipitator inlet.	35
1.9b/ (avg of all tests) 2.2b/ (avg of isokinetic tests)	Ce/ A	Controlled emissions from unspecified source (assume windbox)	Company N (AISI data)	10/75-11/75	113-132 tons sinter/hr	239,000-312,000	128-208	a/	a/	EPA Method 5	92-199	120	a/	10	0.043-0.17b/	0.11b/	0.83-3.8b/	1.9b/	Samples taken at ESP outlet. Five tests were well above the +10% nonisokinetic sampling tolerance.	35
0.55b/	C	(Assume controlled windbox)a/	Company N (AISI data)	4/18-25/74	10,604-11,167 tons sinter/day	256,000-274,000	147-175	In-stack thimble	a/	a/	82-99	a/	a/	2	0.188-0.212b/	0.2b/	0.4-0.7b/	0.55b/		36
107c/	A	Uncontrolled emissions from windbox	Company P (AISI data)	12/29/72	1,350 tons sinter/day	296,000-302,000	90-95	Standard EPA-approved train	In 4 ft x 14.5 ft tile-lined plenum	Modified EPA Method 5. Each test was a traverse along a different single axis.	108-113	97-133	0.4-0.54	3	0.4019-5.0207c/	2.3676c/	18-228c/	107c/	Uncontrolled emissions were observed to be the worst the plant had experienced.	37
0.7c/	Ae/	Controlled emissions from windbox	Company P (AISI data)	12/29/72	1,350 tons sinter/day	305,000-308,000	70-73	Standard EPA-approved train	In 8 ft Ø stack	EPA Method 5	99-103	100	0.53	3	0.014-0.0157c/	0.0148c/	0.65-0.73c/	0.7c/	Control consists of water spray followed by tray-type scrubber.	37
47c/ avg of 2 tests 32c/ avg including suspect test	B Be/	Uncontrolled emissions from unspecified source	Company P (AISI data)	3/27/73	1,471 tons sinter/day	111,800 acfm	a/	a/	Directly after bend in duct leading to baghouse	EPA Method 5(unspecified number of points in traverses)	a/	a/	a/	2(3rd test suspect due to temporary line shut-down)	2.9049-3.7493c/	3.3271c/	42-52c/	47c/		38
0.35c/	Be/	Controlled emissions from unspecified source	Company P (AISI data)	3/27/73	1,471 tons sinter/day	111,000 acfm	a/	a/	In 3 ft Ø stack 1 ft beyond fan and 2 ft from stack exit. Baghouse had 14 stacks, 1/compartment	EPA Method 5 (unspecified number of points in traverse-sampling ports 1 ft beyond fan)	a/	a/	a/	2(3rd test suspect)	0.02275-0.02490c/	0.0238c/	0.32-0.39c/	0.35c/	After Mikropul baghouse.	38

Average emission factor (lb/ton sinter)	Emission factor reliability	Source	Company/location	Test date	Process conditions: Process production rate	Process conditions: Gas flow rate (dscfm)	Process conditions: Gas temp. (°F)	Test methodology: Type of sampling device	Test methodology: Location of sampling device	Test methodology: Sampling methodology	Test methodology: Percent isokinetic	Test methodology: Sampling time per run (min)	Test methodology: Gas flow rate (dscfm)	Test methodology: No. of runs performed	Test results: Measured concentrations Range (gr/dscf)	Test results: Measured concentrations Avg. (gr/dscf)	Test results: Emission factors Range (lb/ton sinter)	Test results: Emission factors Avg. (lb/ton sinter)	Comments	Reference
98[c/] most accurate 46[c/] avg of all 4 tests	B C	Uncontrolled emissions from windbox	Company P (AISI data)	2/73	75 tons sinter/hr	300,000	130	EPA-approved train	In 4 ft x 14 ft scrubber inlet duct at a bend	Modified EPA Method 5 (2 tests at only a single point; 1 test using a partial traverse; 1 test using a full traverse in one direction. Temp. of probe and filter kept the same as duct gas.	a/	90	a/	4	0.379-2.86[c/]	2.86 (most accurate test) [c/]	13-98[c/]	98 (most accurate test)[c/]	Number of traverse points in the "most accurate" test unclear. Lab analysis performed so as not to drive off condensible hydrocarbons. Report noted that Method 5 analysis produced factor of 2 lower total particulate emissions.	39
0.9[c/]	B	Controlled emissions from windbox	Company P (AISI data)	2/73	75 tons sinter/hr	250,000-289,000	100	EPA-approved train	After tray type scrubber (assume 8 ft Ø stack)	Modified EPA Method 5 (probe and filter temp. set to coincide with flue gas temp.)	a/	90	a/	3	0.0195-0.0388[c/]	0.0295[c/]	0.6-1.2[c/]	0.91[c/]	Tray-type scrubber pressure drop of 9 to 11 in. H_2O. Lab analysis performed so as not to drive off condensible hydrocarbons.	39
11[d/]	B	Uncontrolled emissions from discharge and other unspecified sources	Company A (AISI data)	1/71	3,400 tons sinter/day	a/	a/	Thimble	a/	WP-50	a/	a/	a/	1	None	5.65[d/]	None	11[d/]	Emissions from hot screen hood, sinter breaker, and two unknown sources.	40
0.05[d/]	B	Controlled emissions from discharge and other unspecified sources	Company A (AISI data)	1/71	3,400 tons sinter/day	138,200	120	Thimble	After baghouse	WP-50	a/	a/	a/	1	None	0.006[d/]	None	0.05[d/]		40
0.63[b/]	B	Controlled emissions from windbox	Company A (AISI data)	5/75	3,600 tons sinter/day	288,000	300	Model EPA-2 emissions parameter analyzer by Western Precipitation Div. of Joy Manufacturing	In 153 in. Ø stack after ESP	EPA Method 5. 48 points along 2 perpendicular lines.	87-91	192	0.5	3	0.034-0.045[b/]	0.038[b/]	0.56-0.74[b/]	0.63[b/]		41
2.6[b/] (in stack) lb/ton feed 10.5[b/] (leaving grate) lb/ton feed	B B	Uncontrolled windbox (every windbox has at least an inertial collector for large particles)	Armco, Inc. Ashland, KY	8/70-11/70	150 tons feed/hr (feed here includes hot recycle fines from windbox and hot screen)	a/	a/	Alundum thimble filter packed with fine glass wool. Wet impinger. Water trap.	Induced draft stack. After S-collector, multicyclones, and policeman.	a/	a/	a/	a/	40	0.2-0.44[b/] gr/scf	0.31[b/] gr/scf	a/	2.6 lb/ton feed (in stack)	75% of dust leaving grate is captured by S-collectors multicyclones and policeman. Only dust emissions are reported, not oil.	42
a/	a/	Controlled windbox	Armco, Inc. Ashland, KY	8/70-11/70	150 tons feed/hr	a/	a/	Same as above	After pilot scrubber	a/	a/	a/	a/	8	0.005-0.021[b/]	a/	a/	a/	Concentration varies from high to low as pressure drops across scrubber was increased from 23 to 76 in. of H_2O.	42
0.03[c/] 0.0012[b/]	A A	a/	Inland Steel E. Chicago, IL	7/75	159 tons sinter/hr	118,500	118	Standard EPA sampling train	In stack after baghouse	EPA Method 5	98.4	60	0.6	3	0.0040-0.0051[c/] 0.0012-0.0016[b/]	0.0047[c/] 0.0014[b/]	0.026-0.034[c/] 0.0079-0.01[b/]	0.030[c/] 0.0092[b/]	12 sample point/run; 5 min/sampling point; stainless steel probe on tests 1 and 2, glass lined probe in test 3.	43

Average emission factor (lb/ton sinter)	Emission factor reliability	Source	Company/ location	Test date	Process conditions			Test methodology							Test results				Comments	Reference
					Process production rate	Gas flow rate (dscfm)	Gas temp. (°F)	Type of sampling device	Location of sampling device	Sampling methodology	Percent isokinetic	Sampling time per run (min)	Gas flow rate (dscfm)	No. of runs performed	Measured concentrations Range (gr/dscf)	Measured concentrations Avg. (gr/dscf)	Emission factors Range (lb/ton sinter)	Emission factors Avg. (lb/ton sinter)		
4.8c/ 3.8b/ lb/tons input	C	Controlled Windboxes	Bethlehem Steel Johnstown, PA	12/75	105 tons feed/hr (including recycled fines but excludes hearth layer)	184,600	225	Modified EPA sampling train	In stack after Research Cottrell ESP	EPA Method 5	105	120	0.6	1	NA	0.32c/ 0.256b/	NA	4.8c/ 3.8b/ lb/tons input	Emission factor based on tonnage input and not sinter output. 12 sampling points; 10 min/sampling point.	44
a/	a/	Uncontrolled windbox	Armco, Inc. Houston, TX	7/71	1194 tons input/ day	a/	a/	Modified EPA sampling trains w/2 impingers	In inlet to pilot sized venturi scrubber	a/	a/	a/	a/	55	0.02-0.33b/ gr/wet scf	0.205b/ gr/wet scf	a/	a/	Concentrations represent only dust emissions and not condensed hydrocarbons.	45
a/	a/	Controlled windbox	Armco, Inc. Houston, TX	7/71	1194 tons input/ day	a/	a/	Modified EPA sampling trains w/2 impingers	In out from pilot sized venturi	a/	a/	a/	a/	55	0.003-0.0125b/ gr/wet scf	0.003b/ gr/wet scf	a/	a/	Pressure drops were varied between 23 and 61 in. H_2O during the 55 tests.	45
a/	a/	Controlled emissions (Assume windbox emissions)	Alan Wood Steel Conshohocken, PA	5/71-6/71	a/	2000-3000	123-180	Glass probe in stainless steel housing, glass cyclone, and glass fiber filter	After hydro-clean scrubber pilot unit	Modified EPA Method 5	a/	33-53	0.35-0.72	15	0.0049-0.0403b/	0.017b/	a/	a/		46
0.49c/	C	Combined effluent from sinter machines 1, 2, and 3	Alan Wood Steel Conshohocken, PA	4/74	73.5 tons/hr of sinter (including recycled fines)	279,200 scfm	87	Standard EPA sampling train	In stack after hydro cleaners	EPA Method 5	94.2	120	a/	1	NA	0.015c/	NA	.49c/		47
0.43b/ 0.9c/	B B	Controlled effluent from two windboxes	Bethlehem Steel Bethlehem, PA	6/75	120 tons/hr of sinter/two machines	200,300	268	Modified EPA sampling train	In stack after ESP	EPA Method 5	a/	144	a/	3	0.0203-0.0417b/ 0.0472-0.0759c/	0.0301b/ 0.0631c/	0.146-0.299b/ 0.34-0.54c/	0.43b/ 0.9c/		48
0.1b/	B	Controlled effluent from 4 sinter machine breakers and hot screens	Bethlehem Steel Bethlehem, PA	5/75	239 tons/hr of sinter/four machines	138,100	237	Modified EPA sampling train	In stack after baghouse	EPA Method 5	a/	120	a/	3	0.019-0.022b/	0.02b/	0.19-0.22b/	0.2b/		48
0.30b/ 0.41c/	A A	Controlled effluent from sinter draft system from machine No. 2 (Includes windbox and discharge emissions)	Kaiser Steel Fontana, CA	6/75	160 tons/hr of sinter	132,700	302	Microchemical Specialties Co. Misco Model 7200 CM glass lined stainless steel probe and glass fiber filters	In stack after baghouse	EPA Method 5	96.2	180	0.9	3	0.03-0.497b/ 0.0450-0.0672c/	0.042b/ 0.0578c/	0.21-0.38b/ 0.31-0.52c/	0.30b/ 0.41c/		140

Average emission factor (lb/ton sinter)	Emission factor reliability	Source	Company/ location	Test date	Process conditions: Process production rate	Process conditions: Gas flow rate (dscfm)	Process conditions: Gas temp. (°F)	Test methodology: Type of sampling device	Test methodology: Location of sampling device	Test methodology: Sampling methodology	Test methodology: Percent isokinetic	Test methodology: Sampling time per run (min)	Test methodology: Gas flow rate (dscfm)	Test methodology: No. of runs performed	Test results: Measured concentrations: Range (gr/dscf)	Test results: Measured concentrations: Avg. (gr/dscf)	Test results: Emission factors: Range (lb/ton sinter)	Test results: Emission factors: Avg. (lb/ton sinter)	Comments	Reference
2.0b/ 2.3c/	A A	Controlled effuent from windboxes.	CF&I Pueblo, CO	6/75	329 ton/hr feed rate (including recycled fines) 164 ton sinter/hr	232,400	221	a/	In stack after multi-clones and ESP	EPA Method 5	101.6	143	0.4	3	0.148-0.179b/ 0.168-0.229c/	0.159b/ 0.192c/	1.8-2.0b/ 2.16-2.7c/	2.0b/ 2.34c/		49
6.87b/ lb/ton feed 6.96c/ lb/ton feed	C C	Uncontrolled effluent from windboxes.	CF&I Pueblo, CO	6/75	329 ton/hr feed rate (including recycled fines) 164 ton sinter/hr	247,500	195	a/	In ducting before multi-clones and ESP	EPA Method 5	117	108	0.4	3	0.510-1.494b/ 0.544-1.528c/	1.053b/ 1.078c/	3.01-10.63b/ 3.21-10.87c/	6.87b/ lb/ton feed 6.96c/ lb/ton feed	4 of the six tests were above 110% isokinetic.	49
0.32b/ 0.72c/	A A	Controlled effluent gases from windboxes	Granite City Steel Division Granite City, IL	5/75	102 tons/ hr of sinter	199,000	149	Standard EPA sampling train	In stack after venturi scrubber	EPA Method 5	99	176	a/	3	0.017-0.025b/ 0.039-0.053c/	0.019b/ 0.042c/	0.28-0.37b/ 0.64-0.82c/	0.32b/ 0.72c/		50
a/	a/	Controlled emissions (source unclear).	Jones & Laughlin Steel Aliquippa, PA	8/72	a/	146,200	407		"A" Duct leading to main stack after precipitator	EPA Method 5	99	180	a/	5	0.042-0.158b/	0.11b/	a/	a/		51
a/	a/	Controlled emissions (source unclear).	Jones & Laughlin Steel Aliquippa, PA	8/72	a/	138,200	419		"B" Duct leading to main stack after precipitator	EPA Method 5	99.6	180	a/	5	0.067-0.252b/	0.131b/	a/	a/		51
a/	a/	Controlled effluent. Portion of windbox emissions.	Jones & Laughlin Steel Aliquippa, PA	2/73	a/	2,010	320	Modified EPA sampling train	After precipitator	EPA Method 5	a/	180	0.5	3	0.0122-0.0988b/	0.0312b/	0.195-0.997 lb/hr	0.565 lb/hr	Test on ESP pilot unit.	52
0.03 (solid part.)	C	Controlled effuent. Portion of windbox emissions.	Jones & Laughlin Steel Aliquippa, PA	2/74	a/	2,130	113	Stainless steel probe, impingers fiberglass filter	After precipitator	a/	a/	125	a/	6	0.0065-0.0174 (solid part. and cond. HC) 0.0011-0.0033 (solid particulate)	0.0115 0.0092	0.04-0.08	0.16 0.03	Test on Mikropul pilot wet ESP. Sample not analyzed by EPA Method 5.	53
0.13 (solid part.)	B	Controlled effleunt. Portion of windbox emissions.	Jones & Laughlin Steel Aliquippa, PA	4/73	a/	1,632	246	Stainless steel probe, impinters (no filter)	After gravel bed	Sample taken at center point of duct	a/	60-120	a/	7	0.005-0.0206 (solid particulate) 0.0333-0.0472 (solid part. and cond. HC)	0.0092 0.039	a/	0.13 0.56	Test on pilot gravel bed filter. Sample not analyzed by EPA Method 5 since drying filter and evaporating impinger water drives off condensible hydrocarbons.	54
a/	a/	Controlled effluent from windboxes.	Jones & Laughlin Steel Aliquippa, PA	5/75	a/	a/	351	Standard EPA sampling train	East breeching 15 ft downstream of fan outlet & after mechanical col-lectors	EPA Method 5	a/	120	0.49	1	NA	0.15b/	NA	a/		55

Average emission factor (lb/ton sinter)	Emission factor reliability	Source	Company/ location	Test date	Process production rate	Gas flow rate (dscfm)	Gas temp (°F)	Test methodology: Type of sampling device	Location of sampling device	Sampling methodology	Percent isokinetic	Sampling time per run (min)	Gas flow rate (dscfm)	No. of runs performed	Test results: Measured concentrations: Range (gr/dscf)	Measured concentrations: Average (gr/dscf)	Emission factors: Range (lb/ton sinter)	Emission factors: Average (lb/ton sinter)	Comments	Reference
a/	a/	Controlled emissions from windboxes	Jones & Laughlin Steel Alquippa, PA	5/75	a/	207,400	310	Standard EPA sampling train	West breeching 15 ft downstream of fan outlet and after mechanical collectors	EPA Method 5	a/	120	0.47	1	NA	0.19b/	NA	a/		55
0.185b/ lb/ton feed	B	Controlled emissions from windboxes	Facility C	2/76	184 tons feed/hr	351,900	229	a/	After baghouse	Modified EPA Method 5	a/	75	a/	3	0.0085-0.0132b/	0.0113b/	0.13-0.21b/ lb/ton feed	0.185b/ lb/ton feed	Method 5 analytical procedures were modified to include chloroform-ether extractions of the impinger fraction.	56
a/	a/	Controlled emissions from discharge hood, breakers, hot fines bin, two transfer points and vibrating feeder to cooler	Facility C	7/75	a/	118,500	169	a/	After baghouse	Modified EPA Method 5	a/	a/	a/	3	0.004-0.0051b/	0.0047b/	a/	a/	Same as above	56
6.86b/ lb/ton feed 6.86c/ lb/ton feed	B	Uncontrolled emissions from windboxes	Facility F	6/75	329 tons feed/hr	247,500	194	a/	Cyclone inlet	Modified EPA Method 5	a/	107	a/	3	0.94-1.16b/ 0.94-1.16c/	1.05b/ 1.05c/	5.86-7.37b/ lb/ton feed 5.9-7.4c/ lb/ton feed	6.86b/ lb/ton feed 6.86c/ lb/ton feed	Same as above	56
2.0b/ lb/ton feed 2.2c/ lb/ton feed	B B	Uncontrolled emissions from windboxes	Facility G	5/75	257 tons feed/hr	179,000	272	a/	Scrubber inlet	Modified EPA Method 5	a/	180	a/	4	0.323-0.362b/ 0.349-0.392c/	0.338b/ 0.369c/	1.9-2.2b/ lb/ton feed 2.0-2.4c/ lb/ton feed	2.0b/ lb/ton feed 2.2c/ lb/ton feed	Same as above	56
0.13b/ lb/ton feed 0.19c/ lb/ton feed	B B	Controlled emissions fron windboxes	Facility G	5/75	257 tons feed/hr	199,000	149	a/	Scrubber outlet	Modified EPA Method 5	a/	175	a/	4	0.017-0.025b/ 0.023-0.033c/	0.019b/ 0.027c/	0.11-0.16b/ lb/ton feed 0.15-0.21c/ lb/ton feed	0.13b/ lb/ton feed 0.19c/ lb/ton feed	Same as above	56
0.093b/	B	Controlled emissions from windboxes	Facility R	4/76	473 tons sinter/hr	272,200	125	a/	Scrubber outlet	Modified EPA Method 5	a/	a/	a/	3	0.019-0.022b/	0.0198b/	a/	0.093b/		56
0.17b/ 0.21c/	B B	Controlled emissions from windboxes	Facility S	a/	55 tons sinter/hr	49,600	105	a/	Wet ESP outlet	Modified EPA Method 5	a/	a/	a/	38	0.003-0.022b/ 0.003-0.017c/	0.01b/ 0.012c/	a/ a/	0.17b/ 0.21c/		56
0.956b/ 1.18c/	A	Controlled emissions from windboxes for east sinter strand	Geneva Works, USS	6/7-9/78	61 tons sinter/hr	192,000	103	EPA Method 5 train	In north orifice scrubber outlet stack	EPA Method 5 at 48 points	98.4-100.9	120-144	0.49-0.57	3	0.0273-0.0437b/ 0.0334-0.0513c/	0.0359b/ 0.0442c/	0.812-1.1b/ 0.993-1.291c/	0.956b/ 1.18c/		138
0.934b/ 1.19c/	A	Controlled emissions from windboxes for west sinter strand	Geneva Works, USS	6/7-9/78	58 tons sinter/hr	181,000	105	EPA Method 5 train	In south orifice scrubber outlet stack	EPA Method 5 at 32 points	98.9-102.4	112-128	0.54-0.57	3	0.0265-0.0439b/ 0.0342-0.0553c/	0.0354b/ 0.0451c/	0.72-1.13b/ 0.93-1.423c/	0.934b/ 1.19c/		138
0.59b/ 0.604c/	A	Controlled emissions from discharge ends of east and west sinter strand	Geneva Works, USS	6/7-9/78	119 tons sinter/hr	41,200	104	EPA Method 5 train	In orifice scrubber outlet stack	EPA Method 5 at 48 points	95.7-102.2	120-144	0.46-0.49	3	0.0941-0.2727b/ 0.0963-0.282c/	0.2013b/ 0.206c/	0.286-0.782b/ 0.293-0.809c/	0.59b/ 0.604c/		138

a/ Reference provides insufficient data or corroboration of data.
b/ Based on particulate collected in the front half of sampling train.
c/ Based on particulate collected in the front and back halves of the sampling train.
d/ Unclear whether value is based on particulate collected in front half of sampling or in front and back halves combined.
e/ AISI-compiled tests selected as acceptable by Peter Westlin, Test Support Section, OAQPS.

TABLE 7. SUMMARY OF EMISSION FACTORS FOR BASIC OXYGEN FURNACES

Average emission factor (lb/ton steel)	Emission factor reliability	Source	Company/ location	Test date	Process conditions: Process production rate	Process conditions: Gas flow rate (dscfm)	Process conditions: Gas temp. (°F)	Process conditions: Gas velocity (fpm)	Test methodology: Type of sampling device	Test methodology: Location of sampling device	Test methodology: Sampling methodology	Test methodology: Percent isokinetic	Test methodology: Sampling time per run (min)	Test methodology: Sampling flow rate (dscfm)	Test methodology: No. of runs performed	Test results: Measured concentrations: Range (gr/dscf)	Test results: Measured concentrations: Avg. (gr/dscf)	Test results: Emission factors: Range (lb/ton steel)	Test results: Emission factors: Avg. (lb/ton steel)	Comments	References
30 lb/ton of input	D	Uncontrolled melting and refining	Company B (AISI data)	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	30 lb/ton of input	Estimate; open hood	57
37	B	Uncontrolled melting and refining	Company H (AISI data)	8/29-30/72	80 tons of steel per hour	159,000 scfm	380-440	a/	ASTM sampling train assembled as components	In 8.5 ft Ø duct before scrubber	ASTM D2928	a/	Approx. 20 min to 30 min	a/	2 - Silicon steel 3 - Alloy steel	2.83-5.57	3.28 for silicon steel 4.96 for alloy steel	22-50	37	Sampling during blowing; open hood	58,59
0.11b/lb/ton of input	A	Controlled melting and refining emissions collected from 4 heats	Company B (AISI data)	12/19/74	290.9 tons of input to furnace per hour	269,000	245	3,564 avg	Lear-Siegler PM100 manual stack sampler	In 18 ft Ø stack following ESP	EPA Method 5	106	2.3 hr during 4 hr of production	0.53	1	None	0.02b/	None	0.11b/ lb/ton of input	Open hood	60
0.09b/ 0.11c/	Ce/ C	Controlled melting and refining emissions collected from 4 heats	Company B (AISI data)	12/8-10/71	a/	214,000-224,900	a/	a/	RAC 2343 Staksamplr	In 17 ft Ø stack following venturi scrubber	EPA Method 5	81.1-93.3	120	a/	3	0.0199-0.0353b/ 0.0281-0.0424c/	0.0293b/ 0.0369c/	0.0705-0.106b/ 0.0998-0.127c/	0.09b/ 0.11c/	In two of the 3 tests, some particulates passed around filter and passed into impingers; open hood	57
0.21 reported 0.15 avg	Ce/ B	Controlled melting and refining emissions	Company H (AISI data)	9/9-10/75	80 tons of steel per hour	a/	a/	a/	a/	In 8.5 ft Ø duct after scrubber	EPA Method 5	a/	a/	a/	7	a/	a/	0.07-0.28	0.15	Scrubber operated between 50 and 60 in. H_2O.	58
0.033	B	Controlled melting and refining emissions	Company A (AISI data)	a/	216-230 tons of steel per heat	245,000-262-500	82-122	a/	ASME sampling train	In stack after quencher and scrubber	ASME PTC 27 only during blowing	a/	69	a/	3	0.004-0.02	0.011	0.012-0.059	0.033	Sampled during blowing of 4 heats; Scrubber operated between 65 and 76 in. H_2O; open hood.	61
0.015d/	Ce/	Controlled melting and refining emissions	Company A (AISI data)	11/6-7/74	200 tons of steel per hour	67,900-69,200	140-155	2,660	Unspecified but EPA approved	In 6.5 ft Ø stack	EPA Method 5	100-102	59-75	a/	3	0.013-0.015d/	0.014d/	0.0138-0.0163d/	0.015d/	After unknown gas cleaning system; Closed hood; sampled during blowing of 4-5 heats per run.	62,143
0.007	C	Controlled melting and refining emissions	Company A (AISI data)	11/16-18/71	200 tons of steel per hour	56,600-62,400	a/	a/	a/	a/	a/	101-113	a/	a/	3	0.005-0.014	0.008	0.004-0.0089	0.007	Same as above.	63,143
0.105b/	Ae/	Controlled melting and refining emissions	Company J (AISI data)	10/20-22/75	170 tons of steel per hour. (42 min avg cycle time)	227,000-258,000	202-207	3,100-3,600	RAC Staksamplr	In 12 ft Ø stack after dry ESP	EPA Method 5	100-108	140	1.06-1.09 acfm	3	0.012-0.013b/	0.012	0.0926-0.115	0.105	Sampled during blowing of consecutive heats; open hood	64

Average emission factor (lb/ton steel)	Emission factor reliability	Source	Company/ location	Test date	Process conditions: Process production rate	Process conditions: Gas flow rate (dscfm)	Process conditions: Gas temp. (°F)	Process conditions: Gas velocity (fpm)	Test methodology: Type of sampling device	Test methodology: Location of sampling device	Test methodology: Sampling methodology	Test methodology: Percent isokinetic	Test methodology: Sampling time per run (min)	Test methodology: Sampling flow rate (dscfm)	Test methodology: No. of runs performed	Test results: Measured concentrations: Range (gr/dscf)	Test results: Measured concentrations: Avg. (gr/dscf)	Test results: Emission factors: Range (lb/ton steel)	Test results: Emission factors: Avg. (lb/ton steel)	Comments	Reference
0.269[c] 0.21[b]	A A	Controlled melting and refining emissions	Bethlehem Steel, Bethlehem, PA	1/72	274 tons of steel per heat 344 tons of steel per hour	493500	200	2,955	RAC Model 2343 Staksamplr modified with EPA approval	In 18 ft Ø stack after ESP	Modified EPA Method 5	106.5	120	0.72	3	0.0231 - 0.0516[c] 0.0156 - 0.0451[b]	0.0347[c] 0.027[b]	0.161-0.402[c] 0.109-0.352[b]	0.269[c] 0.21[b]	Sampling from end of charge to beginning of tap; covered 4 heats; open hood.	65
0.083[c] 0.052[b]	C C	Controlled melting and refining emissions	Alan Wood Steel, Conshohocken, PA	11/71	146 tons of steel per heat 160 tons of steel per hour	211900	240	1,555	RAC Model 2343 Staksamplr Modified	190 ft up in 16.5 ft Ø stack after ESP	EPA Method 5	116.2 (113.7 - 119.2)	94	0.42	3	0.00831 - 0.0138[c] 0.00499 - 0.00939[b]	0.0106[c] 0.0067[b]	0.0631-0.107[c] 0.037-0.073[b]	0.083[c] 0.052[b]	Sampling from beginning of scrap preheat to beginning of tap; covered 4 heats/run; open hood.	66
0.0047[c] 0.0028[b]	A A	Controlled melting and refining emissions	U.S. Steel, Lorain, Ohio	1/72	230 tons of steel per heat 276 tons of steel per hour	57650	126	2,597	RAC Model 2343 Staksamplr Modified	After cyclone and venturi scrubber.	EPA Method 5	103.4	161	0.72	3	0.00375 - 0.00637[c] 0.00164 - 0.00503[b]	0.0049[c] 0.0029[b]	0.00335-0.00612[c] 0.00147-0.00484[b]	0.0047[c] 0.0028[b]	Sampling from beginning of blow to beginning of tap; 6 heats covered; closed hood.	67
0.0079[c] 0.0044[b]	A A	Controlled melting and refining emissions	U.S. Steel, Lorain, Ohio	11/71	230 tons of steel per heat 276 tons of steel per hour	58770	120	2,620	RAC Model 2343 Staksamplr Modified	After cyclone and venturi scrubber.	EPA Method 5	106.4	160	0.76	3	0.00466 - 0.0145[c] 0.00222 - 0.007[b]	0.0081[c] 0.0036[b]	0.00515-0.0135[c] 0.00202-0.00827[b]	0.0079[c] 0.0044[b]	Sampling from end of charge to beginning of tap; 6 heats covered; newly installed scrubbers; closed hood.	68
a/	B	Controlled melting and refining emissions	Inland Steel, E. Chicago, Illinois	4/75	257 tons of input per heat	50580	123.2	2,160	Model No. AP-5000 Modular Stack-o-Lator	a/	EPA Method 5	a/	a/	a/	6	0.004 - 0.006[b]	0.005[b]	a/	a/	Sampling from beginning of blow to beginning of tap; 2 heats/run; closed hood.	69
a/	B	Controlled melting and refining emissions	Inland Steel, E. Chicago, IL	5/75	257 tons of input per heat	54250	139.8	2,382	Model No. AP-5000 Modular Stack-o-Lator	a/	EPA Method 5	a/	a/	a/	6	0.007 - 0.027[c] 0.006 - 0.011[b]	0.014[c] 0.008[b]	a/	a/	Sampling from beginning of preheat to beginning of tap; 2 heats/run; closed hood.	69
a/	C	Controlled melting and refining emissions	Kaiser Steel, Fontana, Calif.	7/72	a/	190900	340	a/	47 mm filter attached to front of probe followed by condensate trap	Precipitator stacks	a/	a/	15-20	a/	2	a/	0.01134 gr/scf	a/	a/	Sampling during one blow period/run; open hood.	70

Average emission factor (lb/ton steel)	Emission factor reliability	Source	Company/ location	Test date	Process conditions: Process production rate	Process conditions: Gas flow rate (dscfm)	Process conditions: Gas temp. (°F)	Process conditions: Gas velocity (fpm)	Test methodology: Type of sampling device	Test methodology: Location of sampling device	Test methodology: Sampling methodology	Test methodology: Percent isokinetic	Test methodology: Sampling time per run (min)	Test methodology: Sampling flow rate (dscfm)	Test methodology: No. of runs performed	Test results: Measured concentrations: Range (gr/dscf)	Test results: Measured concentrations: Avg. (gr/dscf)	Test results: Emission factors: Range (lb/ton steel)	Test results: Emission factors: Avg. (lb/ton steel)	Comments	Reference
0.0158c/ 0.0132b/	A A	Controlled melting and refining emissions	Armco Steel, Middletown, Ohio	10/71	200 tons of steel per heat	39,300	148	1,835	RAC Model 2343 Staksamplr conforming to Method 5	BOF Stack No. 15, after venturi scrubbers	EPA Method 5	103	237	0.49	3	0.0125-0.0164c/ 0.0112-0.0145b/	0.0145c/ 0.0125b/	0.0158c/ 0.0115-0.0141b/	0.0158c/ 0.0132b/	Sampling from end of charge to beginning of tap; 6 heats per test; closed hood.	71
0.114c/ 0.106b/	C C	Controlled melting and refining emissions	National Steel, Weirton, WVA	12/71	340 tons of steel per heat	219,000	138	1,304	RAC Model 2343 Staksamplr Modified with EPA approval	In stack after venturi scrubber	EPA Method 5	87 (only one test between 90 and 110)	137	0.65	3	0.0281-0.0424c/ 0.0353b/	0.0369c/ 0.0353b/	0.0998-0.127c/ 0.106b/	0.1143c/ 0.106b/	Sampling from end of charge to beginning of tap; 4 heats per run; open hood.	72
0.0556b/-primary hood 0.0504b/-secondary hood	A A	Controlled melting, refining, charging and tapping emissions from a Q-BOP	Republic Steel, Chicago, IL	8/77	247 tons of input per heat 247 tons of input per hr	90,000-primary hood 180,000-secondary hood	140-primary hood 120-secondary hood stack gas	a/	a/	In stack after venturi scrubber	EPA Method 5 with approved modifications	98	a/	a/	2-primary hood 2-secondary hood	0.0221-0.0225b/ (primary hood) 0.0066-0.0112b/ (secondary hood)	0.0223b/ (primary hood) 0.0089b/ (sec. hood)	0.0548-0.0564b/ (primary hood) 0.037-0.0638b/ (secondary hood)	0.0556b/ (primary hood) 0.0504b/ (second. hood)	6 heats per run; secondary hood collects charging and tapping emissions; primary hood collects blowing emissions; closed hood.	73
0.0092d/ lb per ton of input	C	Controlled melting refining, charging and tapping emissions from a Q-BOP	U.S. Steel, Fairfield, AL	11/74	227 tons of input per heat 332 tons of input per hr	68,600	145	a/	a/	In stack after gravity collector, quencher, and scrubber	a/	101	60	a/	3	0.013-0.015d/	0.014d/	a/	0.0092d/	Closed hood; pressure drop across scrubber is 57 in. H_2O; sampled during oxygen blow.	74
a/	a/	Controlled melting refining, charging and tapping emissions from. a Q-BOP	U.S. Steel, Fairfield, AL	10/78	a/	76,300	163	3,352	Standard EPA Method 5 train	After scrubber controlling primary hood catch	EPA Method 5	98.7	60	a/	3	0.02108-0.02311b/	0.02180b/	a/	a/	Sampled during oxygen blow; closed hood.	75
a/	a/	Controlled melting, refining, charging and tapping emissions from a Q-BOP	U.S. Steel Fairfield, AL	10/78	a/	92,700	158	3,752	Standard EPA Method 5 train	After scrubber controlling primary hood catch	EPA Method 5	105	63	a/	3	0.00997-0.01573b/	0.01006b/	a/	a/	Sampled from beginning of blow to beginning of tapping (therefore, includes turndown); closed hood.	75
a/	a/	Controlled melting and refining emissions	Bethlehem Steel Burns Harbor, IL	1974	300 tons per heat	a/	a/	a/	a/	After venturi scrubber	EPA Method 5	a/	60	0.53	3	a/	0.022b/	a/	a/	Open hood; pressure drop across scrubber is 55 in. H_2O.	76
a/	a/	Controlled melting and refining emissions	Kaiser Steel, Fontana, Calif.	1972	120 tons per heat	a/	a/	a/	a/	After ESP	a/	a/	60	0.53	3	a/	0.006b/	a/	a/	Open hood.	76
a/	a/	Controlled melting and refining emissions	Interlake Steel, Chicago, IL	1975	80 tons per heat	a/	a/	a/	a/	After ESP	a/	a/	60	0.53	3	a/	0.009b/	a/	a/	Open hood.	76

TABLE 7 (continued)

Average emission factor (lb/ton steel)	Emission factor reliability	Source	Company/ location	Test date	Process conditions: Process production rate	Process conditions: Gas flow rate (dscfm)	Process conditions: Gas temp. (°F)	Process conditions: Gas velocity (fpm)	Test methodology: Type of sampling device	Test methodology: Location of sampling device	Test methodology: Sampling methodology	Test methodology: Percent isokinetic	Test methodology: Sampling time per run (min)	Test methodology: Sampling flow rate (dscfm)	Test methodology: No. of runs performed	Test results: Measured concentrations: Range (gr/dscf)	Test results: Measured concentrations: Avg. (gr/dscf)	Test results: Emission factors: Range (lb/ton steel)	Test results: Emission factors: Avg. (lb/ton steel)	Comments	Reference
24.2b/	A	Uncontrolled melting and refining emissions.	CF&I Steel, Pueblo, CO	4/10-17/78	120 tons/heat	90,600-104,400	458-515	4,780-5,550	In-stack alundum thimble	In duct before ESP	ASME PTC 27	90-109	72-79	0.3	5	7.26-9.32b/	8.1b/	21.4-27.7b/	24.2b/	Sampled during blowing and reblowing; open hood.	137
0.0614b/	A	Controlled melting and refining emissions.	CF&I Steel, Pueblo, CO	4/10-17/78	120 tons/heat	151,500-169,900	247-289	4,040-4,410	Method 5 train	In stack after ESP	EPA Method 5 (undetermined No. of points)	92-100	75-83	0.6	5	0.00935-0.022b/	0.0125b/	0.0426-0.1122b/	0.0614b/	Sampled during blowing and reblowing; open hood.	137
0.137d/ lb/ton of input	Ce/	Controlled melting and refining emission	Company J (AISI data)	2/11,12, 17/76	305 tons charged per hour 45 min. avg cycle time	383,000-399,000	250-282	5,900-6,400	a/	In 12 ft Ø stack after dry ESP	EPA Method 5	85-94	144	a/	3	0.0115-0.018d/	0.0165d/	0.12-0.15d/	0.137d/ lb/ton input	Sampled during oxygen blow of consecutive heats. Open Hood	78
0.162d/ lb/ton of input	Ce/	Controlled melting and refining emission	Company J (AISI data)	12/8-10/75	a/	268,000-287,000	247-269	4,400-5,000	a/	After dry ESP	EPA Method 5	a/	a/	a/	5	0.014-0.029d/	0.019d/	0.14-0.21d/ lb/ton input	0.162d/ lb/ton input	Open hood	79
0.291	Be/	Tapping	Company D (AISI data)	4/28-29/75	196-216 tons of steel per heat	a/	a/	a/	a/	a/	In-stack filter; tapping emissions captured by primary hood.	a/	a/	a/	15	0.0218-0.387 gr/acf	0.0935 gr/acf	0.051-0.891	0.291	Value represents uncontrolled emissions factor calculated assuming 93% avg capture efficiency.	80
0.142 lb/ton of hot metal charged	Be/	Charging	Company D (AISI data)	4/28-29/75	147-182 tons of hot metal charged per heat	a/	a/	a/	a/	a/	In-stack filter; charging emissions captured by primary hood.	a/	a/	a/	15	0.0675-0.526 gr/acf	0.210 gr/acf	0.025-0.369 lb/ton hot metal charged	0.142 lb/ton hot metal charged	Value represents uncontrolled emission factor calculated assuming 78% avg capture efficiency.	81
0.056 lb/ton of metal poured	Be/	Hot metal transfer	Company D (AISI data)	5/1/75	160-184 tons of hot metal poured per heat	a/	a/	a/	a/	a/	In-stack filter; emissions captured by reladling station hood.	a/	a/	a/	8	0.0690-0.237 gr/acf	0.13 gr/acf	0.029-0.098 lb/ton hot metal poured	0.056 lb/ton hot metal poured	Assumed 100% capture efficiency.	82
0.28	C	Monitor emissions	Company A (AISI data)	a/	a/	a/	a/	a/	Hi-Vols and hot wire anemometers	In roof monitor	Divided monitor into 12 equal area sections and sampled in each section.	a/	a/	a/	1 in each of 12 sections.	a/	a/	a/	a/		83
0.34-Emissions escaping monitor during 1 hr time 0.16-captured charging emissions 0.5-captured charging emissions and uncaptured monitor emissions	Be/	Uncontrolled monitor emissions	Company A (AISI data)	Feb. and March 1975	6,400 tons of steel per day	30,700-104,000 acfm (through an opening within a zone)	a/	169-378 fpm (through openings)	3 Gelman Hurricane air samplers and Datametrics air flow multimeters (hot-wire anemometers)	In front of openings in room monitor and side of building	Divided building into 8 zones. Each zone has 3 openings: an east and west monitor opening and an opening in the east side of the building at at intermediate level. Sampled all 3 openings simultaneously. Repeated process for each zone.	a/	1 hr/zone	33-57 acfm	3 simultaneous runs/zone and 8 zones/test and 3 tests.	0.0026-0.0389 gr/acf	-	0.28-0.44	0.34	This BOF shop had a secondary hood capturing charging emissions. 0.16 lb/ton was captured in the hood.	84

Average emission factor (lb/ton steel)	Emission factor reliability	Source	Company/ location	Test data	Process conditions: Process production rate	Process conditions: Gas flow rate (dscfm)	Process conditions: Gas temp. (°F)	Process conditions: Gas velocity (fpm)	Test methodology: Type of sampling device	Test methodology: Location of sampling device	Test methodology: Sampling methodology	Test methodology: Percent isokinetic	Test methodology: Sampling time per run (min)	Test methodology: Sampling flow rate (dscfm)	Test methodology: No. of runs performed	Test Results: Measured concentrations: Range (gr/dscf)	Test Results: Measured concentrations: Avg. (gr/dscf)	Test Results: Emission factors: Range (lb/ton steel)	Test Results: Emission factors: Avg. (lb/ton steel)	Comments	Reference
0.3	Ce/	Monitor emissions	Company A (AISI data)	7/1-2/75	12,000 tons of steel per day	152,000-33,150 330,150 acfm (through an opening)	a/	380-1,080 fpm (through openings)	1 Gelman Hurricane air sampler and a flowtronic Model 55B1 hot-wire anemometer	In front of opening in roof monitor	Divided building into 9 zones. Each zone has only one opening.	a/	a/	a/	1 run/zone and 9 zones/ test and 3 tests	0.02-0.037 gr/acf	0.008 gr/acf	0.26-0.31	0.3	Open hood	85
0.147	C	Monitor emissions	Interlake, Inc. Riverdale, IL	a/	100 tons of steel per hr	a/	300	a/	MSA personnel samplers	Grate in roof monitor above operating 80T BOF.	a/	a/	a/	0.06 acfm	4	a/	0 0027 gr/acf	a/	0.147	Made multipoint nonsimultaneous velocity measurements with thermal and vane type anemometers.	86,87
a/	a/	Uncontrolled monitor emissions	CF&I Steel Pueblo, Col.	12/2-4/75	120 tons/ heat	1.62×10^6-2.58×10^6 scfm	a/	488-775	a/	Roof monitor openings	High volume samplers	95	a/	a/	3	0.019-0.028	0.024	a/	a/	Short term tests from charging initiation to time when building clears.	88
a/	a/	Uncontrolled monitor emissions	CF&I Steel Pueblo, Col.	12/2-4/75	120 tons/heat	2.44×10^6 scfm	a/	729	a/	Roof monitor openings	High volume samplers	95	a/	a/	1		0.005	a/	a/	Test ran over cycle marked by the time the building clears after charging.	88
a/	a/	Uncontrolled monitor emissions	CF&I Steel Pueblo,Col.	12/2-4/75	120 tons/heat	2.24×10^6 2.53×10^6 scfm	a/	669-757	a/	Roof monitor openings	High volume samplers	95	a/	a/	3	0.005-0.012	0.009	a/	a/	Tests ran over cycle marked by slagging initiation.	88
a/	a/	Uncontrolled monitor emissions	CF&I Steel Pueblo,Col.	12/2-4/75	120 tons/heat	2.35×10^6-2.45×10^6 scfm	a/	721-736	a/	Roof monitor openings	High volume samplers	95	a/	a/	2	0.005-0.007	0.006	a/	a/	Tests ran over cycle marked by charge initiation.	88
0.19b/ lb/ton metal 0.192c/ lb/ton hot metal	A	Hot metal transfer	Wisconsin Steel Chicago, IL	April, May 1978	29.1-90.4 tons of hot metal/min of pouring	33,000-46,000	135-248	3,840-4,530	Method 5 train	In hot metal transfer hood branch duct leading to ESP	EPA Method 5. 8 points sampled per test.	91.1-109.7	1.3-3.0	2.8-5.1	8	0.0844-9.682b/ 0.1095-9.6994c/	1.6567b/ 1.6769c/	0.009-0.511b/ lb/ton hot metal 0.012-0.512b/ lb/ton hot metal	0.118b/ lb/ton hot metal 0.119c/ lb/ton hot metal	Tests ran over 1-2 transfer operations. Avg EF in far left column is adjusted to account for uncaptured emissions.	133
0.6b/ lb/ton hot metal 0.66c/ lb/ton hot metal	A	Charging	Republic Steel Chicago, IL	March, May 1978	49.5-91.6 tons of hot metal/min of charging	268,000-463,000	168-234	4,610-7,600	Method 5 train	In secondary hood duct leading to wet scrubber; probe located 1.5 dia. downstream of bend in duct	Single point sample	97.2-107.5	2.2-4.3	2.8-4.5	6	0.379-2.359b/ 0.4445-2.3902c/	0.917b/ 1.0118c/	0.2-1.2b/ lb/ton hot metal 0.23-1.22c/ lb/ton hot metal	0.6b/ lb/ton hot metal 0.66c/ lb/ton hot metal	Sampling was done at a different point along the traverse for each test so that only the avg of the six tests is representative	134
0.92b/ 0.96c/	A	Tapping	Republic Steel Chicago, IL	March 1978	37.6-48 tons of steel tapped/min	106,000-196,500	173-313	1,790-3,850	Method 5 train	Same as above	EPA Method 5. 10-12 points sampled/test	92.6-102.5	4.7-6.0	1.0-2.0	3	0.3853-3.8973b/ 0.4413-3.9714c/	1.6558b/ 1.7269c/	0.15-2.28b/ 0.18-2.32c/	0.92b/ 0.96c/		134
0.3-0.4	D	Charging	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	0.3-0.4	0.35	Estimate	77
0.15-0.2	D	Tapping	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	0.15-0.2	0.17	Estimate	77

a/ Reference provides insufficient data or corroboration of data.
b/ Based on particulate collected in front half of sampling train.
c/ Based on particulate collected in front and back halves of sampling train.
d/ Unclear whether value is based on particulate collected in front half of sampling train or in fron and back halves combined.
e/ AISI-compiled tests selected as acceptable by Peter Westlin, Test Support Section, OAQPS.

There are also specific charging and tapping EFs listed in Table 7. There are seventeen A-rated EFs, nine B-rated factors, sixteen C-rated factors, three D-rated factors, and nine unrateable tests in Table 7.

Also shown in Table 7, where data were avilable is whether the furnace was top or bottom blown and whether the hood was open or closed. Under the table heading entitled Source, a top blown furnace should be inferred unless the furnace is specifically identified as a Q-BOP. Whether the hood is open or closed is a fact to be found under the table heading entitled Comments.

The exact processes included in the source listed as Melting and Refining in Table 7 are of importance in utilizing the emission factor value given. There are three possible sources: (a) scrap preheat, (b) blowing or refining, and (c) turndown, i.e., the period during which a sample of the heat is taken and analyzed. Where the data were available, what precise processes were tested are listed under the table heading entitled Comments.

3.5 ELECTRIC ARC FURNACES

There are several sources of particulate emission in the electric arc furnace steelmaking process. The emission sources are (a) emissions from the melting and refining of the heat itself, often vented through a hole in the furnace roof, (b) charging scrap, (c) dumping slag, and (d) tapping steel.

There are several possible configurations of control systems to capture and remove emissions. Figures 3 and 4 show some of the more common configurations. Configuration 1 in Figure 3 is the building evacuation system; Configuration 2 in Figure 4 is direct shell evacuation (DSE) of melting and refining emissions and canopy hood capture of charging, tapping, and slagging emissions with both venting to a common baghouse. There are several variations on Configuration 2: (a) the roof monitor can be open to release those emissions not captured by the canopy hood or closed, or (b) the canopy hood and the DSE system can be vented to separate control devices rather than a common emission removal device.

In interpreting emission factor data for EAFs, it is important to know which configuration was sampled and where the sample was collected. For example, suppose Configurations 1 and 2 shown in Figures 3 and 4 are both sampled at the baghouse inlet. The value obtained from Configuration 1 would represent all melting, refining, charging, tapping, and slagging emissions which ascended to the building roof while the value obtained from Configuration 2 would represent nearly all the melting and refining emissions but only that portion of the charging, tapping, and slagging emissions which were captured by the canopy hood.

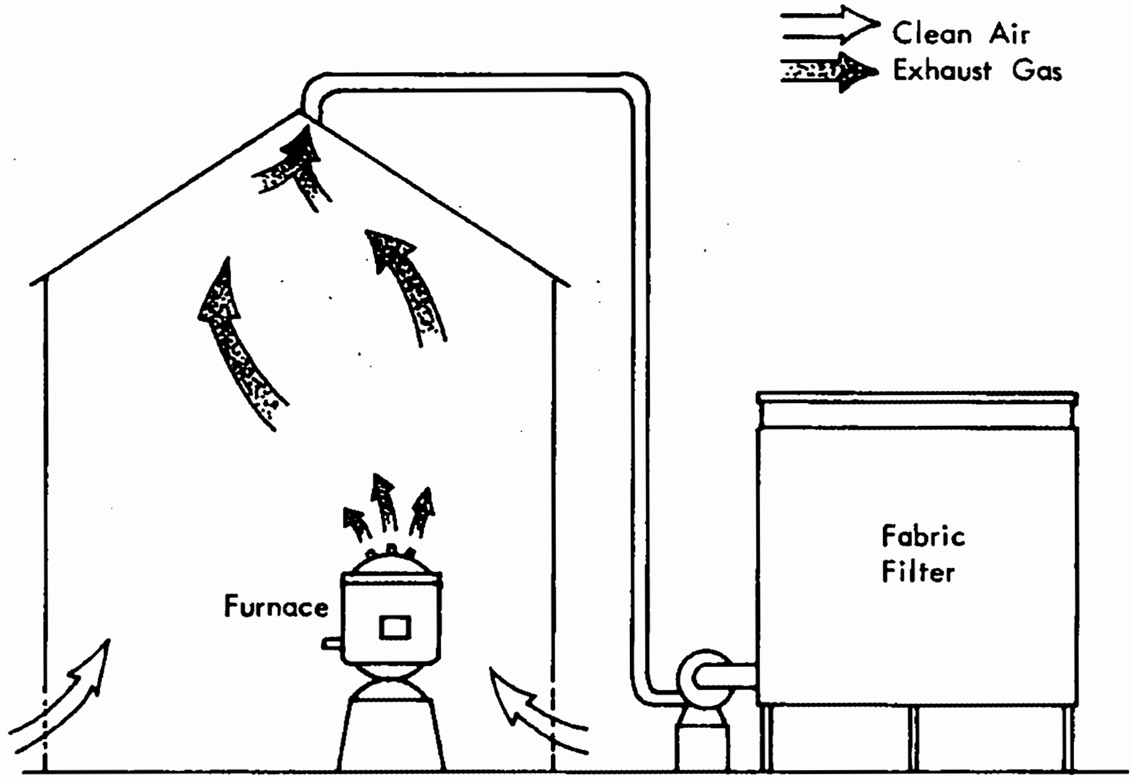

Figure 3. Building evacuation (BE) system closed roof--Configuration 1.

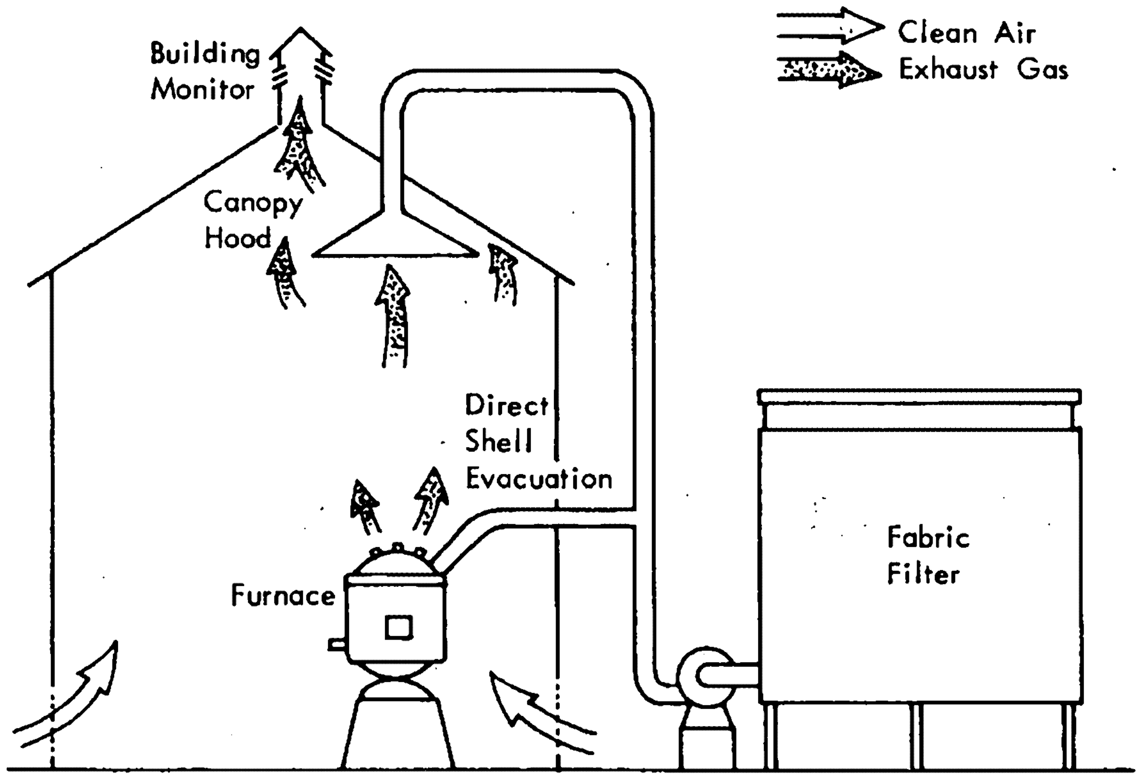

Figure 4. Canopy hood (CH) open roof--Configuration 2.

Table 8 lists EFs for particulate sources in EAF shops. Melting and refining, referred to in Table 8, imply mainly emissions captured by direct shell evacuation through a hole in the furnace roof. Monitor emissions include the portion of charging, tapping, and slagging emissions that escape into the atmosphere. When the secondary controls are not specified for a monitor test, it is difficult to judge the typicalness of or to utilize the results.

Listed in the comments column of Table 8 are two of the important parameters which effect the emission factors: (a) whether the process was to produce carbon or alloy steel (two significantly different processes), and (b) what control device configuration was used.

There are four A-rated EFs in Table 8 and twenty-one C-rated EFs. The dearth of A- and B-rated EFs is due to poor sampling methods or a failure to report the sampling method. The poor sampling methods were often not the fault of the test designer but coupled more with the problems encountered in sampling a pressure baghouse.

3.6 OPEN HEARTH FURNACES

There are several sources of particulate emission in the open hearth furnace steelmaking process. The activities generating emissions are (a) transferring hot metal, (b) melting and refining the heat, (c) charging of scrap and/or hot metal, (d) dumping slag, and (e) tapping steel.

Table 9 lists EFs for particulate sources in OHF shops. Monitor emissions refer to the portion of the hot metal transfer, charging, tapping, and slagging emissions that enter the atmosphere through the shop roof monitor. There are only 10 total EFs presently included in the data base. Four of these are A-rated, one is B-rated, and five are C-rated. The main problem is failure to report not only the details of the tests, but the test methodologies themselves.

3.7 TEEMING

Only one investigative effort to quantify an emission factor for teeming is available.[133] The emission factors were measured via stack testing in the ductwork leaving a side draft hood which captured emissions from a teeming operation. Emissions were measured simultaneously before and after the baghouse removing the captured emissions.

Tests were performed during the teeming of leaded and unleaded steel. Only the material captured by the hood could be measured via stack tests. The material captured varied from nearly 100% of that emitted to a much lower efficiency (not quantified) when the wind was blowing from directions where building openings occurred.

Average emission factor (lb/ton steel)	Emission factor reliability	Source	Company/ location	Test date	Process conditions: Process production rate	Process conditions: Gas flow rate (dscfm)	Process conditions: Gas temp. (°F)	Test methodology: Type of sampling device	Test methodology: Location of sampling device	Test methodology: Sampling methodology	Test methodology: Percent isokinetic	Test methodology: Sampling time (min)	Test methodology: Gas flow rate (dscfm)	Test methodology: Number of runs performed	Test results: Measured concentrations: Range (gr/dscf)	Test results: Measured concentrations: Average (gr/dscf)	Test results: Emission factors: Range lb/ton steel	Test results: Emission factors: Average lb/ton steel	Comments	Reference
0.3d/(Alloy Steel) 0.58e/	A A	Controlled EAF melting, refining, charging, tapping, and slagging emissions.	Babcock and Wilcox Beaver Falls, PA	10/18-20/72	18T steel/hr	452,000 (bldg evacuation system included)	98	Method 5 EPA train	In short stacks after baghouse	EPA method 5 except probe was not heated	96-104.7	240	0.75-0.79	9	0.0005-0.0032d/ 0.0014-0.0047e/	0.0014c/ 0.0027e/	0.11-0.66d/ 0.34-0.95e/	0.3 0.58e/	Shop has 1/50 T and 1/75 T alloy Steel EAF; control device configuration 1	89
11.3d/ (Alloy Steel) 11.7e/	A A	Uncontrolled EAF melting, refining, charging, tapping, and slagging emissions.	Babcock and Wilcox Beaver Falls, PA	10/18-20/72	18T steel/hr	452,000 (bldg evacuation system included)	98	Method 5 EPA train	In 12 ft Ø duct before baghouse	EPA Method 5 except probe was not heated	97.4-99.5	240	0.72-0.79	3	0.0386-0.0605d/ 0.0397-0.0618e/	0.0518d/ 0.0537e/	8-13.6d/ 8.2-13.9e/	11.3d/ 11.7e/	Shop has 1/50 T and 1/75 T alloy steel EAF; control device configuration 1	89
7.6	C	Uncontrolled EAF melting and refining emissions.	a/	a/	14.4T input/hr	23,920	209	a/	a/	a/	a/	a/	a/	1	None	0.5373	None	7.6	50 T furnace. Unclear whether carbon or alloy steel.	90
11.0	C	Uncontrolled EAF melting and refining emissions.	a/	a/	13.6-23.5T/hr	a/	281-297	a/	a/	a/	a/	a/	a/	5	a/	a/	6.9-18.6	11.0	50 and 75 T furnace. Unclear whether carbon or alloy steel.	90
4.8	C	Controlled EAF melting and refining emissions.	a/	a/	13.6-22 T input/hr	25,900	297	a/	In stack after scrubber	a/	a/	a/	a/	2	0.109-0.556	0.333	2.04-7.65	4.8	50 and 75 furnace. Scrubber control efficiencies of 37 and 70%. Unclear whether carbon or alloy steel.	90
19.5 lb/ingot ton	C	Uncontrolled EAF melting and refining emissions.	Company K (AISI data)	1/15-24/75	a/	a/	a/	a/	a/	Weighed control device catch and divided by ingot tons produced	a/	a/	a/	10	None	None	15.1-34.8 lb/ingot ton	19.5 lb/ingot ton	Carbon steel	91,143
28.8 lb/T of input (stainless and alloy)	C	Uncontrolled EAF melting and refining emissions.	Company J (AISI data)	Jan.-April 1976	78,000-83,000 T steel/month	a/	a/	a/	a/	Weighed control device catchand divided by tons of steel melted	a/	a/	a/	4	None	None	29-34.2 lb/T steel	31.7 lb/T steel		92
17.1	C	Uncontrolled EAF melting and refining emissions.	Company H (AISI data)	10/18-25/75 and 6/8/76	4,080 T steel tapped over 7-day test period. 536 T steel tapped over weekend.	a/	a/	a/	a/	Weighed control device catch and divided by tons of steel tapped	a/	a/	a/	2	None	None	13.4-20.8	17.1	Alloy steel	93,143

TABLE 8. (continued)

Average emission factor (lb/ton steel)	Emission factor reliability	Source	Company/ location	Test date	Process conditions: Process production rate	Process conditions: Gas flow rate (dscfm)	Process conditions: Gas temp. (°F)	Test methodology: Type of sampling device	Test methodology: Location of sampling device	Test methodology: Sampling methodology	Test methodology: Percent isokinetic	Test methodology: Sampling time (min)	Test methodology: Gas flow rate (dscfm)	Test methodology: Number of runs performed	Test results: Measured concentrations Range (gr/dscf)	Test results: Measured concentrations Average (gr/dscf)	Test results: Emission factors Range lb/ton steel	Test results: Emission factors Average lb/ton steel	Comments	Reference
0.043	Cb/	Controlled EAF melting and fugitive emissions and uncontrolled, uncaptured monitor emissions.	Company L (AISI data)	10/9/74	33 ton steel/hr	247,000-256,000	a/	Rader pneumatics high volume sampler.	In north exhaust plenum of baghouse.	Single point sampled	150-204	140-245	17.3	2	0.00065-0.00121	0.0009	0.041-0.045	0.043	Canopy hood is 70 ft above furnace. Estimated that 25% of total emissions escaped capture and left monitor; O_2 lanced carbon steel; control device configuration 2	94
25	C	Uncontrolled EAF melting and refining emissions.	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	20-30	25	Unclear whether carbon or alloy steel.	95
16	C	Uncontrolled EAF melting and refining emissions.	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/	3-30	16	Unclear whether carbon or alloy steel.	96
50	C	Uncontrolled EAF melting and refining emissions.	Lukens Steel Coatsville, PA	a/	a/	a/	a/	a/	a/	Weighed baghouse catch	a/	a/	a/	a/	None	a/	a/	50	Carbon steel; control device configuration 2	97
51c/	C	Uncontrolled EAF melting and refining emissions.	Jones & Laughlin Cleveland, OH	a/	a/	a/	a/	a/	Test at inlet to ESP	a/	a/	a/	a/	a/	a/	a/	a/	51c/	Carbon steel; modified control device configuration consists of DSE vented to ESP.	98
22	C	Uncontrolled EAF melting and refining emissions.	Bethlehem Steel Seattle, WA	a/	a/	a/	a/	a/	a/	Weighed baghouse catch	a/	a/	a/	a/	None	None	a/	22	Carbon steel; modified control device configuration 1 with DSE. Building evaluation and DSE each vented to separate baghouse.	99
1.2	C	Charging and tapping emissions.	Bethlehem Steel Seattle, WA	a/	a/	a/	a/	a/	a/	Weighed baghouse catch	a/	a/	a/	a/	None	None	0.9-1.5	1.2		99
1.7	C	Charging and tapping emissions.	Bethlehem Steel Steelton, PA	a/	a/	a/	a/	a/	a/	Took measurements in roof monitor	a/	a/	a/	a/	a/	a/	a/	1.7	Carbon steel; control device configuration consists of DSE vented to baghouse.	100
27.5	C	Uncontrolled EAF melting and refining emissions.	Bethlehem Steel Steelton, PA	a/	a/	a/	a/	a/	a/	Weighed baghouse catch	a/	a/	a/	a/	None	None	a/	25-30	Carbon steel; control device configuration consists of DSE vented to baghouse.	99
43.0	C	Uncontrolled EAF melting and refining emissions plus all fugitive emissions.	Bethlehem Steel Los Angeles, CA	a/	a/	a/	a/	a/	a/	Weighed baghouse catch	a/	a/	a/	a/	None	None	a/	43	Carbon steel; control device configuration 2 with motorized monitor louvers to enable closing the monitor to capture fugitive emissions.	99

TABLE 8. (Concluded).

Average emission factor (lb/ton steel)	Emission factor reliability	Source	Company/ location	Test date	Process conditions: Process production rate	Process conditions: Gas flow rate (dscfm)	Process conditions: Gas temp. (°F)	Test methodology: Type of sampling device	Test methodology: Location of sampling device	Test methodology: Sampling methodology	Test methodology: Percent isokinetic	Test methodology: Sampling time (min)	Test methodology: Gas flow rate (dscfm)	Test methodology: Number of runs performed	Test results: Measured concentrations: Range (gr/dscf)	Test results: Measured concentrations: Average (gr/dscf)	Test results: Emission factors: Range lb/ton steel	Test results: Emission factors: Average lb/ton steel	Comments	Reference
58.0	C	Uncontrolled EAF melting, and refining emissions plus portion of charging, tapping, slagging emissions.	Inland Steel E. Chicago, IN	a/	a/	a/	a/	a/	a/	Weighed baghouse catch	a/	a/	a/	a/	None	None	33-83	58	Carbon steel; control device configuration 2.	101
.029c/	C	Controlled EAF melting and refining emissions.	Witteman Steel Mills Fontana, CA	2/20/75	6.2 T steel/hr	4,290	a/	In stack glass filter	In stack after scrubber	Single point sampled	a/	a/	a/	a/	a/	0.005c/	a/	0.029c/	1-25 T furnace making carbon steel.	102
0.145c/lb/T scrap melted	C	Controlled EAF melting, refining building evacuation emissions.	TAMCO (Affiliate of Ameron Steel Corp) Etiwanda, California	3/21/78	41.7 T scrap melted/hr	549,000	119	Rader Hi-vol. with 3-1/2 in. nozzle	After open baghouse (i.e., no shell around bags)	Sampled 8 random points over top of open baghouse	103	a/	a/	a/	a/	0.00128c/	a/	0.145c/	No sampling was performed while bags were being cleaned. 1-120 T furnace; unclear whether carbon or alloy steel was being made during testing.	103
1.7d/ lb/T input	C	Controlled EAF melting, refining and building evacuation emissions.	Marathon Steel Tempe, AZ	4/16/77	7.9 T input/hr	35,800	213	a/	In stack after old baghouse	a/	94.6-99.2	(54-57 dscf sampled per run)		3	0.039-0.049d/	0.044d/	1.5-1.9d/	1.7d/	Old baghouse on furnace #1 (120 T capacity); possibility of leaking bags; unclear whether carbon or alloy steel was being made during testing.	104
0.33d/lb/T input	C	Controlled EAF melting, refining and building evacuation emissions.	Marathon Steel Tempe, AZ	9/13-16/77	18.7 T input/hr	146,000	161	a/	In stack after new baghouse	a/	98.2-108.9	(40.8-57.4 dscf sampled per run)		8	a/	0.0051d/	a/	0.33d/	New baghouse on furnaces #2 and #3; unclear whether carbon or alloy steel was being made during testing.	104

a/ Reference provides insufficient data or corroboration of data.
b/ Tests selected as acceptable by Peter Westlin, Test Support Section, OAQPS.
c/ Unclear whether value is based on particulate collected in front half of sampling train or in front and back halves combined.
d/ Based on particulate collected in front half of sampling train.
e/ Based on particulate collected in front and back halves of sampling train.

Average emission factor (lb/ton steel)	Emission factor reliability	Source	Company/ location	Test date	Process conditions: Process production rate	Process conditions: Gas flow rate (dscfm)	Process conditions: Gas temp. (°F)	Test methodology: Type of sampling device	Test methodology: Location of sampling device	Test methodology: Sampling methodology	Test methodology: Percent isokinetic	Test methodology: Sampling time (min)	Test methodology: Sampling flow rate (dscfm)	Number of runs performed	Test results: Measured concentrations: Range (gr/dscf)	Test results: Measured concentrations: Average (gr/dscf)	Test results: Emission factors: Range (lb/ton steel)	Test results: Emission factors: Average (lb/ton steel)	Comments	Reference
5.3c/	C	Uncontrolled OHF melting, and refining emissions.	Company A (AISI data)	7/5-6/73	3,840 T/day	301,000	350	a/	Precipitator inlet	a/	a/	a/	a/	8	0.14-0.58c/	0.33c/	2.2-9.4c/	5.3c/	8 furnaces in operation.	105
0.64c/	C	Controlled OHF melting and refining emissions	Company A (AISI data)	7/5-6/73	3,840 T/day	301,000	a/	a/	Precipitator outlet	a/	a/	a/	a/	2	0.02-0.05c/	0.04c/	0.32-0.81c/	0.64c/	8 furnaces in operation	105
0.28d/	A[b/]	Controlled OHF melting and refining emissions	Company A (AISI data)	6/25-27/74	4,750-5,012 T/day	296,000-326,000	430-450	EPA Method 5 sampling train	In 12 ft Ø precipitator exit stack	EPA Method 5	103-104	144	0.57	3	0.015-0.029d/	0.022d/	0.18-0.36d/	0.28d/	10-11 furnaces in operation; 3-4 furnaces were being blown.	106
0.1c/	B	Controlled OHF melting and refining emissions.	Company N (AISI data)	3/20/72	176 T steel/hr	534,000	385	Western precipitation stack sampling train. In-stack thimble.	In 16.5 ft Ø precipitator exit stack	WP-50	a/	180	0.55	1	None	0.004c/	None	0.1c/	6 furnaces with O_2 lances	107
0.33c/reported 0.45c/average	C C	Controlled OHF melting and, refining emissions.	Company C (AISI data)	5/16-26/71	27 T steel/hr/ furnace	94,500	a/	a/	a/	a/	a/	a/	a/	24	0.0055-0.037c/	0.015c/	0.16-1.1c/	0.45c/	Venturi scrubber pressures from 25 to 47 in. H_2O.	108
0.168 weighted by sampling time above and between furnaces	C	Roof monitor emissions	Company F (AISI data)	6/14-18/73	125 T steel/hr	1,117,000 acfm (total flow above and on either side of one furnace)	118 above furnace; 102 between furnaces	a/	In roof monitor over one furnace and between two furnaces	Profiled velocity across 19 ft wide monitor with vane type anemometer. Unknown particle concentration measuring technique.	65% of the data was more than 10% above isokinetic.	8-75 (tests conducted during various segments of the operation such as refining, scrap melt, etc.)	0.3-0.4 acfm	28	0.000639-0.0116 gr/acf (above furnace) 0.000881-0.0045 gr/acf (between furnaces)	0.00504 gr/acf (above furnace) 0.00261 gr/acf (between furnaces)	0.07-0.64 (various segments of the operation as measured above furnace) 0.029-0.12 (various segments of the operation as measured between furnaces)	0.22 avg. of the entire operation as measured above furnace. 0.063 avg of entire operation as measured between furnaces	Only iron oxide was collected. No kish was deposited on filters.	109
23.7d/ducted emissions avg during charging and blowing; 0.5d/avg during charging; 21.1d/avg during blowing.	A A A	Uncontrolled OHF melting and refining emissions	United States Steel, Fairfield, AL	9/30/75 10/1-2/75	30 T steel/ hr/furnace	52,600	608	In-stack alundum thimble followed by heated cyclone and filter outside stack.	In 88 in. Ø stack	Modified EPA Method 5	98.4-104.4	126-236	0.66	3	0.8685-1.5429d/	1.4101d/	12.3-30.8d/	23.7d/	Only two tests were performed for charging and blowing alone while three were performed for charging and blowing combined.	110

a/ Reference provides insufficient data or corroboration of data.
b/ Tests selected as acceptable by Peter Westlin, Test Support Section, OAQPS.
c/ Unclear whether value represents particulate collected in front half of sampling train or in front and back halves combined.
d/ Based on particulate collected in front half of sampling train.

The results of the tests on the teeming of leaded steel are shown in Table 10. The average uncontrolled emission factor measured by the front half of a Method 5 train was 0.81 lb/ton steel teemed. The average controlled emission factor measured by the front half of a Method 5 train after the baghouse was 0.0038 lb/ton steel teemed. The average EFs are given an A rating.

The results of six tests on the teeming of unleaded steel are shown in Table 11. The average uncontrolled emission factor measured by the front half of a Method 5 train was 0.07 lb/ton steel teemed. The average controlled emission factor measured by the front half of a Method 5 train after the baghouse was 0.0016 lb/ton steel teemed. These average EFs are given an A rating.

3.8 SCARFING

Particulate emissions occur when semi-finished steel products are manually or machine scarfed to remove surface defects. Table 12 lists controlled and uncontrolled EFs for machine scarfing. There are seven A-rated, five B-rated, and three unrateable EFs.

In comparing hand scarfing EFs to machine scarfing EFs, one must consider the units of the EFs and the process differences. The units for the machine scarfing EFs are a pound of particulate per ton of steel put through the machine. In machine scarfing, the entire surface of the product is removed to a depth that is dependent on the speed of the product through the machine and on the flame temperature. Hand scarfing does not involve removal of an entire surface but rather only spots on the product are scarfed.

If hand and machine scarfing were compared on a pound of particulate per ton of material removed basis, then one might, as a first estimate, assume that the hand scarfing EF can be likened in quantity to uncontrolled machine scarfing. But if the comparison is performed on the basis of pound of particulate per ton of steel put through the process, it is believed that hand scarfing is significantly less than uncontrolled machine scarfing. Unfortunately, no test data are available to support this assumption for hand scarfing emissions.

3.9 MISCELLANEOUS COMBUSTION SOURCES

Miscellaneous combustion sources include the burning of blast furnace gas, coke oven gas, natural gas, No. 6 fuel oil, or coal for heat used in boilers, soaking pits, and slab furnaces.

TABLE 10. EMISSIONS FROM LEADED STEEL TEEMING AT WISCONSIN STEEL, CHICAGO, ILLINOIS - SUMMARY OF TEST PROCEDURES AND RESULTS

Variable	Baghouse inlet	Baghouse outlet
Test date	April and May, 1978	April and May, 1978
Process production rate (T/min of teeming operation[a/])	5.1-5.4	5.1-5.4
Gas flowrate (dscfm)	28,000-42,600[b/]	56,600[b/]
Gas temperature (°F)	90-127	78-118
Gas velocity (fpm)	2,760-4,240	3,070-3,800
Type of sampling device	Method 5 train	Method 5 train
Location of sampling device	In 6' Ø BH inlet duct	In 3' Ø BH outlet duct
Sampling methodology	EPA Method 5. 24 pts sampled per test.	EPA Method 5. 36 pts sampled per test.
Percent isokinetic	100.3-101.1	95.4-103.1
Sampling time per run (min)	24	27-29
Sampling flowrate (dscfm)	2.6-4.0	4.5-5.0
Number of runs performed	3	3
Range/average of front half concentrations measured (gr/dscf)	0.6794-1.0877 (0.8172)	0.0012-0.0033 (0.0025)
Range/average of combined front and back half concentrations (gr/dscf)	0.6918-1.0968 (0.8285)	0.0103-0.0155 (0.0135)
Range/average of front half emission factors (lb/T steel teemed)	0.51-1.14 (0.81)	- (0.0038)
Average of combined front and back half emission factors (lb/T steel teemed)	0.81	0.021

a/ The averaging time began with the initiation of teeming into the first mold and ended with the conclusion of teeming into the last mold.

b/ Some of the flow rate data were incomplete since velocity traverses were not completed. It still appears, through, that there was a leak in the collection system that will cause the outlet concentrations to be reported lower than actual. However, this problem will not affect the emission factor values.

TABLE 11. EMISSIONS FROM UNLEADED STEEL TEEMING AT WISCONSIN STEEL, CHICAGO, ILLINOIS - SUMMARY OF TEST PROCEDURES AND RESULTS

Variable	Baghouse inlet	Baghouse outlet
Test date	April and May, 1978	April and May, 1978
Process production rate (T/min of teeming operation[a/])	3.8-5.9	3.8-5.9
Gas flowrate (dscfm)	38,700-44,700[b/]	40,100-44,800[b/]
Gas temperature (°F)	81-101	88-92
Gas velocity (fpm)	4,860-6,060	2,450-3,530
Type of sampling device	Method 5 train	Method 5 train
Location of sampling device	In 6' Ø BH inlet duct	In 3' Ø BH outlet duct
Sampling methodology	EPA Method 5. 24 pts sampled per test.	EPA Method 5. 36 pts sampled per test.
Percent isokinetic	97.2-108.1	92.1-108.9
Sampling time per run (min)	20-24	24-30
Sampling flowrate (dscfm)	3.7-4.1	3.6-4.6
Number of runs performed	6	6
Range/average of front half concentrations measured (gr/dscf)	0.035-0.068 (0.0565)	0.004-0.0028 (0.0011)
Range/average of combined front and back half concentrations (gr/dscf)	0.0375-0.0753 (0.061)	0.0039-0.0133 (0.0067)
Range/average of front half emission factors (lb/T steel teemed)	0.04-0.11 (0.07)	- (0.0016)
Average of combined front and back half emission factors (lb/T steel teemed)	0.076	0.0093

a/ The averaging time began with the initiation of teeming into the first mold and ended with the conclusion of teeming into the last mold.

b/ Some of the flow rate data were incomplete since velocity traverses were not completed.

TABLE 12. SUMMARY OF EMISSION FACTORS FOR SCARFING OPERATIONS

Average emission factor (lb/ton metal scarfed)	E.F. reliability	Company/ location	Scarfer designation	Test date	Process parameters: Tons scarfed per hr	Process parameters: Emission control system	Process parameters: Gas flow rate (dscfm)	Process parameters: Gas temp. (°F)	Test methodology: Sampling methodology	Test methodology: No. of runs	Test methodology: Sample time (min)	Test methodology: Percent isokinetic	Average measured concentration (gr/dscf)	Average emission factor (lb/ton metal scarfed)	Comments	References
0.08c/	A[b/]	Company A (AISI data)	40 in. bloom	2/76	60	ESP	69,900	80	EPA-5	3	120	99.7-100.7	0.008c/	0.08c/	After ESP	111
0.001c/	A[b/]		46 in. slab	10/75	486	ESP	69,900 (wet scfm)	83	EPA-5	3	140	99.1-100.5	0.001c/	0.001c/	After ESP	112
0.008c/	A[b/]		24 in. billet	10/75	147	ESP	17,000 (wet scfm)	84	EPA-5	3	140	97.5-99.4	0.003c/	0.008c/	After ESP	112
0.032c/	A[b/]		18 in. billet No. 1	10/75	105	ESP	18,700	77	EPA-5	3	140	96.8-98.9	0.007c/	0.032c/	After ESP	112
0.014c/	A[b/]		18 in. billet No. 2	10/75	89	ESP	19,300	80	EPA-5	3	140	98.2-100.2	0.002c/	0.014c/	After ESP	112
0.003c/	A[b/]		Rail-mill	11/75	111	ESP	11,300	90	EPA-5	3	140	99.9-101.1	0.002c/	0.003c/	After ESP	112
0.10	B		46 in. slab	1/67	207	-	72,700	60	WP-50	3	7-41	a/	0.25d/	0.1d/	Uncontrolled-sampled only while slabs were being scarfed. Assumed zero emissions between scarfs.	113
0.087d/	A[b/]		Blooming mill	7/74	275	-	31,600	110	EPA-5	3	144	98-103	0.089d/	0.087d/	Uncontrolled; concentration probably represents combined scarfing and non-scarfing periods.	114
a/	a/	Company B (AISI data)	No. 3 slabbing mill	5/73	a/	-	95,500	114	ASME PTC-21,27	3	39-150	a/	0.14e/	a/	Uncontrolled	115
a/	a/	Company C (AISI data)	a/	1/66	200	-	62,800	146	a/	5	150-180	a/	0.570	a/	Uncontrolled; concentration may or may not be converted to scarfing period only.	116
a/	a/		a/	1/66	200	Kinpactor	62,800	133	NA	5	150-180	a/	0.04	a/	After Kinpactor and Type R rotoclone.	116
0.22d/	B		a/	8/71	98.8	-	22,700 ACFM	120	EPA-5	1	4	a/	0.54d/	0.22d/	Uncontrolled; sampled only during scarfing.	117

Average emission factor (lb/ton metal scarfed)	E.F. reliability	Company/ location	Scarfer designation	Test date	Process parameters: Tons scarfed per hr	Process parameters: Emission control system	Process parameters: Gas flow rate (dscfm)	Process parameters: Gas temp. (°F)	Test methodology: Sampling methodology	Test methodology: No. of runs	Test methodology: Sample time (min)	Test methodology: Percent isokinetic	Average measured concentration (gr/dscf)	Average emission factor (lb/ton metal scarfed)	Comments	Reference
0.24d/	B		a/	8/71	112.5	-	10,500 ACFM	85-120	EPA-5	1	80	a/	0.34d/	0.24d/	Uncontrolled; sampled during scarfing and non-scarfing.	117
0.10e/	B	Company Q (AISI data)	Blooming mill	9/73	125	Scrubber	a/	a/	ASME PTC-27	4	46	a/		0.11e/	After scrubber.	118
0.07c/	B		a/	3/73	236.5	a/	a/	a/	In stack thimble	3	50	a/	0.035c/	0.07c/	Unclear whether controlled or uncontrolled.	119

a/ Reference provides insufficient data or corroboration of data.
b/ Tests selected as acceptable by Peter Westlin, Test Support Section, OAQPS.
c/ Based on particulate measured in front half of sampling train.
d/ Unclear whether value represents particulate captured in front half of sampling train or in front and back halves combined.
e/ Based on particulate measured in front and back halves of sampling train.

The EFs to be used for burning natural gas, No. 6 fuel oil, or coal in boilers can be acquired from AP-42 as follows:

Fuel	Uncontrolled emission factor	Rating
Bituminous coal	16 A lb/ton coal (A is ash content in percent; assume 10%)	A
No. 6 fuel oil	10 (S) + 3 lb/1,000 gal. (S is sulfur content in percent by weight; assume 1%)	A
Natural gas	10 $lb/10^6\ ft^3$	A

The EFs for burning of the above fuels in soaking pits or slab furnaces can be estimated to be the same as those for boilers, but since this is an estimate, the rating would drop to D.

The EFs for blast furnace gas and coke oven gas have not been researched by experimentation. The EFs must therefore be acquired by estimation. There are three facts available in making the estimation. First, the gas exiting the blast furnace passes through primary and secondary cleaners and can be cleaned to less than 0.02 gr/ft^3 (2.86 $lb/10^6\ ft^3$).[120/] Second, nearly one-third of coke oven gas is methane. Third, there are no constituents of blast furnace gas that generate particulate when burned.[121/] The combustible constituent of blast furnace gas is CO which burns clean.

Based on the above three facts, the EFs for burning blast furnace gas can be estimated. The EF for burning blast furnace gas is assumed to equal the particulate carried into the burning process with the fuel plus the particulate generated in burning the fuel. The particulate carried in with blast furnace gas is 2.86 $lb/10^6\ ft^3$. There is no appreciable amount of particulate generated in burning blast furnace gas since there is no particulate generating combustible gas in it. Consequently, the EF for burning blast furnace gas is estimated at 2.86 $lb/10^6\ ft^3$.

The EF for burning coke oven gas can be estimated in the same fashion. Assuming that cleaned coke oven gas has as much particulate in it initially as cleaned blast furnace gas, the particulate carried in with coke oven gas is estimated at 2.86 $lb/10^6\ ft^3$. Since one-third of coke oven gas is methane, the main component of natural gas, it is assumed that the burning of coke oven gas generates one-third the particulate that the burning of natural gas does, i.e., 3.33 $lb/10^6\ ft^3$. Thus, the EF for burning coke oven gas is estimated at 6.2 $lb/10^6\ ft^3$.

Also necessary for calculations is the heating value of each fuel. The following is a list of heating values and the reference from which they were obtained:

Fuel	Heating value (sensible heat)	Reference
Blast furnace gas	75-90 Btu/ft^3	122
Coke oven gas	500 Btu/ft^3	123
No. 6 fuel oil	141,000 Btu/gal.	124
Bituminous coal	25 million Btu/ton	125
Natural gas	1,000 Btu/ft^3	126

Putting the EFs into similar units yields the following table:

Fuel	Uncontrolled emission factor ($lb/10^6$ Btu)	Emission factor reliability		
		Boilers	Soaking pits	Slab furnaces
Blast furnace gas	0.035	D	D	D
Coke oven gas	0.012	D	D	D
No. 6 fuel oil	0.09	A	D	D
Bituminous coal	6.4	A	D	D
Natural gas	0.01	A	D	D

3.10 OPEN DUST SOURCES

In addition to process sources, open dust sources contribute to the atmospheric particulate burden. Open dust sources at iron and steel plants include vehicular traffic on paved and unpaved roads, loading into and loading from storage piles, storage pile maintenance, and storage pile and exposed area wind erosion.

3.10.1 Identification of Emission Sources

Emissions occur when vehicles travel on unpaved surfaces. Such vehicles as passenger cars, pick-up trucks, haul trucks, and delivery trucks all produce emissions as the tires interact with the road. The heavier the vehicle, all other variables being the same, the more emissions one can expect.

Emissions occur when vehicles traveling on paved roads elevate dust from the road surface. The dust is deposited on the road surface by carry-on, pavement wear, tire wear, and erosion from adjacent areas, to name a few points of origin.

As stated above, storage piles are also sources of dust. Dust producing mechanical activities include:

1. Unloading of raw materials from a barge by a clamshell or bucket wheel and from a railcar by dumping.

2. Adding material to a storage pile via stacker, loader, or truck.

3. Loading of material from the pile onto a conveyor or into a truck.

4. Maintenance of pile shape with loaders or dozers.

In addition to mechanical activities which produce dust, natural activities such as wind erosion occur. Particulate is generated from exposed areas and storage piles where wind speed exceeds the threshold velocity which for some materials is about 12 mph at 1 ft above the surface.[127]

Finally, emissions occur when material drops from one conveyor to another. This is the standard procedure for changing transport direction. It is thought that little emissions occur elsewhere in the conveying process. The belts themselves rest on idler rolls which cause the belts to incline upward 20 or 30 degrees on both edges. This provides a shield from the wind and minimizes spillage.

3.10.2 Quantification of Emission Factors

Empirically derived predictive EF equations for open dust sources have been developed by Midwest Research Institute (MRI).[127-130] The predictive equations have been modified as more tests have been added to the data base. A summary of the most currently refined predictive equations is shown in Table 13.

The predictive EFs listed in Table 13 can be used for, but are not limited to, iron and steel plants. Table 14 shows the quality assurance rating currently assigned to the EFs for each of the source categories listed in Section 3.10.1. While many of the emission factors are rated A or B when applied to the source categories listed in Table 14, the rating would be lowered for some of the factors if controlled emission factors were to be predicted. For example, the effects of watering and chemical dust suppressants on the emissions from vehicles traveling on unpaved roads are not well known.

Some of the correction parameters in Table 13 can be determined from published literature. Vehicle weight and dumping device capacity, for example, can be found in manufacturer literature. Mean wind speed, number of dry days, and percent of time the wind speed exceeds 12 mph at 1 ft above the ground can be found in the Climatic Atlas[131] or from other local weather stations. The precipitation-evaporation index has been calculated by MRI for all the state

TABLE 13. FUGITIVE DUST EMISSION FACTORS EXPERIMENTALLY DETERMINED BY MRI

Source category	Measure of extent	Emission factor[a] (lb/unit of source extent)	Correction Parameters
1. Unpaved roads	Vehicle-Miles Traveled	$5.9 \left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{0.7}\left(\frac{w}{4}\right)^{0.5}\left(\frac{d}{365}\right)$	s = Material Silt Content (%) S = Average Vehicle Speed (mph) W = Vehicle Weight (tons) L = Surface Dust Loading on Traveled Portion of Road (lb/mile) U = Mean Wind Speed (mph) M - Material Surface Moisture Content (%) Y = Dumping Device Capacity (yd^3) K = Activity Correction[b] d = Number of Dry Days Per Year f = Percentage of Time Wind Speed Exceeds 12 mph at 1 ft above the ground D = Duration of Material Storage (days) e = Surface Erodibility (tons/acre/year) P-E = Thornthwaite's Precipitation-Evaporation Index N = Number of Traveled Lanes I = Industrial Road Augmentation Factor[c] w = Average Number of Wheels on Vehicle Mix h = Drop Height (ft)
2. Paved Roads	Vehicle-Miles Traveled	$0.09\ I \left(\frac{4}{N}\right)\left(\frac{s}{10}\right)\left(\frac{L}{1,000}\right)\left(\frac{W}{3}\right)^{0.7}$	
3. Batch Load-In (e.g., front-end loader, railcar dump)	Tons of material Loaded In	$0.0018 \dfrac{\left(\frac{s}{5}\right)\left(\frac{U}{5}\right)\left(\frac{h}{10}\right)}{\left(\frac{M}{2}\right)^{2}\left(\frac{Y}{6}\right)}$	
4. Continuous Load-In (e.g., stacker, transfer station)	Tons of Material Loaded In	$0.0018 \dfrac{\left(\frac{s}{5}\right)\left(\frac{U}{5}\right)\left(\frac{h}{10}\right)}{\left(\frac{M}{2}\right)^{2}}$	
5. Active Storage Pile Maintenance and Traffic	Tons of Material Put Through Storage	$0.10\ K \frac{s}{1.5}\left(\frac{d}{235}\right)$	
6. Active Storage Pile Wind Erosion	Tons of Material Put Through Storage	$0.05 \left(\frac{s}{1.5}\right)\left(\frac{d}{235}\right)\left(\frac{f}{15}\right)\left(\frac{D}{90}\right)$	
7. Batch Load-Out	Tons of Material Loaded Out	$0.0018 \dfrac{\left(\frac{s}{5}\right)\left(\frac{U}{5}\right)\left(\frac{h}{10}\right)}{\left(\frac{M}{2}\right)^{2}\left(\frac{Y}{6}\right)}$	
8. Wind Erosion of Exposed Areas	Acre-Years of Exposed Land	$3,400 \dfrac{\left(\frac{e}{50}\right)\left(\frac{s}{15}\right)\left(\frac{f}{25}\right)}{\left(\frac{P-E}{50}\right)^{2}}$	

a/ Represents particulate smaller than 30 μm in diameter based on particle density of 2.5 g/cm^3.

b/ Equals 1.0 for front-end loader maintaining pile tidiness and 50 round trips per truck per day in the storage area.

c/ * Equals 7.0 for trucks coming from unpaved to paved roads and releasing dust from underbody of vehicle;
* Equals 3.5 when 20% of the vehicles are forced to travel temporarily with one set of wheels on an unpaved road berm while passing on narrow roads;
* Equals 1.0 for traffic entirely on paved surfaces.

TABLE 14. EMISSION FACTOR QUALITY ASSURANCE LIMITATIONS (Effective September 1979)

Source category	Quality assurance rating
Vehicular Traffic on Unpaved Roads - Dry Conditions	A
Vehicular Traffic on Unpaved Roads - Controlled Conditions	C
Vehicular Traffic on Paved Roads	B
Storage Pile Formation by Means of Translating Conveyor Stacker	B
Transfer of Aggregate from Loader to Truck	B
Storage Pile Maintenance and Related Traffic	C
Wind Erosion from Storage Piles and Exposed Areas	C

climatic regions in the United States and is reported in published literature.[127] The erodibility of materials can also be obtained from published literature.[132]

Some of the correction parameters in Table 13 can be determined with reasonable accuracy by estimation. Average vehicle speed and number of wheels can be estimated. The number of traveled paved road lanes can be estimated for a particular iron and steel plant by plant personnel. The drop height for aggregate material can be measured or visually estimated with reasonable accuracy.

Finally, there are correction parameters in Table 13 that can best be estimated by MRI personnel. These parameters are raw material silt and moisture content, paved and unpaved road material silt content, and total surface dust loading on paved roads.

Tables 15 through 17 show the results of silt, moisture, and loading analysis of field samples collected by MRI. For each type of material, the number of samples obtained, the range of values measured, and the mean values for these correction parameters are given. Samples listed in Tables 15 through 17 were collected at as many as 12 different iron and steel plants in a wide range of geographic locations.

TABLE 15. SILT CONTENT VALUES APPLICABLE IN THE IRON AND STEEL INDUSTRY

Source	Number of tests	Range of silt content (%)	Average silt content (%)
1. Unpaved roads	12	4-13	7.3
2. Paved roads	9	1.1-13	5.9
3. Material handling activities and storage pile wind erosion			
a. Coal	7	2-7.7	5.0
b. Iron ore pellets	10	1.4-13	4.9
c. Lump iron ore	9	2.8-19	9.5
d. Coke breeze	1	-	5.4
e. Slag	3	3.0-7.3	5.3
f. Blended ore	1	-	15.0
g. Sinter	1	-	0.7
h. Limestone	1	-	0.4
i. Flue dust	2	14-23	18.0

TABLE 16. SURFACE MOISTURE CONTENT VALUES APPLICABLE IN THE IRON AND STEEL INDUSTRY

Source	Number of tests	Range of surface moisture content (%)	Average surface moisture content (%)
1. Material handling activities and storage pile wind erosion			
a. Coal	6	2.8-11	4.8
b. Iron ore pellets	8	0.64-3.5	2.1
c. Lump iron ore	6	1.6-8.1	5.4
d. Coke breeze	1	-	6.4
e. Slag	3	0.25-2.2	0.92
f. Blended ore	1	-	6.6
g. Flue dust	1	-	12.4

TABLE 17. SURFACE LOADING ON TRAVELED LANES OF PAVED ROADS IN IRON AND STEEL PLANTS

Number of tests	Range of surface loading (lb/mile)	Average surface loading (lb/mile)
9	65-17,000	2,700

SECTION 4.0

DEVELOPMENT OF REPRESENTATIVE EMISSION FACTORS

The final objective of this report is to develop a representative EF value or predictive equation for each particulate emission source in the iron and steel industry. Section 3.0 presents all the EF data presently available. It is from the data in Section 3.0 that the representative EF values were developed.

4.1 PROCESS STACK AND FUGITIVE EMISSIONS

Table 18 shows a summary of the EFs by source and by reliability rating. (The rating system was defined in Section 3.0). Recalling that nearly every EF in the left-hand column of Tables 2 through 10 represents an average of a number of runs (test series), the average of these test series average values as presented in Table 18 was calculated as follows:

$$EF_{avg} = \sum_{i=1}^{i=T} EF_i \; N_i \Big/ \sum_{i=1}^{i=T} N_i \qquad (1)$$

EF_i = average of test series i,

N_i = number of runs in test series i (if $N_i > 3$, then set $N_i = 3$),

T = number of test series, and

EF_{avg} = emission factor average for a specific reliability rating category.

The philosophy behind Equation 1 is that within the same rating category the test series composed of the most runs should receive the most weight. However, a limit to the weighting is set at a value of 3. This is to eliminate the possibility that a very high number of tests performed at a very dirty or very clean, and consequently nonrepresentative, plant could unfairly weight the overall average. Thus, a test series with three tests will be weighted three times that with only one test while the possibility of a nonrepresentative plant with many tests distorting the overall average is eliminated.

TABLE 18. SELECTION OF SINGLE EMISSION FACTOR VALUES TO REPRESENT EACH PARTICULATE SOURCE CATEGORY IN THE IRON AND STEEL INDUSTRY

Source	Test series					Average EF for rating category	Calculated single EF value		
	Rating	Average EF (EF_t)	EF units	Number of runs	Bibliography reference	(EF average)	Average	Range	Rating
I. By-product Coke Ovens									
A. Coal Charging			lb/T coal						
1. Uncontrolled	C	0.11		10	141	0.21	0.85	0.11-1.5	C
	C	0.52		?-assume 1	6				
	D	1.5		?-assume 1	5	1.5			
2. Controlled									
a. Larry car vented to scrubber	C	0.02		?-assume 1	6	0.02	0.02		C
b. Sequential charging	C	0.016		6	141	0.016	0.016		C
B. Uncontrolled Door Leaks	A	0.44	lb/T coal	3	8	0.58	0.51	0.36-0.72	B
		0.72		3	9				
	B	0.36		3	7	0.36			
C. Coke Pushing			lb/T coal						
1. Uncontrolled Suspended Emissions (as measured in duct venting coke side shed)	A	0.69		3	8,12	0.5	0.47	0.25-0.68	A
		0.55		4	13				
		0.25		3	9,12				
	B	0.68		2	11	0.4			
		0.29		28	15				
		0.26		4	15				
		0.34		2	17				
		0.43		2	17				
		0.53		23	12				
		0.37		2	17				
	C	0.49		3	11	0.49			
2. Controlled Suspended Emissions									
a. Water sprays	A	0.39		15	13	0.39	0.39		A
3. Uncontrolled Total Emissions (suspended plus dustfall)	A	2.3		9	14	2.3	2.0	0.7-2.3	B
	B	2.0		39	10	1.4			
		0.7		25	10				
	C	0.4		6	16	0.4			
4. Controlled Total Emissions (suspended plus dustfall)									
a. Water sprays	B	1.2		15	13	1.2	1.2		B
b. Enclosed coke car and guide vented to scrubber	C	0.024		6	16	0.024	0.024		C

(continued)

TABLE 18. (continued)

Source	Test series: Rating	Test series: Average EF (EF_i)	Test series: EF units	Test series: Number of runs	Test series: Bibliography reference	Average EF for rating category (EF average)	Calculated single EF value: Average	Calculated single EF value: Range	Calculated single EF value: Rating
D. Quenching			lb/T coal						
1. Controlled by Baffles	A	1.4		13	18,19	1.0 [a/]	1.0 [a/]	0.21-2.6	A
		2.6		12	18,19				
		0.25		9	21				
		0.21		2	21				
		0.23		6	21				
	C	0.06		?-assume 1	22	0.04			
E. Uncontrolled Combustion Stacks	B	0.35	lb/T coal	3	23	0.58	0.58	0.08-1.31	B
		0.53		1	23				
		1.31		47	23				
		0.36		2	23				
		1.04		2	23				
		0.08		4	25				
		0.66		3	23				
		0.36		1	23				
		0.42		2	23				
		0.74		3	23				
		0.18		2	23				
		0.43		5	23				
		0.42		3	23				
		0.9		1	23				
		0.53		3	23				
		0.82		3	23				
	C	0.16		2	23	0.55			
		0.12		1	23				
		0.7		10	24				
		0.8		10	24				
F. Coal Preheaters			lb/T coal						
1. Uncontrolled	C	7.0		18	135	7.0	7.0		C
2. Controlled by Scrubber	C	0.65		18	135	0.65	0.65		C
II. Blast Furnaces									
A. Slips	D		lb/slip		26	87.0	87.0	27.6-276	D
B. Uncontrolled Cast House Emissions			lb/T hot metal						
1. Monitor	A	0.78		2	29	0.78	0.6	0.2-0.78	B
	B	0.2		19	29	0.25			
		0.31		10	30				
	C	0.25		?-assume 1	29	0.39			
		0.52		?-assume 1	29				
2. Tap Hole and Trough (not runners)	B	0.31		3	28	0.3	0.3	0.29-0.31	B
		0.29		3	28				

(continued)

TABLE 18. (continued)

Source	Rating	Average EF (EF_i)	EF units	Number of runs	Bibliography reference	Average EF for rating category (EF average)	Calculated single EF value: Average	Range	Rating
III. Sintering									
A. Windbox Emissions			lb/T sinter						
1. Uncontrolled									
a. Leaving grate	B	10.8		17	31	11.1	11.1	10.8-11.8	B
		11.8		6	33				
b. After coarse particulate removal	A	8.7		10	35	8.7	8.7		A
2. Controlled by Dry ESP	A	2.2		10	35	2.1	1.6	0.43-2.2	B
		2.0		3	49				
	B	0.43		3	48	0.53			
		0.63		3	41				
3. Controlled by Wet ESP	B	0.17		38	56	0.17	0.17		B
	C	0.03		6	43	0.03			
4. Controlled by Scrubber	A	0.7		3	37	0.66	0.47	0.093-0.95	B
		0.32		3	50				
		0.95		6	138				
	B	0.093		3	56	0.093			
5. Controlled by Cyclone	B	1.0		16	34	1.0	1.0		B
B. Sinter Discharge (breaker and hot screens)			lb/T sinter						
1. Uncontrolled	B	6.8		15	32	6.8	6.8		B
2. Controlled by Baghouse	B	0.1		3	48	0.1	0.1		B
3. Controlled by Orifice Scrubber	A	0.59		3	138	0.59	0.59		A
C. Windbox and Discharge	A	0.3		3	140	0.3	0.3		A
1. Controlled by baghouse									
IV. BOFs									
A. Top Blown Furnace Melting and Refining			lb/T steel						
1. Uncontrolled	A	24.2		5	137	24.2	28.5		B
	B	37.0		5	58,59	37.0			
2. Controlled by Open Hood Vented to:									
a. ESP	A	0.0614		5	137	0.13	0.13	0.0614-0.21	A
		0.105		3	64				
		0.21		3	65				
	C	0.052		3	66	0.052			
b. Scrubber	B	0.15		7	58	0.09	0.09	0.033-0.15	B
		0.033		3	61				
	C	0.09		3	57	0.098			
		0.106		3	72				

(continued)

TABLE 18. (continued)

Source	Test series: Rating	Test series: Average EF (EF_i)	Test series: EF units	Test series: Number of runs	Test series: Bibliography reference	Average EF for rating category (EF average)	Calculated single EF value: Average	Calculated single EF value: Range	Calculated single EF value: Rating
3. Controlled by Closed Hood Vented to:									
a. Scrubber	A	0.0028		3	67	0.0068	0.0068	0.0028-0.0132	A
		0.0044		3	68				
		0.0132		3	71				
B. Q-BOP Melting and Refining			lb/T steel						
1. Controlled by Scrubber	A	0.0556		2	73	0.056	0.056		A
C. BOF Charging			lb/T hot metal						
1. At Source	A	0.6		6	134	0.6	0.6		A
2. At Building Monitor	B	0.142		15	81	0.142	0.142		B
D. BOF Tapping			lb/T steel						
1. At Source	A	0.92		3	134	0.92	0.92		A
2. At Building Monitor	B	0.29		15	80	0.29	0.29		B
E. Hot Metal Transfer			lb/T hot metal						
1. At Source	A	0.19		8	133	0.19	0.19		A
2. At Building Monitor	B	0.056		8	82	0.056	0.056		B
F. BOF Monitor (all sources)	B	0.5	lb/T steel	3	84	0.5	0.5		B
	C	0.28		1	83	0.23			
		0.3		3	85,143				
		0.147		4	86,87				
V. EAFs									
A. Melting and Refining			lb/T steel						
1. Uncontrolled									
a. Carbon steel	C	50		?-assume 1	97	38	38	22-51	C
		51		?-assume 1	98				
		22		?-assume 1	99				
		27.5		?-assume 1	99				
B. Charging, Tapping, and Slagging			lb/T steel						
1. Uncontrolled Emissions Escaping Monitor	C	1.2		?-assume 1	99	1.2	1.4	1.2-1.7	C
		1.7		?-assume 1	100	1.7			

(continued)

TABLE 18. (continued)

Source	Test series: Rating	Test series: Average EF (EF_i)	Test series: EF units	Test series: Number of runs	Test series: Bibliography reference	Average EF for rating category (EF average)	Calculated single EF value: Average	Calculated single EF value: Range	Calculated single EF value: Rating
C. Melting, Refining, Charging, Tapping, and Slagging			lb/T steel						
1. Uncontrolled									
a. Alloy steel	A	11.3		1	89	11.3	11.3		A
b. Carbon steel	C	43.0		?-assume 1	99	50	50		C
		58.0		?-assume 1	101				
2. Controlled by:									
a. Configuration 1 (building evacuation to baghouse for alloy steel)	A	0.3		9	89	0.3	0.3		A
b. Configuration 2 (DSE plus charging hood vented to common baghouse for carbon steel)	C	0.043		2	96	0.043	0.043		C
VI. OHF									
A. Melting and Refining			lb/T steel						
1. Uncontrolled	A	21.1		3	110	21.1	21.1		A
2. Controlled by ESP	A	0.28		3	106	0.28	0.28		A
B. Roof Monitor Emissions	C	0.168		28	109	0.168	0.168		C
VII. Teeming			lb/T steel						
A. Leaded Steel									
1. Uncontrolled (as measured at the source)	A	0.81		3	133	0.81	0.81		A
2. Controlled by Side-draft Hood Vented to Baghouse	A	0.0038		3	133	0.0038	0.0038		A
B. Unleaded Steel									
1. Uncontrolled (as measured at the source)	A	0.07		6	133	0.07	0.07		A
2. Controlled by Side-draft Hood Vented to Baghouse	A	0.0016		6	133	0.0016	0.0016		A
VIII. Machine Scarfing									
A. Uncontrolled	B	0.1	lb/T metal through scarfer	3	113	0.1	0.1		B
B. Controlled by ESP	A	0.08	lb/T metal through scarfer	3	111	0.023	0.023	0.001-0.08	A
		0.001		3	112				
		0.008		3	112				
		0.032		3	112				
		0.014		3	112				
		0.003		3	112				

(continued)

TABLE 18. (concluded)

Source	Test series: Rating	Test series: Average EF (EF_i)	Test series: EF units	Test series: Number of runs	Test series: Bibliography reference	Average EF for rating category (EF average)	Calculated single EF value: Average	Calculated single EF value: Range	Calculated single EF value: Rating
IX. Miscellaneous Combustion Sources									
A. Boilers Burning the Following:			$lb/10^6$ Btu						
1. Blast Furnace Gas	D	0.035		-	120-122	0.035	0.035		D
2. Coke Oven Gas	D	0.012		-	120-122	0.012	0.012		D
3. No. 6 Fuel Oil	A	0.09		-	AP-42	0.09	0.09		A
4. Bituminous Coal	A	6.4		-	AP-42	6.4	6.4		A
5. Natural Gas	A	0.01		-	AP-42	0.01	0.01		A
B. Soaking Pits Burning the Following:			$lb/10^6$ Btu						
1. Coke Oven Gas	D	0.012		-	120-122	0.012	0.012		D
2. No. 6 Fuel Oil	D	0.09		-	AP-42	0.09	0.09		D
3. Natural Gas	D	0.01		-	AP-42	0.01	0.01		D
C. Slab Reheat Furnaces Burning the Following:			$lb/10^6$ Btu						
1. Coke Oven Gas	D	0.012		-	120-122	0.012	0.012		D
2. No. 6 Fuel Oil	D	0.09		-	AP-42	0.09	0.09		D
3. Natural Gas	D	0.01		-	AP-42	0.01	0.01		D

a/ Even though the tests were performed in an acceptable manner and all data were reported (A-rating), there are independent variables which effect the EF measurement and caused the wide range of results (see p. 12).

The value 3 was selected as the cutoff point for weighting averages of test series averages. This value arises from the unwritten rule generally followed by the U.S. EPA that 3 tests are sufficient to quantify emissions from a source. This is evidenced by the multiplicity of sets of three tests used in the published background documents for BOF[65-68, 71-72] and EAF[89] standards.

The process for identifying the test series averages that were excluded from Table 18 was as follows:

1. Test series averages reported in units incompatible with the selected reporting units shown in the Table 18 column entitled "EF Units" were excluded. For example, EFs for sintering operations reported in pounds per ton input could not be converted to pounds per ton sinter for two reasons. First, input can be defined in three ways--raw material from bins, raw material from bins and recycle fines, and finally, raw material from bins, recycle fines, and hearth layer. The definition utilized was not made clear in many of the reports. Second, depending on plant operations, the mass ratio between input and output product may not be the same from plant to plant.

2. Test series averages representing front and back half particulate as measured by EPA Method 5 were excluded. Test series which were reported unclearly as to whether they represented front and back half or just front half particulate were also excluded.

3. Test series for controlled tests for which the control device was not specified were excluded.

4. Test series that were unclearly reported as to what process source they represented were excluded.

5. Test series that were reported unclearly as to whether they were controlled or uncontrolled were excluded.

The rules for calculating the representative EF for a source were:

1. If any source category has four or more A-rated test series, then the representative EF value shall be equal to the average of these A-rated test series as determined by Equation 1.

2. If any source category has less than four A-rated test series but more than zero, then the representative EF value shall be a weighted average of the A- and B-rated averages with the A-rated EF average receiving twice the weight that the B-rated EF average does.

3. If there are no A-rated values, then the representative EF value shall be equal to the average of the B-rated test series averages as determined by Equation 1.

If there are no A- and B-rated values, then the representative EF value shall be equal to the average of C- and D-rated values.

The philosophy behind the above rules is as follows. If there is a significant number of A-rated test series, that is, tests performed by a sound methodology and reported in enough detail to adequately validate the test series, then the single value should be set equal to the average of the A-rated values alone. If there is not enough A-rated test series to cover a significant number of plants (estimated as four), then the B-rated test series should also be included in the averaging process so that the single EF value approaches a true industry-wide average. But, in order to counterbalance the fact that B-rated test series may not have been performed properly, the A-rated average should be weighted as more important than (twice as heavily as) the B-rated average. If there are no A-rated test series, then the single value should be set equal to the average of the B-rated test series. No C- or D-rated test series should be included with A- or B-rated tests in determining the single EF, since they were performed by either an unacceptable or unknown methodology or are based on estimates which cannot be corroborated. If there are no A- or B-rated test series, then the single EF value should be set equal to the average of the C- and D-rated test series. This provides at least an order of magnitude value for the source, but should by no means be expected to provide any more precision. These C- and D-rated test series are only used as a last resort since no other data are available.

4.2 OPEN DUST SOURCES

The single EFs that should be used to represent open dust sources at existing plants are shown in Table 13. These factors are in the form of predictive equations and, consequently, their use necessitates that the independent variables be quantified. For cases where estimates must be made for plant expansions or new plants, the equations in Table 13 can also be used, but the independent variables will necessarily have to be estimated. The average values presented in Tables 15-17 could be used for these estimates.

SECTION 5.0

SUMMARY

The purpose of this report was to develop a representative particulate EF or predictive equation for each significant source in the iron and steel industry. To accomplish this, results of emission tests performed by industry, EPA contractors, local, state, and regional environmental regulatory bodies were compiled in Section 3.0 and each EF rated as to its reliability.

For process stack and fugitive emissions, weighted averages of the most reliable tests were then calculated in Section 4.0 to develop representative particulate EF values as shown in Table 18. Unfortunately, much of the compiled data were not useful in determining the final representative EF value for reasons of unreliability, reporting of the production rate in incompatible units, inclusion of condensable emissions, unspecified control devices, and lack of clarity concerning which sources were actually sampled.

For open dust sources, predictive equations as shown in Table 13 were selected as the most accurate method to predict emissions from existing and proposed plants. The large difference in EF values for the same source due to varying raw or intermediate material characteristics or climatic variation with geographic location can then be predicted.

In conclusion, it is important to repeat the caution in Section 1.0 that the values in Tables 13 and 18 are average EFs obtained from a wide range of data of varying degrees of accuracy. The reader must be cautioned not to use these emission factors indiscriminately. That is, the factors generally may not yield precise emission factors for an individual installation. Only on-site source tests can provide data sufficiently accurate and precise to determine actual emissions for that source. Emission factors are most appropriate when used in diffusion models for the estimation of the impact of proposed new sources upon the ambient air quality and for community or nationwide air pollution emission estimates.

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APPENDIX

TYPICAL CONVERSION FACTORS FOR MATERIAL FLOW CALCULATIONS

TABLE A-1. TYPICAL CONVERSION FACTORS UTILIZED FOR ENGINEERING ESTIMATES OF QUANTITIES OF MATERIAL HANDLED

Process	Conversion factor	Reference
Coke manufacture	1.0 unit coal / 0.69 unit coke	-
Iron production	0.55 unit coke / 1.0 unit iron	1
	1.55 units of iron bearing material / 1.0 unit iron	1
	0.5 unit sinter / 1.0 unit iron	Average of 5 years of AISI data
	1.0 unit iron ore / 1.0 unit iron	Calculated by difference
	0.2 unit limestone / 1.0 unit iron	1
	0.2 unit slag / 1.0 unit iron	1
	or	
	0.3-0.4 unit slag / 1.0 unit iron	2
	or	
	0.2-0.35 unit slag / 1.0 unit iron	3
BOF steel production	0.7 unit hot metal / 1.0 unit BOF steel	4
	0.3 unit scrap / 1.0 unit BOF steel	4
OHF steel production	0.45-0.55 unit hot metal / 1.0 unit OHF steel	4
	0.45-0.55 unit scrap / 1.0 unit OHF steel	4

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EPA Task Officer - Charles C. Masser

16. ABSTRACT

An intensified effort has occurred in the last 3 years to update the iron and steel industry particulate emission factors presented in AP-42 and to add, for the first time, fugitive source emission factors.

It is the objective of this report to present the results of this data gathering and analysis effort. The report is divided into three major areas. First, background information will be presented related to the processes in the iron and steel industry along with a process flow chart. Second, all of the particulate source test data will be presented and summarized in chart form. Third, the methodology for selecting single source specific emission factors and the resulting particulate emission factors will be presented.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Particulate Emissions Emission Factor	Iron and Steel Particulate Emissions Emission Factor	

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