BACKGROUND REPORT

AP-42 SECTION 12.4

FERROALLOY PRODUCTION

Prepared for

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AP-42 Background Report

TECHNICAL SUPPORT DIVISION

U.S. ENVIRONMENTAL PROTECTION AGENCY

Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

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1.0 INTRODUCTION

The document "Compilation of Air Pollutant Emission Factors" (AP-42) has been published by the U.S. Environmental Protection Agency (the EPA) since 1972. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. AP-42 is routinely updated by the EPA to respond to new emission factor needs of the EPA, State, and local air pollution control programs and industry.

An emission factor relates the quantity (weight) of pollutants emitted to a unit of activity of the source. The uses for the emission factors reported in AP-42 include:

1. Estimates of area-wide emissions;
2. Emission estimates for a specific facility; and
3. Evaluation of emissions relative to ambient air quality.

The purpose of this report is to provide background information from process information obtained from industry comment and four test reports to support revision of emission factors for ferroalloys.

Including the introduction (Chapter 1) this report contains four chapters. Chapter 2 gives a description of the ferroalloy industry. It includes a characterization of the industry, an overview of the different process types, a description of emissions, a description of the technology used to control emissions resulting from manufacturing ferroalloys, and a review of specific data sets.

Chapter 3 is a review of emissions data collection and analysis procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. Chapter 4 details criteria and noncriteria pollutant emission factor development. It includes the review of specific data sets and the results of data analysis. Particle size determination and particle size data analysis methodology are described.

2.0 INDUSTRY DESCRIPTION

2.1 GENERAL

Ferroalloy is an alloy of iron with some element other than carbon. Ferroalloy is used to physically introduce or "carry" that element into molten metal, usually during steel manufacture. Ferroalloy has been further defined by the American Society for Metals and the Bureau of Mines as "an alloy of iron that contains a sufficient amount of one or more other chemical elements to be useful as an agent for introducing these elements into molten metal, usually steel."

In practice, the term "ferroalloy" is used to include any alloys which introduce reactive elements into alloy systems, such as nickel and cobalt based aluminum systems. Silicon metal is consumed in the aluminum industry as an alloying agent and in the chemical industry as a raw material in silicon-based chemical manufacturing.

The ferroalloy industry is associated with the iron and steel industries, its largest customers. Ferroalloys impart distinctive qualities to steel and cast iron and serve important functions during iron and steel production cycles. The principal ferroalloys are those of chromium, manganese, and silicon. Chromium provides corrosion resistance to stainless steels. Manganese is essential to counteract the harmful effects of sulfur in the production of virtually all steels and cast iron. Silicon is used primarily for deoxidation in steel and as an alloying agent in cast iron. Boron, cobalt, columbium, copper, molybdenum, nickel, phosphorus, titanium, tungsten, vanadium, zirconium, and the rare earths impart specific characteristics and are usually added as ferroalloys.

Ferroalloy production in the U.S. in 1989 was approximately 892,000 megagrams (985,000 tons), substantially less than the 1975 production of approximately 1,603,000 megagrams (1,770,000 tons). In 1989, ferroalloys were produced in the U.S. by 28 companies, although five of those produced only ferrophosphorous as a byproduct of elemental phosphorous production.

2.2 PROCESS DESCRIPTION

A variety of furnace types, including submerged electric arc furnaces, exothermic (metallothermic) reaction furnaces and electrolytic cells can be used to produce ferroalloys. Furnace descriptions and their ferroalloy products are given in Table 2.2-1. Vacuum and induction furnaces are not discussed because they have few emissions and are not widely used.

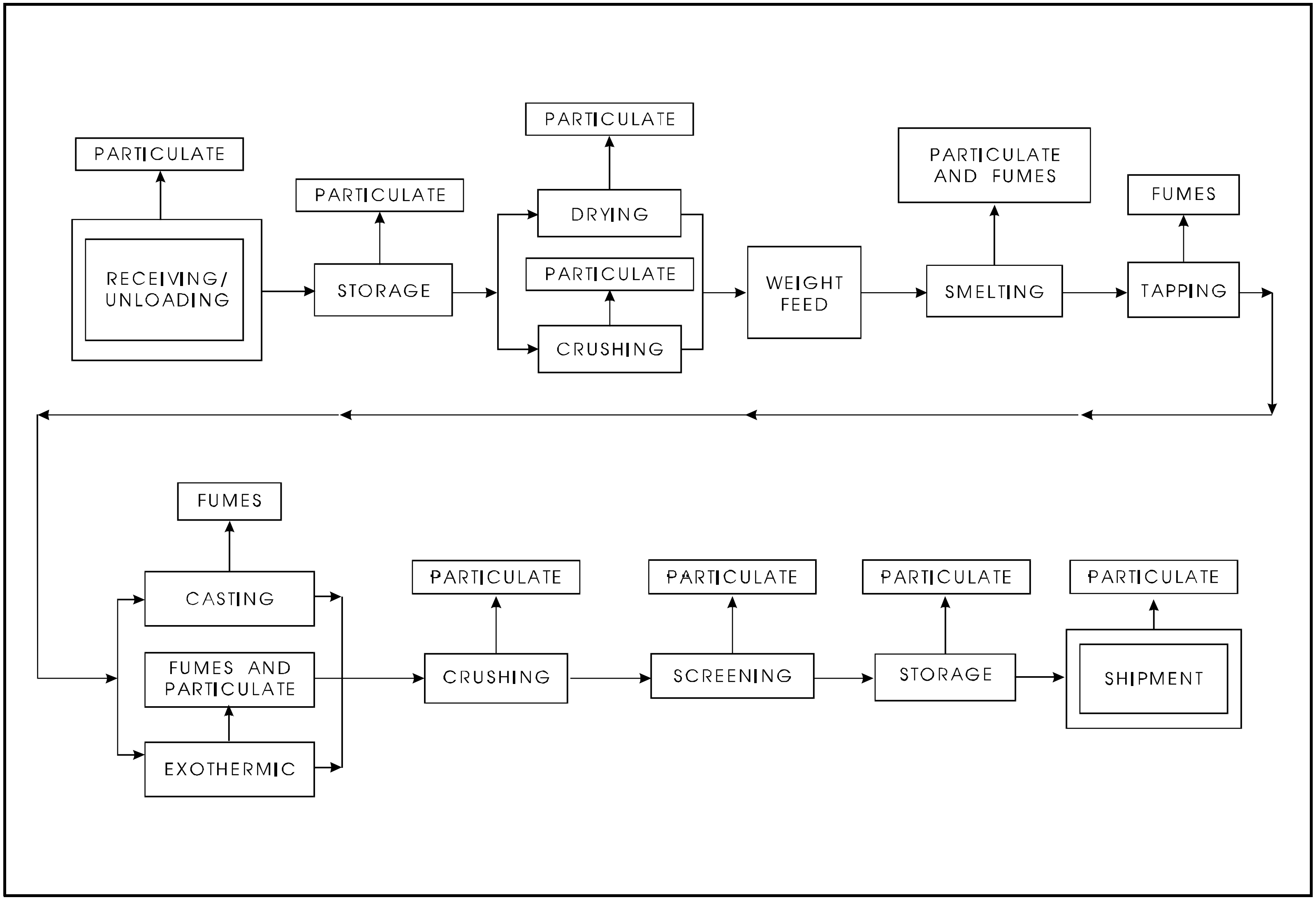

Figure 2.2-1 Typical ferroalloy production process

Submerged Electric Arc Process

In most cases, the submerged electric arc furnace produces the desired product directly. It may produce an intermediate product that is subsequently used in additional processing methods. The submerged arc process is a reduction smelting operation. The reactants consist of metallic ores (ferrous oxides, silicon oxides, manganese oxides, chrome oxides, etc.) and a carbon-source reducing agent, usually in the form of coke, low-volatility coal or wood chips. Limestone may also be added as a flux material. Raw materials are crushed, sized, and in some cases, dried, and then conveyed to a mix house for weighing and blending. Conveyors, buckets, skip hoists, or cars transport the processed material to hoppers above the furnace. The mix is then gravity-fed through a feed chute either continuously or intermittently, as needed. At high temperatures in the reaction zone, the carbon source reacts with metal oxides to form carbon monoxide and to reduce the ores to base metal. A typical reaction producing ferrosilicon is shown below:

$$Fe_2O_3 + 2\,SiO_2 + 7\,C \rightarrow 2\,FeSi + 7\,CO \qquad (1)$$

Smelting in an electric arc furnace is accomplished by conversion of electrical energy to heat. An alternating current applied to the electrodes causes current to flow through the charge between the electrode tips. This provides a reaction zone at temperatures up to 2000°C (3632°F). The tip of each electrode changes polarity continuously as the alternating current flows between the tips. To maintain a uniform electric load, electrode depth is continuously varied automatically by mechanical or hydraulic means.

TABLE 2.2-1
FERROALLOY PROCESSES AND RESPECTIVE PRODUCT GROUPS

Process	Product
Submerged arc furnace[a]	Silvery iron (15-22% Si) Ferrosilicon (50% Si) Ferrosilicon (65-75% Si) Silicon metal Silicon/manganese/zirconium (SMZ) High carbon (HC) ferromanganese Siliconmanganese HC ferrochrome Ferrochrome/silicon FeSi (90% Si)
Exothermic[b]	
Silicon reduction	Low carbon (LC) ferrochrome, ferromanganese, medium carbon (MC) ferromanganese
Aluminum Reduction	Chromium metal, ferrotitanium, ferrocolumbium, ferrovanadium
Mixed aluminothermal/ silicothermal	Ferromolybdenum, ferrotungsten
Electrolytic[c]	Chromium metal, manganese metal
Vacuum furnace[d]	LC ferrochrome
Induction furnace[e]	Ferrotitanium

[a] Process by which metal is smelted in a refractory-lined cup shaped steel shell by submerged graphite electrodes.

[b] Process by which molten charge material is reduced, in exothermic reaction, by addition of silicon, aluminum or a combination of the two.

[c] Process by which simple ions of a metal, usually chromium or manganese in an electrolyte, are plated on cathodes by direct low-voltage current.

[d] Process by which carbon is removed from solid state high-carbon ferrochrome within vacuum furnaces maintained at temperatures near melting point of alloy.

[e] Process which converts electrical energy into heat, without electrodes, to melt metal charges in a cup or drum-shaped vessel.

A typical submerged electric arc furnace design is depicted in Figure 2.2-2. The lower part of the submerged electric arc furnace is composed of a cylindrical steel shell with a flat bottom or hearth. The interior of the shell is lined with two or more layers of carbon blocks. The furnace shell is water cooled to protect it from the heat of the process. A water-cooled cover and fume collection hood are mounted over the furnace shell. Normally, three carbon electrodes arranged in a triangular formation extend through the cover and into the furnace shell opening. Prebaked or self-baking (Soderberg) electrodes ranging from 76 to over 100 centimeters (30 to over 40 inches) in diameter are typically used. Raw materials are sometimes charged to the furnace through feed chutes from above the furnace. The surface of the furnace charge, which contains both molten material and unconverted charge during operation, is typically maintained near the top of the furnace shell. The lower ends of the electrodes are maintained at about 1 to 2 meters (3 to 7 feet) below the charge surface. Three-phase electric current arcs from electrode to electrode, passing through the charge material. The charge material melts and reacts to form the desired product as the electric energy is converted into heat. The carbonaceous material in the furnace charge reacts with oxygen in the metal oxides of the charge and reduces them to base metals. The reactions produce large quantities of carbon monoxide (CO) which passes upward through the furnace charge. The molten metal and slag are removed (tapped) through one or more tap holes extending through the furnace shell at the hearth level. Feed materials may be charged continuously or intermittently. Power is applied continuously. Tapping is intermittent based on production rate of the furnace.

Submerged electric arc furnaces are of two basic types, open and covered. Most of the submerged electric arc furnaces in the U.S. are open furnaces. Open furnaces have a fume collection hood at least one meter (3.3 feet) above the top of the furnace shell. Moveable panels or screens are sometimes used to reduce the open area between the furnace and hood, and to improve emissions capture efficiency. Carbon monoxide rising through the furnace charge burns in the area between the charge surface and the capture hood. This substantially increases the volume of gas the containment system must handle. Additionally, the vigorous open combustion process entrains finer material in the charge. Fabric filters are typically used to control emissions from open furnaces.

Covered furnaces have a water-cooled steel cover which fits closely to the furnace shell. The objective of covered furnaces is to reduce air infiltration into the furnace gases, which reduces combustion of that gas. This reduces the volume of gas requiring collection and treatment. The

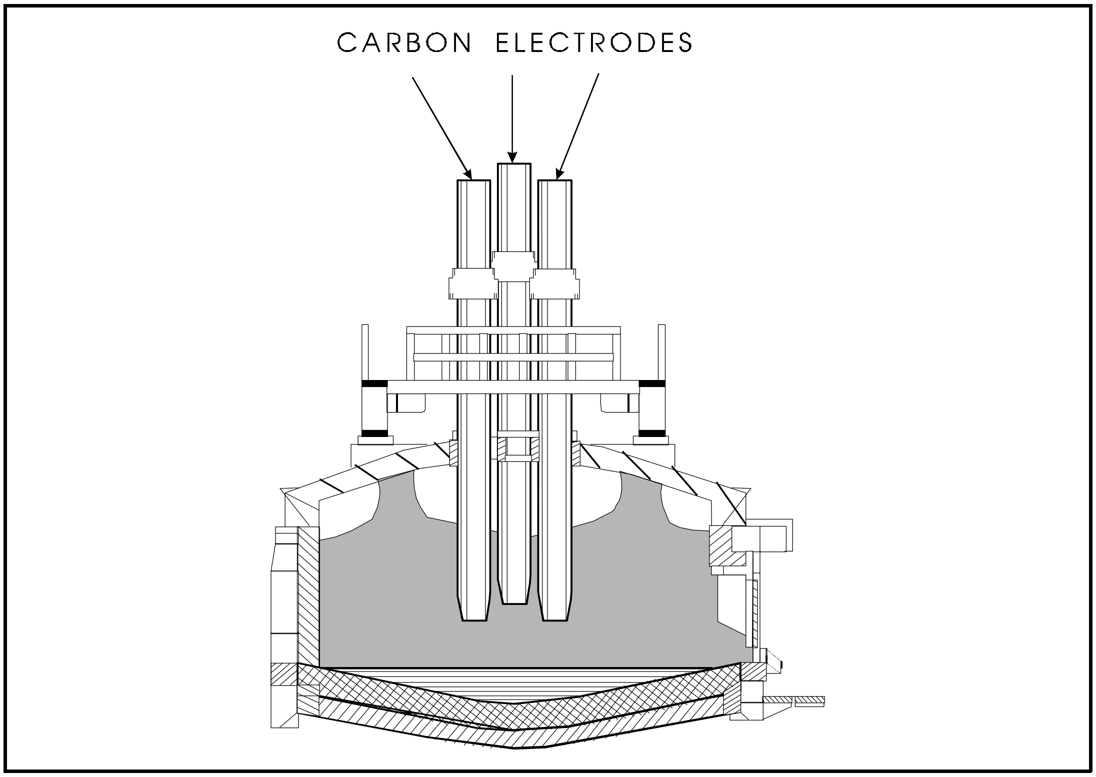

Figure 2.2-2 Submerged three-phase electric arc furnace.

cover has holes for the charge and electrodes to pass through. Covered furnaces which partially close these hood openings with charge material are referred to as "mix-sealed" or "semi-enclosed furnaces." Although these covered furnaces significantly reduce air infiltration, some combustion still occurs under the furnace cover. Covered furnaces that have mechanical seals around the electrodes and sealing compounds around the outer edges are referred to as "sealed" or "totally closed." These furnaces have little, if any, air infiltration and undercover combustion. Water leaks from the cover into the furnace must be minimized as this leads to excessive gas production and unstable furnace operation. Products prone to highly variable releases of process gases are typically not made in covered furnaces for safety reasons. As the degree of enclosure increases, less gas is produced for capture by the hood system and the concentration of carbon monoxide in the furnace gas increases. Wet scrubbers are used to control emissions from covered furnaces. The scrubbed, high carbon monoxide content gas may be used within the plant or flared.

The molten alloy and slag that accumulate on the furnace hearth are removed at one to five hour intervals through the tap hole. Tapping typically lasts 10 to 15 minutes. In some cases, tapping is done continuously. Tap holes are opened with pellet shot from a gun, by drilling or by oxygen lancing. The molten metal and slag flow from the tap hole into a carbon-lined trough, then into a carbon-lined runner which directs the metal and slag into a reaction ladle, ingot molds, or chills (chills are low, flat, iron or steel pans that provide rapid cooling of the molten metal). After tapping is completed the furnace is resealed by inserting a carbon paste plug into the tap hole.

Chemistry adjustments may be necessary after furnace smelting to achieve a specified product. Ladle treatment reactions are batch processes and may include metal and alloy additions.

During tapping, and/or in the reaction ladle, slag is skimmed from the surface of the molten metal. It can be disposed of in landfills, sold as road ballast, or used as a raw material in a furnace or reaction ladle to produce a chemically related ferroalloy product.

After cooling and solidifying, the large ferroalloy castings may be broken with drop weights or hammers. The broken ferroalloy pieces are then crushed, screened (sized) and stored in bins until shipment. In some instances, the alloys are stored in lump form in inventories prior to sizing for shipping.

Exothermic (Metallothermic) Process

The exothermic process is generally used to produce high grade alloys with low carbon content. The intermediate molten alloy used in the process may come directly from a submerged electric arc furnace or from another type of heating device. Silicon or aluminum combines with oxygen in the molten alloy, resulting in a sharp temperature rise and strong agitation of the molten bath. Low- and medium-carbon content ferrochromium and ferromanganese are produced by silicon reduction. Aluminum reduction is used to produce chromium metal, ferrotitanium, ferrovanadium, and ferrocolumbium. Mixed alumino/silico thermal processing is used for producing ferromolybdenum and ferrotungsten. Although aluminum is more expensive than carbon or silicon, the products are purer. Low carbon (LC) ferrochromium is typically produced by fusing chromium ore and lime in a furnace. A specified amount is then placed in a ladle (ladle No. 1). A known amount of an intermediate grade ferrochromesilicon is then added to the ladle. The reaction is extremely exothermic and liberates chromium from its ore, producing LC ferrochromium and a calcium silicate slag. This slag, which still contains recoverable chromium oxide, is reacted in a second ladle (ladle No. 2) with molten high carbon (HC) ferrochromesilicon to produce the intermediate grade ferrochromesilicon. Exothermic processes are generally carried out in open vessels and may have emissions similar to the submerged arc process for short periods while the reduction is occurring.

Electrolytic Processes

Electrolytic processes are used to produce high purity manganese and chromium. As of 1989, there were two ferroalloy facilities using electrolytic processes.

Manganese may be produced by the electrolysis of an electrolyte extracted from manganese ore or manganese bearing ferroalloy slag. Manganese ores contain close to 50 percent manganese; furnace slag normally contains about 10 percent manganese. The process has five steps: 1) roasting the ore to convert it to manganese oxide (MnO), 2) leaching the roasted ore with sulfuric acid (H_2SO_4) to solubilize manganese, 3) neutralization and filtration to remove iron and aluminum hydroxides, 4) purifying the leach liquor by treatment with sulfide and filtration to remove a wide variety of metal, and 5) electrolysis.

Electrolytic chromium is generally produced from high carbon ferrochromium. A large volume of hydrogen gas is produced by dissolving the alloy in sulfuric acid. The leachate is treated with ammonium sulfate and conditioned to remove ferrous ammonium sulfate and produce a chrome-alum for feed to the electrolysis cells. The electrolysis cells are well-ventilated to reduce ambient hydrogen and hexavalent chromium concentrations in the cell rooms.

2.3 EMISSIONS AND CONTROLS

Particulate is generated from several activities during ferroalloy production, including raw material handling, smelting, tapping and product handling. Organic materials are generated almost exclusively from the smelting operation. The furnaces are the largest potential sources of particulate and organic emissions. The emission factors are given in Tables 2.3-1.

Particulate emissions from electric arc furnaces in the form of fumes (smoke-like particles) account for an estimated 94 percent of the total particulate emissions in the ferroalloy industry. Large amounts of carbon monoxide and organic materials also are emitted by submerged electric arc furnaces. Carbon monoxide is formed as a byproduct of the chemical reaction between oxygen in the metal oxides of the charge and carbon contained in the reducing agent (coke, coal, etc.). Reduction gases containing organic compounds and carbon monoxide continuously rise from the high temperature reaction zone, entraining fine particles and fume precursors. The mass weight of carbon monoxide produced sometimes exceeds that of the metallic product. The heat-induced fume consists of oxides of the products being produced and carbon from the reducing agent. The fume is enriched by silicon dioxide, calcium oxide, and magnesium oxide, if present in the charge.

In an open electric arc furnace, virtually all carbon monoxide and much of the organic matter burns with induced air at the furnace top. The remaining fume, captured by hooding about one meter above the furnace, is directed to a gas cleaning device. Fabric filter are used to control emissions from 85 percent of the open furnaces in the U.S. Scrubbers are used on 13 percent of the furnaces, and electrostatic precipitators on 2 percent.

Two emission capture systems, not usually connected to the same gas cleaning device, are necessary for covered furnaces. A primary capture system withdraws gases from beneath the furnace cover. A secondary system captures fume released around the electrode seals and during tapping. Scrubbers are used almost exclusively to control exhaust gases from sealed furnaces. The scrubbers capture a substantial percentage of the organic emissions, which are much greater for covered furnaces than open furnaces. The gas from sealed and mix-sealed furnaces is usually flared at the exhaust of the scrubber. The carbon monoxide rich gas is sometimes used as a fuel in kilns and sintering machines. The efficiency of flares for the control of carbon monoxide and the reduction of VOCs has been estimated to be greater than 98 percent. A gas heating reduction of organic and carbon monoxide emissions is 98 percent efficient.

Tapping operations also generate fumes. Tapping is intermittent and is usually conducted during 10 to 20 percent of the furnace operating time. Some fumes originate from the carbon lip liner, but most are a result of induced heat transfer from the molten metal or slag as it contacts the runners, ladles, casting beds and ambient air. Some plants capture these emissions to varying degrees with a main canopy hood. Other plants employ

TABLE 2.3-1. (METRIC UNITS)
EMISSION FACTORS FOR PARTICULATE FROM SUBMERGED ARC FERROALLOY FURNACES[a]

All Emission Factors are in kg/Mg of Product
Ratings (A-E) Follow Each Factor

Product[b]	Furnace Type	Particulate Emission factors Uncontrolled[c]		Control Device[c]	Particulate Emission factors Controlled[c]	
FeSi (50%)	Open[d,e]	35	E	Baghouse[d,e]	0.9	B
	Covered[f]	46	E	Scrubber[f,j] High energy Low energy	 0.24 4.5	 E E
FeSi (75%)	Open[h]	158	E	Scrubber[f,j] Low energy	4.0	E
	Covered[f,g]	103	E			
FeSi (90%)	Open[i]	282	E			
Si metal (98%)	Open[j,k]	436	E	Baghouse[j,k]	16	B
FeMn (80%)	Open[l,m]	14	E	Baghouse[l,m] Scrubber[f,n] High energy	0.24 0.8	B E
FeMn (1% Si)	Covered[f,o]	6	E	Scrubber High energy[r]	0.25	E
	Sealed[p,q]	37	E			
FeCr (high carbon)	Open[s,t]	78	E	ESP[s,t]	1.2	E
SiMn	Open[u]	96	E	Scrubber[u]	2.1	E
				Scrubber[q,r] High energy	0.15	E

(Footnotes for this table follow on the next page.)

Footnotes for Table 2.3-1 (Metric units)

[a] Factors are for main furnace dust collection system before and after control device. Where other emissions, such as leaks or tapping, are included or quantified separately, such is noted. Particulate sources not included: raw material handling, storage, preparation; and product crushing, screening, handling, packaging.

[b] Percentages are of the main alloying agent in product.

[c] Low energy scrubbers are those with $\triangle P < 20$ in. H_20; high energy with $\triangle P > 20$ in. H_20.

[d] Includes fumes captured by tapping hood (efficiency estimated at near 100%).

[e] References 4, 10, 21.

[f] References 4, 10.

[g] Does not include emissions from tapping or mix seal leaks.

[h] References 25-26.

[i] Reference 23.

[j] Estimated 60% of tapping emissions captured by control system (escaped fugitive emissions not included in factor).

[k] References 10, 13.

[l] Estimated 50% of tapping emissions captured by control system (escaped fugitive emissions not included in factor).

[m] References 4, 10, 12.

[n] Includes fume only from primary control system.

[o] Includes tapping fumes and mix seal leak fugitive emissions. Fugitive emissions measured at 33% of total uncontrollable emissions.

[p] Assumes tapping fumes not included in emission factor.

[q] Reference 14.

[r] Does not include tapping or fugitive emissions.

[s] Tapping emissions included.

[t] References 2, 15-17.

[u] References 2, 18-19.

TABLE 2.3-1. (ENGLISH UNITS)
EMISSION FACTORS FOR PARTICULATE FROM SUBMERGED ARC FERROALLOY FURNACES[a]

All Emission Factors are in lb/ton of Product
Ratings (A-E) Follow Each Factor

Product[b]	Furnace Type	Particulate Emission factors Uncontrolled[c]		Control Device[c]	Particulate Emission factors Controlled[c]	
FeSi (50%)	Open[d,e]	70	E	Baghouse[d,e]	1.8	B
	Covered[f]	92	E	Scrubber[f,j]		
				High energy	0.48	E
				Low energy	9.0	E
FeSi (75%)	Open[h]	316	E	Scrubber[f,j] Low energy	8.0	E
	Covered[f,g]	206	E			
FeSi (90%)	Open[i]	564	E			
Si metal (98%)	Open[j,k]	872	E	Baghouse[j,k]	32	B
FeMn (80%)	Open[l,m]	28	E	Baghouse[l,m]	0.48	B
				Scrubber[f,n]		
				High energy	1.6	E
FeMn (1% Si)	Covered[f,o]	12	E	Scrubber High energy[r]	0.5	E
	Sealed[p,q]	74	E			
FeCr (high carbon)	Open[s,t]	157	E	ESP[s,t]	2.4	E
SiMn	Open[u]	192	E	Scrubber[u]	4.2	E
				Scrubber[q,r] High energy	0.30	E

(See next page for footnotes.)

Footnotes for Table 2.3-1 (English units)

[a] Factors are for main furnace dust collection system before and after control device. Where other emissions, such as leaks or tapping, are included or quantified separately, such is noted. Particulate sources not included: raw material handling, storage, preparation; and product crushing, screening, handling, packaging.

[b] Percentages are of the main alloying agent in product.

[c] Low energy scrubbers are those with $\triangle P < 20$ in. H_20; high energy with $\triangle P > 20$ in. H_20.

[d] Includes fumes captured by tapping hood (efficiency estimated at near 100%).

[e] References 4, 10, 21.

[f] References 4, 10.

[g] Does not include emissions from tapping or mix seal leaks.

[h] References 25-26.

[i] Reference 23.

[j] Estimated 60% of tapping emissions captured by control system (escaped fugitive emissions not included in factor).

[k] References 10, 13.

[l] Estimated 50% of tapping emissions captured by control system (escaped fugitive emissions not included in factor).

[m] References 4, 10, 12.

[n] Includes fume only from primary control system.

[o] Includes tapping fumes and mix seal leak fugitive emissions. Fugitive emissions measured at 33% of total uncontrollable emissions.

[p] Assumes tapping fumes not included in emission factor.

[q] Reference 14.

[r] Does not include tapping or fugitive emissions.

[s] Tapping emissions included.

[t] References 2, 15-17.

[u] References 2, 18-19.

separate tapping hoods ducted to either the furnace emission control device or a separate control device. No emission data for tapping operations are available, therefore, no emission factors are presented.

After furnace tapping is completed, a reaction ladle may be used to adjust the metallurgy by chlorination, oxidation, gas mixing and slag metal reactions. Ladle reactions are an intermittent process, and emissions have not been quantified. Reaction ladle emissions are often captured by the tapping emissions control system.

No available data are available to provide emission factors for raw material handling, pretreatment and product handling. Dust particulate is emitted from raw material handling, storage and preparation activities (see Figure 2.2-1). These activities include unloading raw materials from delivery vehicles (ship, railway car or truck), storing raw materials in piles, loading raw materials from storage piles into trucks or gondola cars and crushing and screening raw materials. Raw materials may be dried before charging in rotary or other types of dryers, and these dryers can generate significant particulate emissions. Dust may also be generated by heavy vehicles used for loading, unloading and transferring material. Crushing, screening and storage of the ferroalloy product emit particulate in the form of dust. The properties of particulate emitted as dust are similar to the natural properties of the ores or alloys from which they originated, ranging in size from 3 to 100 micrometers (µm).

Approximately half of all ferroalloy facilities have some type of control for dust emissions. Dust generated from raw material storage may be controlled in several ways, including sheltering storage piles from the wind with block walls, snow fences or plastic covers. Occasionally, piles are sprayed with water to prevent airborne dust. Emissions generated by heavy vehicle traffic may be reduced by using a wetting agent or paving the plant yard. Moisture in the raw materials, which may be as high as twenty percent, helps to limit dust emissions from raw material unloading and loading. Dust generated by crushing, sizing, drying or other pretreatment activities may be controlled by dust collection equipment such as scrubbers, cyclones or fabric filter. Ferroalloy product crushing and sizing usually require a fabric filter. The raw material emission collection equipment may be connected to the furnace emission control system. For fugitive emissions from open sources, see Section 11.2 of the AP-42 document.

2.4 REVIEW OF REFERENCES

Pacific Environmental Services (PES) contacted the following sources to obtain the most up-to-date information on process descriptions and emissions for this industry:

1) Alabama Air Division, ADEM, Montgomery, AL.
2) Florida Department of Environmental Regulation, Tallahassee, FL.
3) Georgia Department of Natural Resources, Atlanta, GA.
4) Kansas Department of Health and Environment, Topeka, KS.
5) Michigan Department of Natural Resources, Lansing, MI.
6) Missouri Department of Natural Resources, Jefferson City, MO.
7) Pennsylvania Department of Environmental Resources, Harrisburg, PA.

No emission source tests were received from the parties contacted.

Process information was expanded using published EPA documents and Shreve's Chemical Process Industries, fifth edition, McGraw Hill, 1984.

Emission factors shown in Table 2.3-1 are unchanged from the previous AP-42 section (October 1986). However, PES has downgraded the ratings from "B" and "C" to an "E" rating, with the one exception of SiMn (high energy scrubber). This change is discussed in detail in Chapter 4.3.

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3.0 GENERAL EMISSION DATA REVIEW AND ANALYSIS PROCEDURES

3.1 LITERATURE SEARCH AND SCREENING SOURCE TESTS

The first step in the investigative process involved a search of available literature relating to criteria and noncriteria pollutant emissions associated with ferroalloy production. This search included, but was not limited to the following references:

1) AP-42 background files maintained by the Emission Factor and Methodologies Section. This is the source of the five air tests that are reviewed below.
2) Files maintained by the Emission Standards Division. No files are available at this time.
3) "PM_{10} Emission Factor Listing Developed by Technology Transfer" (EPA-450/4-89-022). Reviewed but not used due to uncertain quality of data.
4) Background Information Documents for NSPS and NESHAPS. No complete emission source tests included in the documents reviewed.
5) Information in the *Air Facility Subsystems* (AFS) of the EPA *Aerometric Information Retrieval System* (AIRS). Boxes of computer printouts were reviewed under other AP-42 metallurgical sections. PES was unable to retrieve any useful information for this application.
6) Handbook of Emission Factors, Parts I and II, Ministry of Health and Environmental Protection, The Netherlands, 1980/1983. This information substantiated existing AP-42 Section information. No actual emission test data available.
7) The EPA *Clearinghouse for Inventories and Emission Factors* (CHIEF). CHIEF referenced emission source data as coming from AP-42. No new information.
8) The EPA databases, including *Speciation Database Management System* (SPECIATE), the *Crosswalk/Air Toxic Emission Factor Data Base Management System* (XATEF). Both of these database systems were reviewed without tangible benefits.
9) A literature search was conducted in the Duke University library, including a computer network search of the University of North Carolina and the North Carolina State University. In addition, the USEPA Environmental Research Center library was

visited in an attempt to get primary emission source tests for ferroalloy production facilities.

To reduce the amount of literature collected to a final group of references pertinent to this report, the following general criteria were used:

1. Emissions data must be from a primary reference, i.e. the document must constitute the original source of test data. For example, a technical paper was not included if the original study was contained in the previous document.
2. The referenced study must contain test results based on more than one test run.
3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions (e.g., one-page reports were generally rejected).

If no primary data was found and the previous update utilized secondary data, this secondary data was still used and the Emission Factor Rating lowered if needed. A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria. The final set of reference materials is given in Chapter 4.0.

3.2 EMISSION DATA QUALITY RATING SYSTEM

As part of Pacific Environmental Services' analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data were always excluded from consideration.

1. Test series averages reported in units that cannot be converted to the selected reporting units;
2. Test series representing incompatible test methods (i.e., comparison of the EPA Method 5 front-half with the EPA Method 5 front- and back-half);
3. Test series of controlled emissions for which the control device is not specified;
4. Test series in which the source process is not clearly identified and described; and
5. Test series in which it is not clear whether the emissions were measured before or after the control device.

Data sets that were not excluded were assigned equality rating. The rating system used was that specified by the OAQPS for the preparation of AP-42 sections. The data were rated as follows:

A

Multiple tests performed on the same source using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in either the inhalable particulate (IP) protocol documents or the EPA reference test methods, although these documents and methods were certainly used as a guide for the methodology actually used.

B

Tests that were performed by a generally sound methodology but lack enough detail for adequate validation.

C

Tests that were based on an untested or new methodology or that lacked a significant amount of background data.

D

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

The following criteria were used to evaluate source test reports for sound methodology and adequate detail:

1. Source operation. The manner in which the source was operated is well documented In the report. The source was operating within typical parameters during the test.
2. Sampling procedures. The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of the extent such alternative procedures could influence the test results.
3. Sampling and process data. Adequate sampling and process data are documented in the report. Many variations can occur unnoticed and without warning during testing. Such variations can induce wide deviations in sampling results. If a large spread

between test results cannot be explained by information contained in the test report, the data are suspect and were given a lower rating.

4. Analysis and calculations. The test reports contain original raw data sheets. The nomenclature and equations used were compared to those (if any) specified by the EPA to establish equivalency. The depth of review of the calculations was dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was based on factors such as consistency of results and completeness of other areas of the test report.

3.3 EMISSION FACTOR QUALITY RATING SYSTEM

The quality of the emission factors developed from analysis of the test data was rated utilizing the following general criteria:

A (Excellent)

Developed only from A-rated test data taken from many randomly chosen facilities in the industry population. The source category is specific enough so that variability within the source category population may be minimized.

B (Above average)

Developed only from A-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. As in the A-rating, the source category is specific enough so that variability within the source category population may be minimized.

C (Average)

Developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. As in the A-rating, the source category is specific enough so that variability within the source category population may be minimized.

D (Below average)

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

E (Poor)

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

The use of these criteria is somewhat subjective and depends to an extent on the individual reviewer.

3.4 REFERENCES FOR CHAPTER 3

1. Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections. U.S. Environmental Protection Agency, Emission Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 27711, April, 1992. [Note: this document is currently being revised at the time of this printing.]

2. AP-42, Supplement A, Appendix C.2, "Generalized Particle Size Distributions." U.S. Environmental Protection Agency, October, 1986.

4.0 POLLUTANT EMISSION FACTOR DEVELOPMENT

4.1 CRITERIA POLLUTANT EMISSIONS DATA

Volatile Organic Compounds.

No data on emissions of these pollutants were found for the ferroalloy process.

Lead.

No data on emissions of these pollutants were found for the ferroalloy process.

Sulfur dioxide.

No data on emissions of these pollutants were found for the ferroalloy process.

Nitrogen oxides.

No data on emissions of these pollutants were found for the ferroalloy process.

Carbon monoxide.

No data on emissions of these pollutants were found for the ferroalloy process.

Total Suspended Particulate & PM_{10}.

PM_{10} is a subset of total suspended particulate (TSP) and consists of particles having a diameter of less than ten microns (µm). There is no single method which is universally accepted for the determination of particle size. A number of different techniques can be used which measure the size of particles according to their basic physical properties. Since there is no "standard" method for particle size analysis, a certain degree of subjective evaluation was used to determine if a test series was performed using a sound methodology for particle sizing.

For pollution studies, the most common types of particle sizing instruments are cyclones, rotoclones, and cascade impactors. Traditionally, cyclones and rotoclones have been used as a preseparator ahead of a cascade impactor to remove the larger particles. These devices are of the standard reverse-flow design whereby the flue gas enters the cyclone through a tangential inlet and forms a vortex flow pattern. Particles move outward toward the cyclone wall with a velocity that is determined by the geometry and flow rate in the cyclone and by their size. Large particles reach the wall and are collected. A series of cyclones with progressively decreasing cut-points can be used to obtain particle size distributions.

Cascade impactors used for the determination of particle size in process streams consist of a series of plates or stages containing either small holes or slits with the size of the openings decreasing from one plate to the next. In each stage of an impactor, the gas stream passes through the orifice or slit to form a jet directed toward an impaction plate. For each stage, there is a characteristic particle diameter that has a 50 percent probability of impaction. This characteristic diameter is called the cut-point (D50) of the stage. Typically, commercial instruments have six to eight impaction stages with a backup filter to collect those particles which are either too small to be collected by the last stage or which are re-entrained off he various impaction surfaces by the moving gas stream.

Table 4.1-1 was developed from five source tests and studies of past source test and published in earlier editions of AP-42, Section 4.4 (October 1986). Pacific Environmental Services reviewed the five source tests referenced by the table and found them to be technically unsound due to a variety of problems that are discussed in detail in Chapter 4. The most basic problem is related to the baghouse structure. There is no stack to consolidate and direct exhaust gases after the exhaust gases have been filtered. As a result, measuring isokinetic flow in the baghouse plenum chamber above the fabric filters proved impossible, resulting in a low confidence level regarding test information data. PES is including the results of these source tests and studies with the knowledge that even the order-of-magnitude of emissions may be in error.

TABLE 4.1-1 (METRIC UNITS)
SIZE-SPECIFIC EMISSION FACTORS FOR SUBMERGED ARC FERROALLOY FURNACES

All Emission Factors are in kg/Mg of Product
Ratings (A-E) Follow Each Factor

Product	SCC's	Control Device	Particle Size (µm)	Cumulative Percentage	Cumulative mass emission factor	Emission Factor rating
50% FeSi Open furnace	30300601	None[b,c]	0.63	45	16	E
			1.00	50	18	
			1.25	53	19	
			2.50	57	20	
			6.00	61	21	
			10.00	63	22	
			15.00	66	23	
			20.00	69	24	
			d	100	35	
	30300601	Baghouse	0.63	31	0.28	E
			1.00	39	0.35	
			1.25	44	0.40	
			2.50	54	0.49	
			6.00	63	0.57	
			10.00	72	0.65	
			15.00	80	0.72	
			20.00	85	0.77	
				100	0.90	
80% FeMn Open furnace	30300606	None[e,f]	0.63	30	4	E
			1.00	46	7	
			1.25	52	8	
			2.50	62	9	
			6.00	72	10	
			10.00	86	12	
			15.00	96	13	
			20.00	97	14	
			d	100	14	
	30300606	Baghouse[e]	0.63	20	0.024	E
			1.00	30	0.035	
			1.25	35	0.043	
			2.50	49	0.060	
			6.00	67	0.080	
			10.00	83	0.100	
			15.00	92	0.110	
			20.00	97	0.118	
			d	100	0.120	

TABLE 4.1-1 (METRIC UNITS) (*continued*)
SIZE-SPECIFIC EMISSION FACTORS FOR SUBMERGED ARC FERROALLOY FURNACES

All Emission Factors are in kg/Mg of Product
Ratings (A-E) Follow Each Factor

Product	SCC's	Control Device	Particle Size (µm)	Cumulative Percentage	Cumulative mass emission factor	Emission Factor rating
Si Metal[h] Open Furnace	30300604	None[g]	0.63	57	249	E
			1.00	67	292	
			1.25	70	305	
			2.50	75	327	
			6.00	80	349	
			10.00	86	375	
			15.00	91	397	
			20.00	95	414	
			d	100	436	
	30300604	Baghouse	1.00	49	7.8	E
			1.25	53	8.5	
			2.50	64	10.2	
			6.00	76	12.2	
			10.00	87	13.9	
			15.00	96	15.4	
			20.00	99	15.8	
				100	16.0	
FeCr (HC) Open furnace	30300607	None[b,j]	0.5	19	15	E
			1.0	36	28	
			2.0	60	47	
			2.5	63[k]	49	
			4.0	76	59	
			6.0	88[k]	67	
			10.0	91	71	
			d	100	78	
FeCr (HC) Open furnace	30300607	ESP	0.5	33	0.40	E
			1.0	47	0.56	
			2.0	67	0.80	
			2.5	80	0.96	
			4.0	86	1.03	
			6.0	90	1.08	
			10.0	100	1.2	
			d			
SiMn Open furnace	30300605	None[b,m]	0.5	28	27	E
			1.0	44	42	
			2.0	60	58	
			2.5	65	62	
			4.0	76	73	
			6.0	85	82	
			10.0	96[k]	92[k]	
			d	100	96	

TABLE 4.1-1 (METRIC UNITS) (*concluded*)
SIZE-SPECIFIC EMISSION FACTORS FOR SUBMERGED ARC FERROALLOY FURNACES

All Emission Factors are in kg/Mg of Product
Ratings (A-E) Follow Each Factor

Product	SCC's	Control Device	Particle Size (µm)	Cumulative Percentage	Cumulative mass emission factor	Emission Factor rating
	30300605	Scrubber[m,n]	0.5	56	1.18	E
			1.0	80	1.68	
			2.0	96	2.02	
			2.5	99	2.08	
			4.0	99.5	2.09	
			6.0	99.9[k]	2.10[k]	
			10.0	100	2.1	

[a] Aerodynamic diameter, based on Task Group On Lung Dynamics definition. Particle density = 1 g/cm^3.

[b] Includes tapping emissions.

[c] References 4, 10, 21.

[d] Total particulate, based on Method 5 total catch (see table 12.4-3).

[e] Includes tapping fume (estimated capture efficiency 50%).

[f] References 4, 10, 12.

[g] Includes tapping fume (estimated capture efficiency 60%).

[h] References 10, 13.

[j] References 1, 15-17.

[k] Interpolated data.

[m] References 2, 18-19.

[n] Primary emission control system only, without tapping emissions.

TABLE 4.1-1 (ENGLISH UNITS)
SIZE-SPECIFIC EMISSION FACTORS FOR SUBMERGED ARC FERROALLOY FURNACES

All Emission Factors are in lb/ton of Product
Ratings (A-E) Follow Each Factor

Product	SCC's	Control Device	Particle Size (µm)	Cumulative Percentage	Cumulative mass emission factor	Emission Factor rating
50% FeSi Open furnace	30300601	None[b,c]	0.63	45	32	E
			1.00	50	36	
			1.25	53	38	
			2.50	57	40	
			6.00	61	42	
			10.00	63	44	
			15.00	66	46	
			20.00	69	48	
			d	100	70	
	30300601	Baghouse	0.63	31	0.56	E
			1.00	39	0.70	
			1.25	44	0.80	
			2.50	54	0.98	
			6.00	63	1.14	
			10.00	72	1.30	
			15.00	80	1.44	
			20.00	85	1.54	
				100	1.80	
80% FeMn Open furnace	30300606	None[e,f]	0.63	30	8	E
			1.00	46	14	
			1.25	52	16	
			2.50	62	18	
			6.00	72	20	
			10.00	86	24	
			15.00	96	26	
			20.00	97	28	
			d	100	28	
	30300606	Baghouse[e]	0.63	20	0.048	
			1.00	30	0.070	
			1.25	35	0.085	
			2.50	49	0.120	
			6.00	67	0.160	
			10.00	83	0.200	
			15.00	92	0.220	
			20.00	97	0.235	
			d	100	0.240	

TABLE 4.1-1 (ENGLISH UNITS) (*continued*)
SIZE-SPECIFIC EMISSION FACTORS FOR SUBMERGED ARC FERROALLOY FURNACES

All Emission Factors are in lb/ton of Product
Ratings (A-E) Follow Each Factor

Product	SCC's	Control Device	Particle Size (µm)	Cumulative Percentage	Cumulative mass emission factor	Emission Factor rating
Si Metal[h] Open Furnace	30300604	None[g]	0.63	57	498	E
			1.00	67	584	
			1.25	70	610	
			2.50	75	654	
			6.00	80	698	
			10.00	86	750	
			15.00	91	794	
			20.00	95	828	
			d	100	872	
	30300604	Baghouse	1.00	49	15.6	E
			1.25	53	17.0	
			2.50	64	20.4	
			6.00	76	24.4	
			10.00	87	27.8	
			15.00	96	30.8	
			20.00	99	31.6	
				100	32.0	
FeCr (HC) Open furnace	30300607	None[b,j]	0.5	19	30	E
			1.0	36	56	
			2.0	60	94	
			2.5	63[k]	98	
			4.0	76	118	
			6.0	88[k]	134	
			10.0	91	142	
			d	100	156	
FeCr (HC) Open furnace	30300607	ESP	0.5	33	0.80	E
			1.0	47	1.12	
			2.0	67	1.60	
			2.5	80	1.92	
			4.0	86	2.06	
			6.0	90	2.16	
			10.0	100	2.40	
			d			

TABLE 4.1-1 (ENGLISH UNITS) (*concluded*)
SIZE-SPECIFIC EMISSION FACTORS FOR SUBMERGED ARC FERROALLOY FURNACES

All Emission Factors are in lb/ton of Product
Ratings (A-E) Follow Each Factor

Product	SCC's	Control Device	Particle Size (µm)	Cumulative Percentage	Cumulative mass emission factor	Emission Factor rating
SiMn Open furnace	30300605	None[b,m]	0.5	28	54	E
			1.0	44	84	
			2.0	60	116	
			2.5	65	124	
			4.0	76	146	
			6.0	85	164	
			10.0	96[k]	184[k]	
			d	100	192	
	30300605	Scrubber[m,n]	0.5	56	2.36	E
			1.0	80	3.36	
			2.0	96	4.04	
			2.5	99	4.16	
			4.0	99.5	4.18	
			6.0	99.9[k]	4.20	
			10.0	100	4.20	

[a] Aerodynamic diameter, based on Task Group On Lung Dynamics definition. Particle density=1g/cm^3.

[b] Includes tapping emissions.

[c] References 4, 10, 21.

[d] Total particulate, based on Method 5 total catch (see table 12.4-3).

[e] Includes tapping fume (estimated capture efficiency 50%).

[f] References 4, 10, 12.

[g] Includes tapping fume (estimated capture efficiency 60%).

[h] References 10, 13.

[j] References 1, 15-17.

[k] Interpolated data.

[m] References 2, 18-19.

[n] Primary emission control system only, without tapping emissions.

4.2 NONCRITERIA POLLUTION EMISSION DATA

Hazardous Air Pollutants.

Hazardous Air Pollutants (HAPs) are defined in the 1990 Clean Air Act Amendments. No data on emissions of these pollutants were found for the ferroalloy process.

Global Warming Gases.

Pollutants such as methane, carbon dioxide, and N_2O have been found to contribute to overall global warming. No data on emissions of these pollutants were found for the ferroalloy process.

Ozone Depletion Gases.

Chlorofluorocarbons have been found to contribute to ozone depletion. No data on emissions of these pollutants were found for the ferroalloy process.

4.3 REVIEW OF SPECIFIC DATA SETS

Five source tests and past studies are listed in the table and used to develop the emission factors published in the past edition of AP-42, Section 12.4, "Ferroalloy Production" (October 1986). These source tests have been reviewed by PES, using the guidelines discussed in Section 3.2 (Emission Data Quality Rating System). All five of the source tests are rated "D" due to technical problems involving isokinetic flows, poor source collecting points due to control equipment design and space limitations, utility outages during the test period, instruments becoming clogged during testing, and a lack of production data in "real time" to enable accurate emission factors. The six studies also used as references in Table 4.1-1 have not been reviewed. However, the five source tests are discussed in detail below.

Reference 2: Ferroalloy Furnace Emission Factor Development, Roane Limited, Rockwood, Tennessee

Two ferroalloy furnaces, sharing a common fabric filter (baghouse), were tested from February 10 through February 12, 1981 by GCA Corporation for particulate controlled using a fabric filter. Furnaces #3 and #4, open submerged electric arc furnaces, were producing ferromanganese during testing. Pacific Environmental Services has completed a review of the report. A problem is reported in the test results concerning an inability to gather flow rates leaving the control device due to physical limitations at the test site. A disclaimer is made in the summary of results and conclusions, stating that "an emission factor based on the average of all outlet tests results should be considered one complete test run and since very little confidence can be applied to the results of one test, the emission factor should only be considered an estimate."

Therefore, PES has reported the emission factors in this revision with a rating of "E." These stack test results, although flawed, represent the best available information on particulate emission from open submerged electric arc furnaces producing ferromanganese. The primary and most damaging discrepancy in the testing procedures involves particulate collection after the control device. The exit flow rates had to be calculated from measured entry velocities, and exit particulate capture was made above several filters bags during each run. <u>No velocity reading was made in the plenum chamber where exit particulates were sampled</u>. Without exit velocity readings, isokinetic velocity was not available, disallowing confidence in exit samples collected. Additional unrelated problems recorded during the stack tests includes pulling 20 ft^3 of sample gases instead of 30 ft^3 through a method 5 test filter train and the collection of air samples at the low end and below the isokinetic velocity range of 90 to 110 percent. Actual isokinetic readings were taken at 87.9, 90.4, 92.8, 92.9, 93.6, and 92.5 percent.

<u>Reference 3: Union Carbide Corporation, Ferroalloys Division, Marietta, Ohio</u>

This series of stack tests was performed in 1971. Its purpose was to measure and size particulate and to measure SO_2 emissions from a silico-manganese ferroalloy operation. The control device are two high energy venturi-type scrubbers leading to a single exhaust stack. Problems during testing included electrical outages, poor sample port location dictated by the duct design, filters clogging up within a few minutes and the isometric velocity could not be accurately measured. The results of this series of tests have been reported in Section 12.4 Ferroalloy Production. However, due to testing problems, the emission factor for this data has been reduced from a "C" to an "E."

<u>Reference 4: Ferroalloy Furnace Emission Factor Development, Interlake Inc., Alabama Metallurgical Corp., Selma, Alabama</u>

This series of stack tests were performed in March, 1981. Its purpose was to measure and size particulate emissions from a 47 percent ferrosilicon operation, controlled by a baghouse (fabric filter). The test lacked data to establish Methods 1-4. In addition, particulate readings for the air stream entering the fabric filter are not reliable because "the impactor nozzle was in the wake of the cyclone during the run." In addition, particulate measurements for the control device exit are of suspect value as the "nozzles were turned perpendicular to the assumed direction of flow all the time."

Particulate emission rates, controlled by the fabric filter, were sampled inside the baghouse plenum chamber where no isokinetic readings were possible. Such information is of interest for comparison with other similarly designed units, but does not provide an accurate emission rate.

Reference 5: Source Test, Foote Mineral Company, Vancoram Operations, Steubenville, OH

This series of stack tests were performed in September, 1971. Its purpose was to measure and size particulate emissions from a high carbon ferrochrome ferroalloy operation that used an open submerged electric arc furnace. The control device is a baghouse (fabric filter). Several technical problems during the field work were identified. The most important discrepancy is the lack of production rates during the testing periods. There was an unexplained seven percent increase in flow rate exiting the baghouse than entered it on two of the test runs (#1 and #3). Duct design and location made locating and gathering accurate data difficult, as there was little or no straight flow of the gas stream prior to measurements. Also, based upon prior experience with similar applications, plugging of the filters was anticipated. Precautions taken during the first run were found not to be needed. No explanation was reported to account for this lack of filters plugging up.

Reference 6: Source test, Airco Alloys and Carbide, Charleston, SC

Only the summary of results is available for this test. Three test runs were performed at the inlet ducts and stack exhaust of a furnace equipped with electrostatic precipitator (ESP). The test was performed to determine both particulate and sulfur dioxide (SO_2) emissions. Some technical problems were found during the test. Particulate emission rate at the exhaust outlet for Run 1 is significantly high. The problem apparerntly relates to a furnace blow which reduced the effect of the conditioning tower which in turn affected the efficiency of the ESP. It was also found that the SO_2 concentration for Run 2 was in error and not included in the average. Due to lack of test information, the validity of the test methodology cannot be determined.

4.4 DATA GAP ANALYSIS

Information available on emissions from ferroalloy production is currently general in nature, chronologically old, and suffers from a lack of demonstrated accuracy. No new emission factors have been developed. Although ferroalloy production has had heavy foreign competition during the past 14 years, resulting in a 44 percent reduction in U.S. production, more accurate and concise emission factors need to be determined.

In order to maximize source testing resources, the following is a prioritized list of sources, along with their emissions and normally used control equipment. For example, submerged electric arc furnaces are believed to generate 94 percent of the total particulate emissions and almost all of the organic emissions resulting from ferroalloy production. Closed electric arc furnaces generated larger amounts of organic emissions than open electric arc furnaces. Therefore, closed electric arc furnaces have the highest priority to be tested.

- Closed furnaces
- Open furnaces
- Tapping operations
- Exothermic reaction
- Fugitive emissions

Closed Furnace

Closed furnaces generate large amounts of organic compounds and carbon monoxide. The fumes consists of oxides of the products being produced and carbon. Scrubbers are used almost exclusively to control exhaust gases from sealed furnaces with a flare at the exhaust of the scrubber.

Open furnace

The fumes are consistent with those generated by closed furnaces. Most if not all of the carbon monoxide and organic compounds burns with induced air at the furnace top. Testing for the products of that combustion may be important. Fabric filters, scrubbers, and electrostatic precipitators are used to control emissions from open furnaces in the U.S.

Tapping operations

Tapping operations generate fumes. The emissions are captured and controlled by the furnace control device or a separate control device.

Exothermic reaction

Fumes are a result of chlorination, oxidation, gas mixing and slag metal reactions. Emissions are often captured by the tapping emissions control system or a dedicated control device.

Fugitive Emissions

Emission factors for raw material handling, pretreatment and product handling during ferroalloy production are expected to be closely matched in both size distribution and volume to similar operations used by other metallurgical industries.

TABLE 4-4.
LIST OF CONVERSION FACTORS

Multiply:	**by:**	**To obtain:**
mg/dscm	4.37×10^{-4}	gr/dscf
m^2	10.764	ft^2
acm/min	35.31	acfm
m/s	3.281	ft/s
kg/hr	2.205	lb/hr
kPa	1.45×10^{-4}	psia
kg/Mg	2.0	lb/ton
Mg	1.1023	ton

Temperature conversion equations:

Fahrenheit to Celsius:

$$\frac{°F - 32}{1.8} = °C$$

Celsius to Fahrenheit:

$$(1.8°C) + 32 = °F$$

4.5REFERENCES FOR CHAPTER 4

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4.S. Beaton, et al., Ferroalloy Furnace Emission Factor Development, Interlake Inc., Alabama Metallurgical Corp., Selma, Alabama, EPA-600/X-85-324, U.S. Environmental Protection Agency, Washington, DC, May 1981.

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