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Research Laboratory
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Project Summary

Iron and Steel Industry Particulate Emissions: Source Category Report

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

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The purpose of this program was to summarize the best available information on emissions of inhalable particulate matter in the iron and steel industry. The main objective of the program was to develop reliable size-specific emission factors for the various processes used in the production of iron and steel. Both uncontrolled and controlled emission factors are presented in the report. The uncontrolled factors represent emissions which would result if the particulate control device (baghouse, scrubber, etc.) were bypassed, and the controlled factors represent emissions emanating from a particular type of control system. The size-specific emission factors are generally based on the results of simultaneous sampling conducted at the inlet and outlet of the control device(s), utilizing a variety of particle sizing techniques. Other objectives of this program were to present current information on the iron and steel industry as well as prepare a replacement for Section 7.5 of EPA report AP-42, "A Compilation of Air Pollutant Emissions Factors."

The above objectives were met by a thorough literature search which included the following sources:

- Data from inhalable particulate characterization program,
- Fine Particle Emissions Inventory System (FPEIS),
- AP-42 background file at EPA's Office of Air Quality Planning and Standards (OAQPS),
- GCA files, and
- Various industry sources (e.g., American Iron and Steel Institute).

The emission data contained in 45 reference documents were reviewed, analyzed, summarized, and ranked according to the criteria established by OAQPS as published in the report, "Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections," April 1980. After ranking the data, emission factors were calculated using the highest quality data available. The quality of the data used to develop each emission factor is indicated by the emission factor rating.

Process control system operating data as well as general industry information were also obtained and summarized as general background information. It was not part of this program to provide detailed engineering analyses, product specifications, or detailed evaluation of trends in the industry.

Summary of Results

Particulate emissions are generated from several iron and steel facility activities, including sintering, iron and steel production, semifinished product preparation, and open dust sources. The most significant source of emissions from sintering operations is the windbox exhaust. Windbox emissions may be controlled by cyclones, electrostatic precipitators (ESPs), scrubbers, or fabric filters. Most plants use cyclones as pretreatment to remove large particulate from the gas stream to reduce fan wear. Most plants use ESPs or scrubbers for windbox emission controls.

The casthouse is the major source of particulate emissions associated with blast furnace operations. A variety of techniques for capturing emissions from new casthouses and for retrofitting other casthouses have been applied. Several shops have experimented with and installed total casthouse evacuation, partial casthouse evacuation, local hoods, runner evacuation, or passive emission suppression systems. Fabric filters are used to clean collected gas for all collection techniques.

Emissions from basic oxygen furnaces (BOFs) are divided into two categories, primary and secondary. Primary emissions refer to any emissions generated while the furnace is in an upright position. Secondary emissions refer to any emission generated while the furnace is tilted; i.e., charging, turndowns, tapping, and slagging. Primary emissions are captured by open or closed hoods. ESPs are the predominant gas cleaner used in conjunction with open hood systems, and venturi scrubbers are used with closed hood systems. Secondary emissions are captured by one or more of the following techniques: complete furnace enclosures with or without charge- and tap-side interior hoods, partial furnace enclosures, local hoods, deflector mechanisms to direct fumes toward the primary hood in open hood systems, and careful operating and maintenance procedures using the existing primary hood.

Emissions from electric arc furnaces (EAFs) occur during charging, melting, oxygen-blowing, and tapping operations. Fugitive dust emissions are generated by scrap and raw material unloading, storage, and transfer activities. A variety of systems have been developed to capture emissions from EAFs including direct shell evacuation through a fourth hole in the furnace cover, total building evacuation, canopy hoods, and local hoods. Almost all EAFs use fabric filters to clean furnace emissions.

External desulfurization is becoming increasingly popular. The injection and subsequent reaction of desulfurization reagents with the hot metal (iron) create significant amounts of fume. Emissions are captured by collection hoods located above or alongside the mouth of the furnace. The most common gas cleaning devices used for controlling desulfurization fumes are fabric filters.

The total mass controlled and uncontrolled emission factors for iron and steel production are presented in Table 1. The size-specific controlled and uncontrolled emission factors are presented in Table 2. Uncontrolled particulate emission factors for open dust sources in an iron and steel plant are presented in Table 3.

Table 1. *Particulate Emission Factors for Iron and Steel Mills*

Source	Units	Emission Factor		Emission Factor Rating	Particle Size Data
Sintering					
Windbox	*kg/Mg (lb/ton) finished sinter*				
Uncontrolled					
Leaving grate		*5.56*	*(11.1)*	*B*	*Yes*
After coarse particulate removal		*4.35*	*(8.7)*	*A*	
Controlled by dry ESP		*0.8*	*(1.6)*	*B*	
Controlled by wet ESP		*0.085*	*(0.17)*	*B*	*Yes*
Controlled by venturi scrubber		*0.235*	*(0.47)*	*B*	*Yes*
Controlled by cyclone		*0.5*	*(1.0)*	*B*	*Yes*
Sinter discharge (breaker and hot screens)	*kg/Mg (lb/ton) finished sinter*				
Uncontrolled		*3.4*	*(6.8)*	*B*	
Controlled by baghouse		*0.05*	*(0.1)*	*B*	*Yes*
Controlled by venturi scrubber		*0.295*	*(0.59)*	*A*	
Windbox and discharge	*kg/Mg (lb/ton) finished sinter*				
Controlled by baghouse		*0.15*	*(0.3)*	*A*	
Blast furnace					
Slip	*kg/Mg (lb/ton) slip*	*39.5*	*(87.0)*	*D*	
Uncontrolled casthouse	*kg/Mg (lb/ton) hot metal*				
Roof monitor[a]		*0.3*	*(0.6)*	*B*	*Yes*

Table 1. (Continued)

Source	Units	Emission Factor		Emission Factor Rating	Particle Size Data
Furnace with local evacuation[b]		0.65	(1.3)	B	Yes
Taphole and trough only (not runners)		0.15	(0.3)	B	
Hot metal desulfurization					
Uncontrolled[c]	kg/Mg (lb/ton) hot metal	0.55	(1.09)	D	Yes
Controlled by baghouse		0.0045	(0.009)	D	Yes
Basic oxygen furnace (BOF)					
Top blown furnace melting and refining	kg/Mg (lb/ton) steel				
Uncontrolled		14.25	(28.5)	B	
Controlled by open hood vented to:					
ESP		0.065	(0.13)	A	
Scrubber		0.045	(0.09)	B	
Controlled by closed hood vented to:					
Scrubber		0.0034	(0.0068)	A	Yes
BOF Charging	kg/Mg (lb/ton) hot metal				
At source		0.3	(0.6)	D	Yes
At building monitor		0.071	(0.142)	B	
Controlled by baghouse		0.0003	(0.0006)	B	Yes
BOF Tapping	kg/Mg (lb/ton) steel				
At source		0.46	(0.92)	D	Yes
At building monitor		0.145	(0.29)	B	
Controlled by baghouse		0.0013	(0.0026)	B	Yes
Hot metal transfer	kg/Mg (lb/ton) hot metal				
At source		0.095	(0.19)	A	
At building		0.028	(0.056)	B	
BOF monitor (all sources)	kg/Mg (lb/ton) steel	0.25	(0.5)	B	
Q-BOF melting and refining	kg/Mg (lb/ton) steel				
Controlled by scrubber		0.028	(0.056)	B	Yes
Electric arc furnace					
Melting and refining	kg/Mg (lb/ton) steel				
Uncontrolled carbon steel		19.0	(38.0)	C	Yes
Charging, tapping, and slagging	kg/Mg (lb/ton) steel				
Uncontrolled emissions escaping monitor		0.7	(1.4)	C	
Melting, refining, charging, tapping, and slagging	kg/Mg (lb/ton) steel				
Uncontrolled					
Alloy steel		5.65	(11.3)	A	
Carbon steel		25.0	(50.0)	C	
Controlled by:[d]					
Building evacuation to baghouse for alloy steel		0.15	(0.3)	A	
Direct shell evacuation (plus charging hood) vented to common baghouse for carbon steel		0.0215	(0.043)	E	Yes
Open hearth furnace					
Melting and refining	kg/Mg (lb/ton) steel				
Uncontrolled		10.55	(21.1)	D	Yes
Controlled by ESP		0.14	(0.28)	D	Yes
Roof monitor		0.084	(0.168)	C	

Table 1. *(Continued)*

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

[a]Typical of older furnaces with no controls, or for canopy hoods or total casthouse evacuation.
[b]Typical of large, new furnaces with local hoods and covered evacuated runners. Emissions are higher than without capture systems because they are not diluted by outside environment.
[c]Emission factor of 0.55 kg/Mg (1.09 lb/ton) represents one torpedo car, 1.26 kg/Mg (2.53 lb/ton) for two torpedo cars, and 1.37 kg/Mg (2.74 lb/ton) for three torpedo cars.
[d]Building evacuation collects all process emissions, and direct shell evacuation collects only melting and refining emissions.
[e]For various fuels, use the emission factors in Chapter 1 of AP-42. The emission factor rating for these fuels in boilers is A, and is soaking pits and slab reheat furnace is D.
[f]Based on methane content and cleaned particulate loading.

Table 2. *Size Specific Emission Factors*

Source	Emission Factor Rating	Particle Size, µm[a]	Cumulative Mass % ≤ Stated Size	Cumulative Mass Emission Factor kg/Mg	(lb/ton)
Sintering					
Windbox emissions					
Uncontrolled leaving grate	D	0.5	4[b]	0.22	(0.44)
		1.0	4	0.22	(0.44)
		2.5	5	0.28	(0.56)
		5.0	9	0.50	(1.00)
		10	15	0.83	(1.67)
		15	20[c]	1.11	(2.22)
		d	100	5.56	(11.1)
Controlled by wet ESP	C	0.5	18[b]	0.015	(0.03)
		1.0	25	0.021	(0.04)
		2.5	33	0.028	(0.06)
		5.0	48	0.041	(0.08)
		10	59[b]	0.050	(0.10)
		15	69	0.059	(0.12)
		d	100	0.085	(0.17)
Controlled by venturi scrubber	C	0.5	55	0.129	(0.26)
		1.0	75	0.176	(0.35)

Table 2. (Continued)

Source	Emission Factor Rating	Particle Size, µm[a]	Cumulative Mass % ≤ Stated Size	Cumulative Mass Emission Factor kg/Mg	(lb/ton)
		2.5	89	0.209	(0.42)
		5.0	93	0.219	(0.44)
		10	96	0.226	(0.45)
		15	98	0.230	(0.46)
		[d]	100	0.235	(0.47)
Controlled by cyclone[e]	C	0.5	25[c]	0.13	(0.25)
		1.0	37[b]	0.19	(0.37)
		2.5	52	0.26	(0.52)
		5.0	64	0.32	(0.64)
		10	74	0.37	(0.74)
		15	80	0.40	(0.80)
		[d]	100	0.5	(1.0)
Controlled by baghouse	C	0.5	3.0	0.005	(0.009)
		1.0	9.0	0.014	(0.027)
		2.5	27.0	0.041	(0.081)
		5.0	47.0	0.071	(0.141)
		10.0	69.0	0.104	(0.207)
		15.0	79.0	0.119	(0.237)
		[d]	100.0	0.15	(0.3)
Sinter discharge (breaker and hot screens) controlled by baghouse	C	0.5	2[b]	0.001	(0.002)
		1.0	4	0.002	(0.004)
		2.5	11	0.006	(0.011)
		5.0	20	0.010	(0.020)
		10	32[b]	0.016	(0.032)
		15	42[b]	0.021	(0.042)
		[d]	100	0.05	(0.1)
Blast furnace Uncontrolled casthouse emissions Roof monitor[f]	C	0.5	4	0.01	(0.02)
		1.0	15	0.05	(0.09)
		2.5	23	0.07	(0.14)
		5.0	35	0.11	(0.21)
		10	51	0.15	(0.31)
		15	61	0.18	(0.37)
		[d]	100	0.3	(0.6)
Furnace with local evacuation[g]	C	0.5	7[c]	0.04	(0.09)
		1.0	9	0.06	(0.12)
		2.5	15	0.10	(0.20)
		5.0	20	0.13	(0.26)
		10	24	0.16	(0.31)
		15	26	0.17	(0.34)
		[d]	100	0.65	(1.3)
Hot metal desulfurization[h] Uncontrolled	E	0.5	[i]		
		1.0	2[c]	0.01	(0.02)
		2.5	11	0.06	(0.12)
		5.0	19	0.10	(0.22)
		10	19	0.10	(0.22)
		15	21	0.12	(0.23)
		[d]	100	0.55	(1.09)

Table 2. *(Continued)*

Source	Emission Factor Rating	Particle Size, µm[a]	Cumulative Mass % ≤ Stated Size	Cumulative Mass Emission Factor kg/Mg	(lb/ton)
Controlled bag-house	D	0.5	8	0.0004	(0.0007)
		1.0	18	0.0009	(0.0016)
		2.5	42	0.0019	(0.0038)
		5.0	62	0.0028	(0.0056)
		10	74	0.0033	(0.0067)
		15	78	0.0035	(0.0070)
		d	100	0.0045	(0.009)
Basic oxygen furnace Top blown furnace melting and refining controlled by closed hood and vented to scrubber	C	0.5	34	0.0012	(0.0023)
		1.0	55	0.0019	(0.0037)
		2.5	65	0.0022	(0.0044)
		5.0	66	0.0022	(0.0045)
		10	67	0.0023	(0.0046)
		15	72[c]	0.0024	(0.0049)
		d	100	0.0034	(0.0068)
BOF Charging At source[k]	E	0.5	8[c]	0.02	(0.05)
		1.0	12	0.04	(0.07)
		2.5	22	0.07	(0.13)
		5.0	35	0.10	(0.21)
		10	46	0.14	(0.28)
		15	56	0.17	(0.34)
		d	100	0.3	(0.6)
Controlled by bag-house	D	0.5	3	9.0×10^{-6}	1.8×10^{-5}
		1.0	10	3.0×10^{-5}	6.0×10^{-5}
		2.5	22	6.6×10^{-5}	(0.0001)
		5.0	31	9.3×10^{-5}	(0.0002)
		10	45	0.0001	(0.0003)
		15	60	0.0002	(0.0004)
		d	100	0.0003	(0.0006)
BOF Tapping At source[k]	E	0.5	j	j	j
		1.0	11	0.05	(0.10)
		2.5	37	0.17	(0.34)
		5.0	43	0.20	(0.40)
		10	45	0.21	(0.41)
		15	50	0.23	(0.46)
		d	100	0.46	(0.92)
BOF Tapping Controlled by bag-house	D	0.5	4	5.2×10^{-5}	(0.0001)
		1.0	7	0.0001	(0.0002)
		2.5	16	0.0002	(0.0004)
		5.0	22	0.0003	(0.0006)
		10	30	0.0004	(0.0008)
		15	40	0.0005	(0.0010)
		d	100	0.0013	(0.0026)
Q-BOP melting and refining controlled by scrubber	D	0.5	45	0.013	(0.025)
		1.0	52	0.015	(0.029)

Table 2. (Continued)

Source	Emission Factor Rating	Particle Size, µm[a]	Cumulative Mass % ≤ Stated Size	Cumulative Mass Emission Factor kg/Mg	(lb/ton)
		2.5	56	0.016	(0.031)
		5.0	58	0.016	(0.032)
		10	68	0.019	(0.038)
		15	85[c]	0.024	(0.048)
		[d]	100	0.028	(0.056)
Electric arc furnace					
Melting and refining carbon steel uncontrolled[m]	D	0.5	8	1.52	(3.04)
		1.0	23	4.37	(8.74)
		2.5	43	8.17	(16.34)
		5.0	53	10.07	(20.14)
		10	58	11.02	(22.04)
		15	61	11.59	(23.18)
		[d]	100	19.0	(38.0)
Melting, refining, charging, tapping, slagging					
Controlled by direct shell evacuation (plus charging hood) vented to common baghouse for carbon steel[n]	E	0.5	74[b]	0.0159	(0.0318)
		1.0	74	0.0159	(0.0318)
		2.5	74	0.0159	(0.0318)
		5.0	74	0.0159	(0.0318)
		10	76	0.0163	(0.0327)
		15	80	0.0172	(0.0344)
		[d]	100	0.0215	(0.043)
Open hearth furnace					
Melting and refining Uncontrolled	E	0.5	1[b]	0.11	(0.21)
		1.0	21	2.22	(4.43)
		2.5	60	6.33	(12.66)
		5.0	79	8.33	(16.67)
		10	83	8.76	(17.51)
		15	85[c]	8.97	(17.94)
		[d]	100	10.55	(21.1)
Controlled by ESP[p]	E	0.5	10[b]	0.01	(0.02)
		1.0	21	0.03	(0.06)
		2.5	39	0.05	(0.10)
		5.0	47	0.07	(0.13)
		10	53[b]	0.07	(0.15)
		15	56[b]	0.08	(0.16)
		[d]	100	0.14	(0.28)

[a]Particle aerodynamic diameter micrometers (µm) as define by Task Group on Lung Dynamics. (Particle density = 1 g/cm^3).
[b]Interpolated data used to develop size distribution.
[c]Extrapolated, using engineering estimates.
[d]Total particulate based on Method 5 total catch. See Table 1.
[e]Average of various cyclone efficiencies.
[f]Total casthouse evacuation control system.
[g]Evacuation runner covers and local hood over taphole, typical of new state of the art blast furnace technology.

Table 2. *(Continued)*

[h]Torpedo ladle desulfurization with CaC_2 and $CaCO_3$.
[j]Unable to extrapolate because of insufficient data and/or curve exceeding limits.
[k]Doghouse type furnace enclosure using front and back sliding doors, totally enclosing the furnace, with emissions vented to hoods.
[m]Full cycle emissions captured by canopy and side draft hoods.
[n]Information on control system not available.
[p]May not be representative. Test outlet size distribution was larger than inlet may indicate reentrainment problem.

Table 3. *Uncontrolled Particulate Emission Factors for Open Dust Sources at Iron and Steel Mills[a]*

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

[a]Predictive emission factor equations are generally preferred over these single value emission factors. Predictive emission factor estimates are presented in Chapter 11, Section 11.2 of AP-42. VKT = Vehicle kilometer traveled. VMT = Vehicle mile traveled.
[b]Units/unit of material transferred or units/unit of distance traveled.

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***Dale L. Harmon** is the EPA Project Officer (see below).*
The complete report, entitled "Iron and Steel Industry Particulate Emissions: Source Category Report," (Order No. PB 87-119 889/AS; Cost: $13.95, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

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