12.4 Ferroalloy Production

12.4.1 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. In practice, the term ferroalloy is used to include any alloys that introduce reactive elements or 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.

United States ferroalloy production in 1989 was approximately 894,000 megagrams (Mg) (985,000 tons), substantially less than shipments in 1975 of approximately 1,603,000 megagrams (1,770,000 tons). In 1989, ferroalloys were produced in the U. S. by 28 companies, although 5 of those produced only ferrophosphorous as a byproduct of elemental phosphorous production.

12.4.2 Process Description

A typical ferroalloy plant is illustrated in Figure 12.4-1. 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 12.4-1.

12.4.2.1 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, charcoal, high- and 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:

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

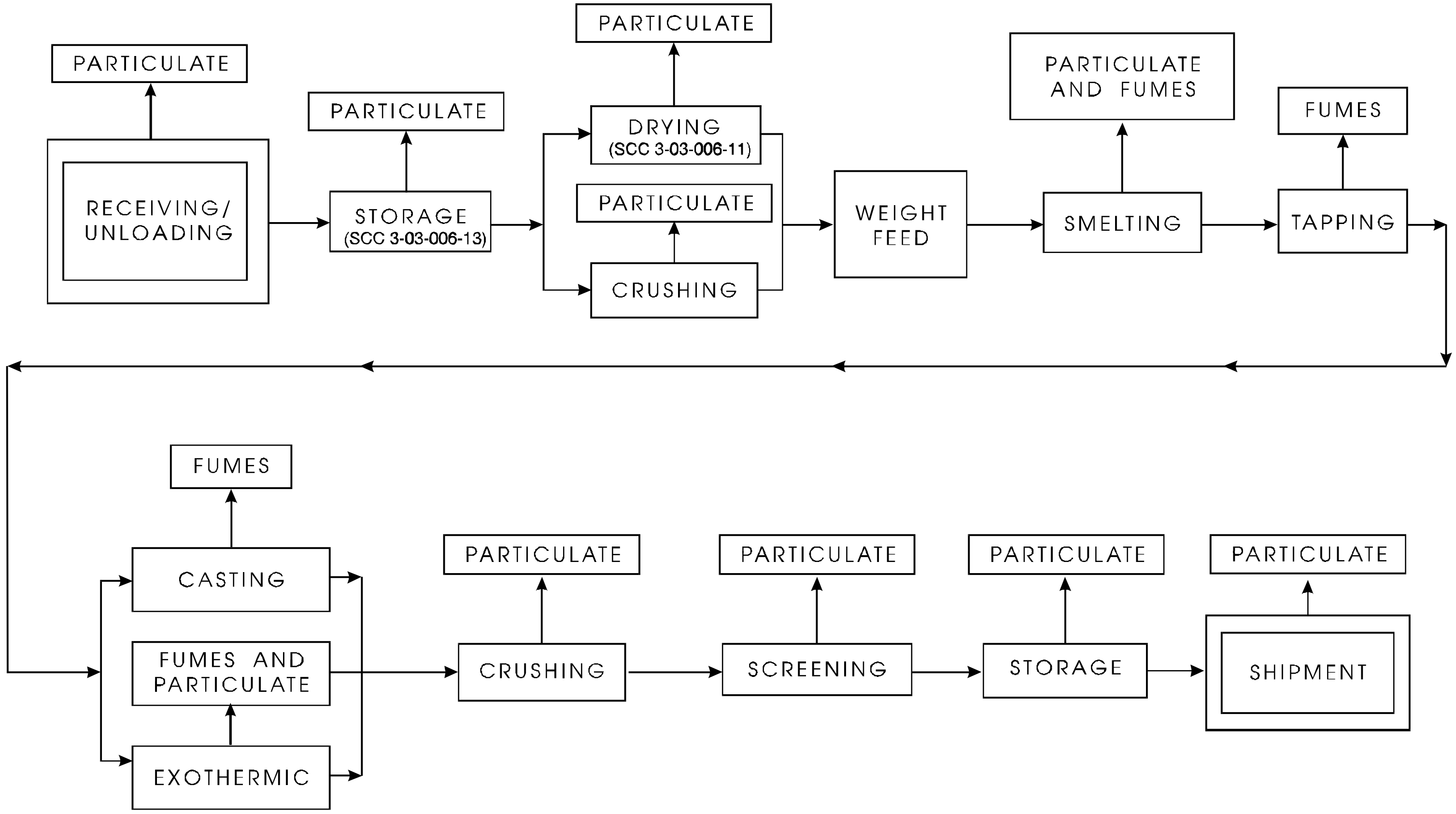

Figure 12.4-1. Typical ferroalloy production process. (Source Classification Code in parentheses.)

Table 12.4-1. 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, LC ferromanganese, medium carbon (MC) ferromanganese
Aluminum Reduction	Chromium metal, ferrotitanium, ferrocolumbium, ferovanadium
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 2.
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 that converts electrical energy into heat, without electrodes, to melt metal charges in a cup or drum-shaped vessel.

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.

A typical submerged electric arc furnace design is depicted in Figure 12.4-2. 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 2 or more layers of carbon blocks. The furnace shell may be 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, 3 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 cm (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 0.9 to 1.5 meters (3 to 5 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) that passes upward through the furnace charge. The molten metal and slag are removed (tapped) through 1 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 can be intermittent or continuous based on production rate of the furnace.

Submerged electric arc furnaces are of 2 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 1 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 may have a water-cooled steel cover that 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 cover has holes for the charge and electrodes to pass through. Covered furnaces that 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 1 to 5-hour intervals through the tap hole. Tapping typically lasts 10 to 15 minutes. 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 that directs the metal and slag into a reaction ladle, ingot molds, or chills. (Chills are low, flat iron or steel pans that provide rapid

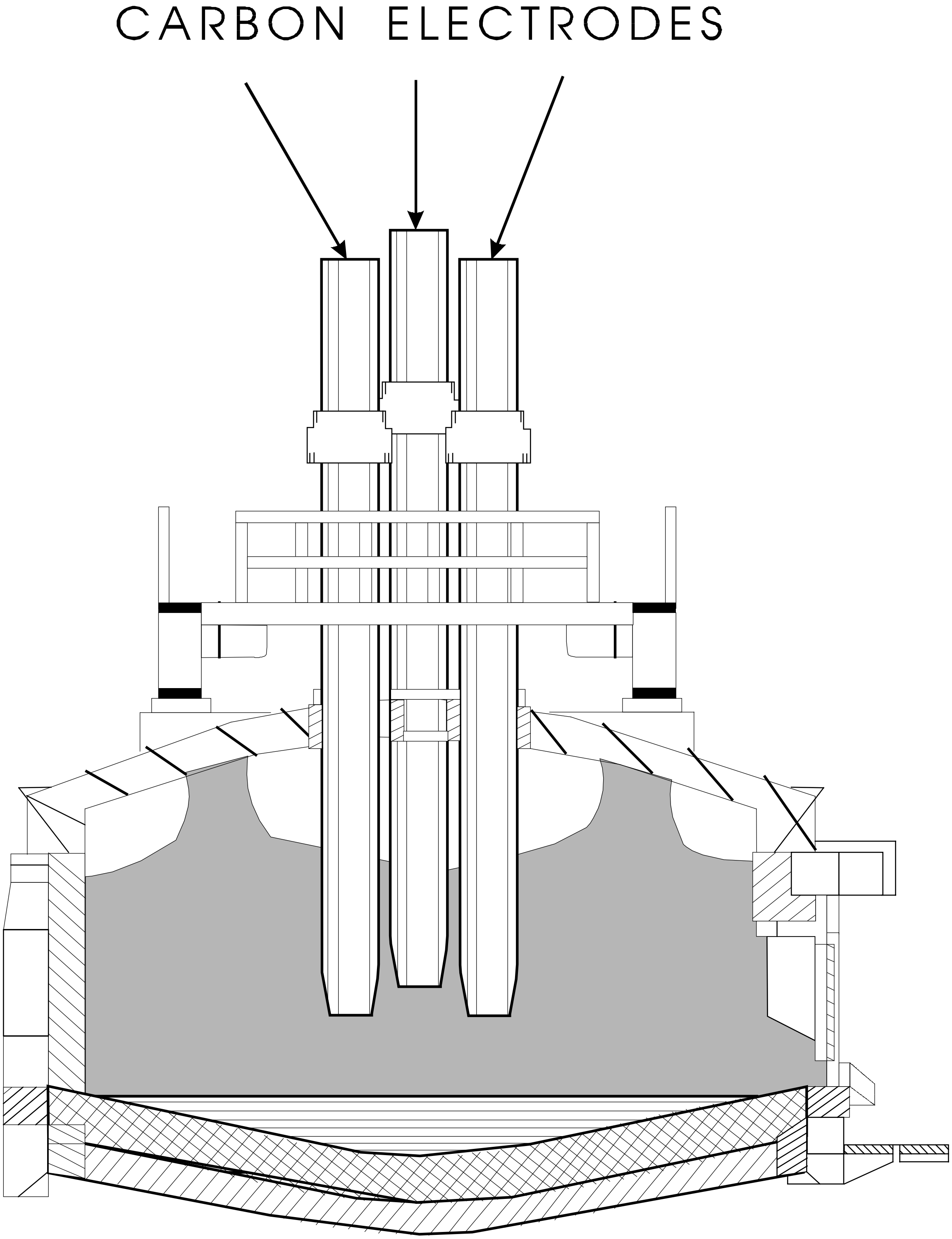

Figure 12.4-2. Typical submerged arc furnace design.

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.

12.4.2.2 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 (FeCr) and ferromanganese (FeMn) 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 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.

12.4.2.3 Electrolytic Processes -

Electrolytic processes are used to produce high-purity manganese and chromium. As of 1989, there were 2 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 5 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 metals, 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.

12.4.3 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 12.4-2 and 12.4-3. Size-specific emission factors for submerged arc ferroalloy furnaces are given in Tables 12.4-4 and 12.4-5.

Particulate emissions from electric arc furnaces in the form of fumes 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 1 meter above the furnace, is directed to a gas cleaning device. Fabric filters 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 fumes 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 separate tapping hoods ducted to either the furnace emission control device or a separate control device. Emission factors for tapping emissions are unavailable due to lack of data.

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.

Table 12.4-2 (Metric Units). EMISSION FACTORS FOR PARTICULATE FROM SUBMERGED ARC FERROALLOY FURNACES[a]

Product[b]	Furnace Type	Particulate Emission Factors Uncontrolled[c]	EMISSION FACTOR RATING	Control Device[d]	Particulate Emission Factors Controlled[c]	EMISSION FACTOR RATING
FeSi (50%) (SCC 3-03-006-01)	Open[e,f,g]	35	B	Baghouse[e,f]	0.9	B
	Covered[h]	46	E	Scrubber[h,j]		
				High energy	0.24	E
				Low energy	4.5	E
FeSi (75%) (SCC 3-03-006-02)	Open[k]	158	E	Scrubber[h,j]		
				Low energy	4.0	E
	Covered[h,j]	103	E	ND	ND	NA
FeSi (90%) (SCC 3-03-006-03)	Open[m]	282	E	ND	ND	NA
Si metal (98%) (SCC 3-03-006-04)	Open[n,p]	436	B	Baghouse[n,p]	16	B
FeMn (80%) (SCC 3-03-006-06)	Open[q,r]	14	B	Baghouse[q,r]	0.24	B
				Scrubber[h,s]		
				High energy	0.8	E
FeMn (1% Si) (SCC 3-03-007-01)	Covered[h,t]	6	E	Scrubber	0.25	**C**
				High energy[h,s,w]		
	Sealed[u,v]	37	E	ND	ND	NA
FeCr (high carbon) (SCC 3-03-006-07)	Open[x,y]	78	C	ESP[x,y]	1.2	C
SiMn (SCC 3-03-006-05)	Open[z,aa]	96	C	Scrubber[aa,bb]	2.1	C
	Sealed	—	—	Scrubber[v,w]		
				High energy	0.15	C

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[a] Emission factors are expressed as kg of pollutant/Mg alloy produced. 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, and preparation; and product crushing, screening, handling, and packaging. SCC = Source Classification Code. ND = no data. NA = not applicable.

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

Table 12.4-2 (cont.).

[c] In most source testing, fugitive emissions are not measured or collected. Where tapping emissions are controlled by primary system, their contribution to total emissions could not be determined. Fugitive emissions may vary greatly among sources, with furnace and collection system design and operating practices.

[d] Low-energy scrubbers are those with $\Delta P < 20$ inches of H_2O; high-energy with $\Delta P > 20$ inches of H_2O.

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

[f] References 4,10,21.

[g] Factor is average of 3 sources, fugitive emissions not included. Fugitive emissions at 1 source measured an additional 10.5 kg/Mg alloy, or 2.7 kg/MW-hr.

[h] References 4,10.

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

[k] References 25-26.

[m] Reference 23.

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

[p] References 10,13.

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

[r] References 4,10,12.

[s] Includes fumes only from primary control system.

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

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

[v] Reference 14.

[w] Does not include tapping or fugitive emissions.

[x] Tapping emissions included.

[y] References 2,15-17.

[z] Factor is average of 2 test series. Tests at 1 source included fugitive emissions (3.4% of total uncontrolled emissions). Second test insufficient to determine if fugitive emissions were included in total.

[aa] References 2,18-19.

[bb] Factors developed from 2 scrubber controlled sources, 1 operated at $\Delta P = 47\text{-}57$ inches of H_2O, the other at unspecified ΔP. Uncontrolled tapping operations emissions are 2.1 kg/Mg alloy.

Table 12.4-3 (English Units). EMISSION FACTORS FOR PARTICULATE FROM SUBMERGED ARC FERROALLOY FURNACES[a]

Product[b]	Furnace Type	Particulate Emission factors Uncontrolled[c]	EMISSION FACTOR RATING	Control Device[d]	Particulate Emission factors Controlled[c]	EMISSION FACTOR RATING
FeSi (50%) (SCC 3-03-006-01)	Open[e,f,g]	70	B	Baghouse[e,f]	1.8	B
	Covered[h]	92	E	Scrubber[h,j]		
				High energy	0.48	E
				Low energy	9.0	E
FeSi (75%) (SCC 3-03-006-02)	Open[k]	316	E	Scrubber[h,j]		
				Low energy	8.0	E
	Covered[h,j]	206	E	ND	ND	NA
FeSi (90%) (SCC 3-03-006-03)	Open[m]	564	E	ND	ND	NA
Si metal (98%) (SCC 3-03-006-04)	Open[n,p]	872	B	Baghouse[n,p]	32	B
FeMn (80%) (SCC 3-03-006-06)	Open[q,r]	28	B	Baghouse[q,r]	0.48	B
				Scrubber[h,s]		
				High energy	1.6	E
FeMn (1% Si) (SCC 3-03-007-01)	Covered[h,t]	12	E	Scrubber		
				High energy[h,s,w]	0.5	C
	Sealed[u,v]	74	E	ND	ND	NA
FeCr (high carbon) (SCC 3-03-006-07)	Open[x,y]	157	C	ESP[x,y]	2.3	C
SiMn (SCC 3-03-006-05)	Open[z,aa]	192	C	Scrubber[aa,bb]	4.2	C
	Sealed	—	—	Scrubber[v,w]		
				High energy	0.30	C

[a] Emission factors expressed as lb of pollutant/ton of Alloy produced. 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, and preparation; and product crushing, screening, handling, and packaging. SCC = Source Classification Code. ND = no data. NA = not applicable.

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

Table 12.4-3 (cont.).

[c] In most source testing, fugitive emissions are not measured or collected. Where tapping emissions are controlled by primary system, their contribution to total emissions could not be determined. Fugitive emissions may vary greatly among sources, with furnace and collection system design and operating practices.

[d] Low-energy scrubbers are those with $\Delta P < 20$ inches of H_2O; high-energy with $\Delta P > 20$ inches of H_2O.

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

[f] References 4,10,21.

[g] Factor is average of 3 sources, fugitive emissions not included. Fugitive emissions at 1 source measured an additional 21 lb/ton alloy, or 5.9 lb/MW-hr.

[h] References 4,10.

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

[k] References 25-26.

[m] Reference 23.

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

[p] References 10,13.

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

[r] References 4,10,12.

[s] Includes fumes only from primary control system.

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

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

[v] Reference 14.

[w] Does not include tapping or fugitive emissions.

[x] Tapping emissions included.

[y] References 2,15-17.

[z] Factor is average of 2 test series. Tests at 1 source included fugitive emissions (3.4% of total uncontrolled emissions). Second test insufficient to determine if fugitive emissions were included in total.

[aa] References 2,18-19.

[bb] Factors developed from 2 scrubber controlled sources, 1 operated at $\Delta P = 47\text{-}57$ inches of H_2O, the other at unspecified ΔP. Uncontrolled tapping operations emissions are 4.2 lb/ton alloy.

Table 12.4-4 (Metric Units). SIZE-SPECIFIC EMISSION FACTORS FOR SUBMERGED ARC FERROALLOY FURNACES

Product	Control Device	Particle Size[a] (µm)	Cumulative Mass % ≤ Stated Size	Cumulative Mass Emission Factor (kg/Mg alloy)	EMISSION FACTOR RATING
50% FeSi Open furnace (SCC 3-03-006-01)	None[b,c]	0.63	45	16	B
		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	
	Baghouse	0.63	31	0.28	B
		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 (SCC 3-03-006-06)	None[e,f]	0.63	30	4	B
		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	
	Baghouse[e]	0.63	20	0.048	B
		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 12.4-4 (cont.).

Product	Control Device	Particle Size[a] (µm)	Cumulative Mass % ≤ Stated Size	Cumulative Mass Emission Factor (kg/Mg alloy)	EMISSION FACTOR RATING
Si Metal[g]					
Open furnace (SCC 3-03-006-04)	None[h]	0.63	57	249	B
		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	
	Baghouse	1.00	49	7.8	
		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 (SCC 3-03-006-07)	None[b,j]	0.5	19	15	C
		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	
	ESP	0.5	33	0.40	C
		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]			

Table 12.4-4 (cont.).

Product	Control Device	Particle Size[a] (μm)	Cumulative Mass % ≤ Stated Size	Cumulative Mass Emission Factor (kg/Mg alloy)	EMISSION FACTOR RATING
SiMn					
Open furnace	None[b,m]	0.5	28	27	C
(SCC 3-03-006-05)		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	
	Scrubber[m,n]	0.5	56	1.18	C
		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 Tables 12.4-2 and 12.4-3).

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

[f] References 4,10,12.

[g] References 10,13.

[h] Includes tapping fumes (estimated capture efficiency 60%).

[j] References 1,15-17.

[k] Interpolated data.

[m] References 2,18-19.

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

Table 12.4-5 (English Units). SIZE-SPECIFIC EMISSION FACTORS FOR SUBMERGED ARC FERROALLOY FURNACES

Product	Control Device	Particle Size[a] (µm)	Cumulative Mass % ≤ Stated Size	Cumulative Mass Emission Factor (lb/ton alloy)	EMISSION FACTOR RATING
50% FeSi Open furnace (SCC 3-03-006-01)	None[b,c]	0.63	45	32	B
		1.00	50	35	
		1.25	53	37	
		2.50	57	40	
		6.00	61	43	
		10.00	63	44	
		15.00	66	46	
		20.00	69	48	
		—[d]	100	70	
	Baghouse	0.63	31	0.56	B
		1.00	39	0.70	
		1.25	44	0.80	
		2.50	54	1.0	
		6.00	63	1.1	
		10.00	72	1.3	
		15.00	80	1.4	
		20.00	85	1.5	
			100	1.8	
80% FeMn Open furnace (SCC 3-03-006-06)	None[e,f]	0.63	30	8	B
		1.00	46	13	
		1.25	52	15	
		2.50	62	17	
		6.00	72	20	
		10.00	86	24	
		15.00	96	26	
		20.00	97	27	
		—[d]	100	28	
	Baghouse[e]	0.63	20	0.10	B
		1.00	30	0.14	
		1.25	35	0.17	
		2.50	49	0.24	
		6.00	67	0.32	
		10.00	83	0.40	
		15.00	92	0.44	
		20.00	97	0.47	
		—[d]	100	0.48	

Table 12.4-5 (cont.).

Product	Control Device	Particle Size[a] (μm)	Cumulative Mass % ≤ Stated Size	Cumulative Mass Emission Factor (lb/ton alloy)	EMISSION FACTOR RATING
Si Metal[g]					
Open Furnace (SCC 3-03-006-04)	None[h]	0.63	57	497	B
		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	
	Baghouse	1.00	49	15.7	B
		1.25	53	17.0	
		2.50	64	20.5	
		6.00	76	24.3	
		10.00	87	28.0	
		15.00	96	31.0	
		20.00	99	31.7	
			100	32.0	
FeCr (HC)					
Open furnace (SCC 3-03-006-07)	None[b,j]	0.5	19	30	C
		1.0	36	57	
		2.0	60	94	
		2.5	63[k]	99	
		4.0	76	119	
		6.0	88[k]	138	
		10.0	91	143	
		—[d]	100	157	
	ESP	0.5	33	0.76	C
		1.0	47	1.08	
		2.0	67	1.54	
		2.5	80	1.84	
		4.0	86	1.98	
		6.0	90	2.07	
		10.0	100	2.3	
		—[d]			

Table 12.4-5 (cont.).

Product	Control Device	Particle Size[a] (µm)	Cumulative Mass % ≤ Stated Size	Cumulative Mass Emission Factor (lb/ton alloy)	EMISSION FACTOR RATING
SiMn Open furnace (SCC 3-05-006-05)	None[b,m]	0.5	28	54	C
		1.0	44	84	
		2.0	60	115	
		2.5	65	125	
		4.0	76	146	
		6.0	85	163	
		10.0	96[k]	177[k]	
		—[d]	100	192	
	Scrubber[m,n]	0.5	56	2.36	C
		1.0	80	3.34	
		2.0	96	4.03	
		2.5	99	4.16	
		4.0	99.5	4.18	
		6.0	99.9[k]	4.20[k]	
		10.0	100	4.3	

[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 Tables 12.4-2 and 12.4-3).
[e] Includes tapping fumes (estimated capture efficiency 50%).
[f] References 4,10,12.
[g] References 10,13.
[h] Includes tapping fumes (estimated capture efficiency 60%).
[j] References 1,15-17.
[k] Interpolated data.
[m] References 2,18-19.
[n] Primary emission control system only, without tapping emissions.

Available data are insufficient 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 12.4-1). 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 matter in the form of dust. The properties of particulate matter 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 20 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 filters. 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 13.2 of this document.

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