12.13 Steel Foundries

12.13.1 General

Steel foundries produce steel castings weighing from a few ounces to over 180 megagrams (Mg) (200 tons). These castings are used in machinery, transportation, and other industries requiring parts that are strong and reliable. In 1989, 1030 million Mg (1135 million tons) of steel (carbon and alloy) were cast by U. S. steel foundries, while demand was calculated at 1332 Mg (1470 million tons). Imported steel accounts for the difference between the amount cast and the demand amount. Steel casting is done by small- and medium-size manufacturing companies.

Commercial steel castings are divided into 3 classes: (1) carbon steel, (2) low-alloy steel, and (3) high-alloy steel. Different compositions and heat treatments of steel castings result in a tensile strength range of 400 to 1700 MPa (60,000 to 250,000 psi).

12.13.2 Process Description[1]

Steel foundries produce steel castings by melting scrap, alloying, molding, and finishing. The process flow diagram of a typical steel foundry with fugitive emission points is presented in Figure 12.13-1. The major processing operations of a typical steel foundry are raw materials handling, metal melting, mold and core production, and casting and finishing.

12.13.2.1 Raw Materials Handling -

Raw material handling operations include receiving, unloading, storing, and conveying all raw materials for the foundry. Some of the raw materials used by steel foundries are iron and steel scrap, foundry returns, metal turnings, alloys, carbon additives, fluxes (limestone, soda ash, fluorspar, calcium carbide), sand, sand additives, and binders. These raw materials are received in ships, railcars, trucks, and containers, and are transferred by trucks, loaders, and conveyors to both open- pile and enclosed storage areas. They are then transferred by similar means from storage to the subsequent processes.

12.13.2.2 Metal Melting[9] -

Metal melting process operations are: (1) scrap preparation; (2) furnace charging, in which metal, scrap, alloys, carbon, and flux are added to the furnace; (3) melting, during which the furnace remains closed; (4) backcharging, which is the addition of more metal and possibly alloys; (5) refining by single (oxidizing) slag or double (oxidizing and reducing) slagging operations; (6) oxygen lancing, which is injecting oxygen into the molten steel to adjust the chemistry of the metal and speed up the melt; and (7) tapping the molten metal into a ladle or directly into molds. After preparation, the scrap, metal, alloy, and flux are weighed and charged to the furnace.

Electric furnaces are used almost exclusively in the steel foundry for melting and formulating steel. There are 2 types of electric furnaces: direct arc and induction.

Electric arc furnaces are charged with raw materials by removing the lid through a chute opening in the lid or through a door in the side. The molten metal is tapped by tilting and pouring through a spout on the side. Melting capacities range up to 10 Mg (11 tons) per hour.

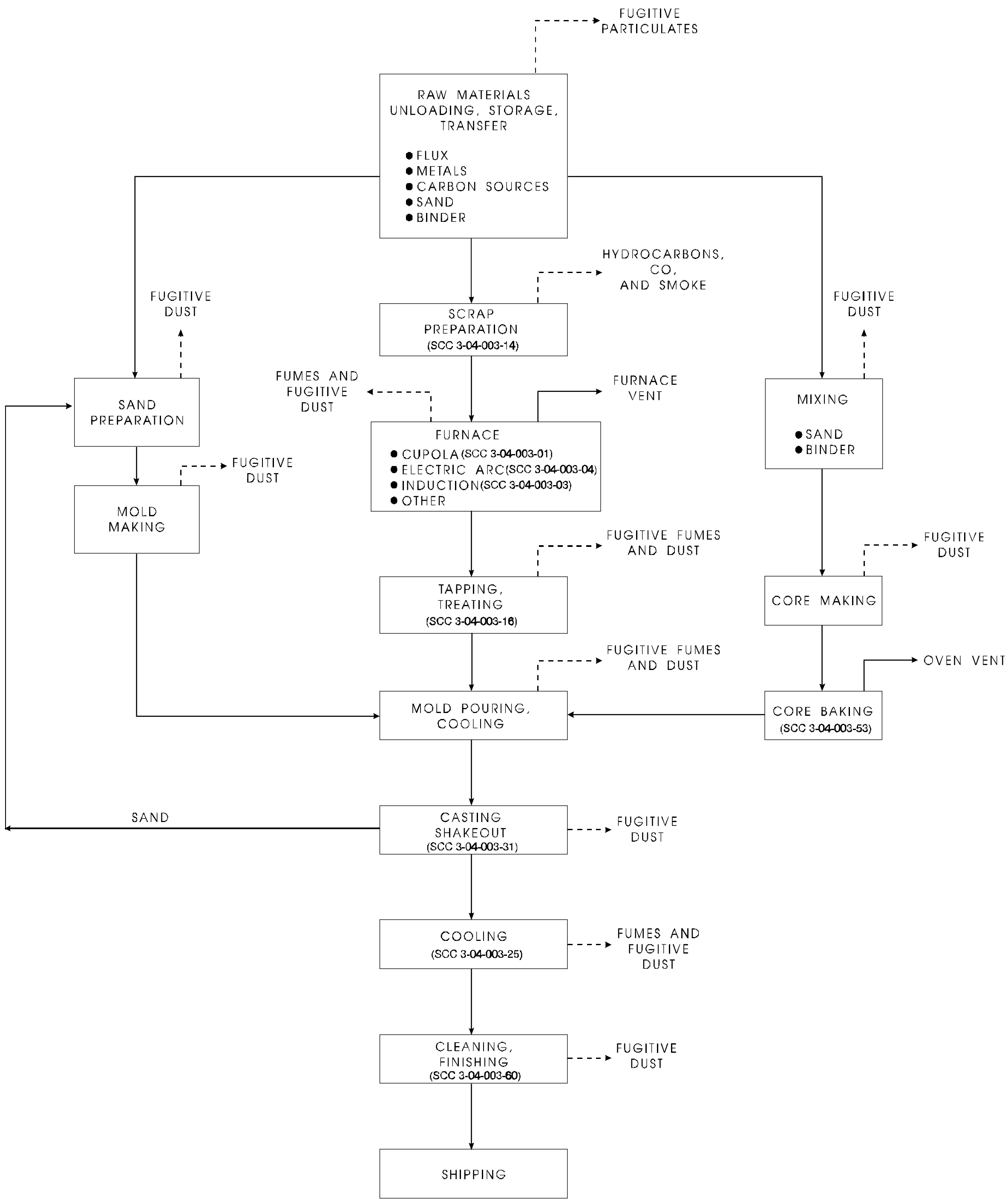

Figure 12.13-1. Flow diagram of a typical steel foundry.
(Source Classification Codes in parentheses.)

A direct electric arc furnace is a large refractory-lined steel pot, fitted with a refractory roof through which 3 vertical graphite electrodes are inserted, as shown in Figure 12.13-2. The metal charge is melted with resistive heating generated by electrical current flowing among the electrodes and through the charge.

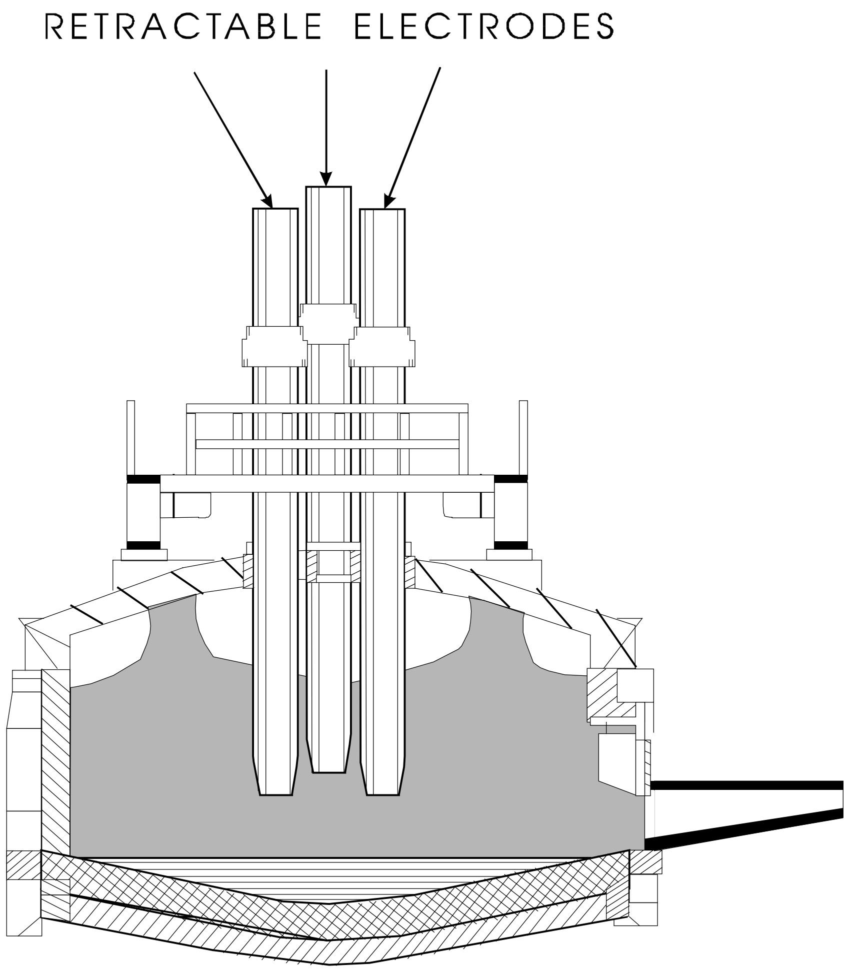

Figure 12.13-2. Electric arc steel furnace.

An induction furnace is a vertical refractory-lined cylinder surrounded by coils energized with alternating current. The resulting fluctuating magnetic field heats the metal. Induction furnaces are kept closed except when charging, skimming, and tapping. The molten metal is tapped by tilting and pouring through a spout on the side. Induction furnaces are also used in conjunction with other furnaces, to hold and superheat a charge, previously melted and refined in another furnace. A very small fraction of the secondary steel industry also uses crucible and pneumatic converter furnaces. A less common furnace used in steel foundries is the open hearth furnace, a very large shallow refractory-lined batch operated vessel. The open hearth furnace is fired at alternate ends, using the hot waste combustion gases to heat the incoming combustion air.

12.13.2.3 Mold And Core Production -

Cores are forms used to make the internal features in castings. Molds are forms used to shape the casting exterior. Cores are made of sand with organic binders, molded into a core and baked in an oven. Molds are made of sand with clay or chemical binders. Increasingly, chemical binders are being used in both core and mold production. Used sand from castings shakeout operations is usually recycled to the sand preparation area, where it is cleaned, screened, and reused.

12.13.2.4 Casting And Finishing -

When the melting process is complete, the molten metal is tapped and poured into a ladle. The molten metal may be treated in the ladle by adding alloys and/or other chemicals. The treated metal is then poured into molds and allowed to partially cool under carefully controlled conditions. When cooled, the castings are placed on a vibrating grid and the sand of the mold and core are shaken away from the casting.

In the cleaning and finishing process, burrs, risers, and gates are broken or ground off to match the contour of the casting. Afterward, the castings can be shot-blasted to remove remaining mold sand and scale.

12.13.3 Emissions And Controls[1,16]

Emissions from the raw materials handling operations are fugitive particulates generated from receiving, unloading, storing, and conveying all raw materials for the foundry. These emissions are controlled by enclosing the major emission points and routing the air from the enclosures through fabric filters.

Emissions from scrap preparation consist of hydrocarbons if solvent degreasing is used and consist of smoke, organics, and carbon monoxide (CO) if heating is used. Catalytic incinerators and afterburners of approximately 95 percent control efficiency for carbon monoxide and organics can be applied to these sources.

Emissions from melting furnaces are particulates, carbon monoxide, organics, sulfur dioxide, nitrogen oxides, and small quantities of chlorides and fluorides. The particulates, chlorides, and fluorides are generated by the flux. Scrap contains volatile organic compounds (VOCs) and dirt particles, along with oxidized phosphorus, silicon, and manganese. In addition, organics on the scrap and the carbon additives increase CO emissions. There are also trace constituents such as nickel, hexavalent chromium, lead, cadmium, and arsenic. The highest concentrations of furnace emissions occur when the furnace lids and doors are opened during charging, backcharging, alloying, oxygen lancing, slag removal, and tapping operations. These emissions escape into the furnace building and are vented through roof vents. Controls for emissions during the melting and refining operations focus on venting the furnace gases and fumes directly to an emission collection duct and control system. Controls for fugitive furnace emissions involve either the use of building roof hoods or special hoods near the furnace doors, to collect emissions and route them to emission control systems. Emission control systems commonly used to control particulate emissions from electric arc and induction furnaces are bag filters, cyclones, and venturi scrubbers. The capture efficiencies of the collection systems are presented in Tables 12.13-1 and 12.13-2. Usually, induction furnaces are uncontrolled.

Molten steel is tapped from a furnace into a ladle. Alloying agents can be added to the ladle. These include aluminum, titanium, zirconium, vanadium, and boron. Ferroalloys are used to produce steel alloys and adjust the oxygen content while the molten steel is in the ladle. Emissions consist of iron oxides during tapping in addition to oxide fumes from alloys added to the ladle.

The major pollutant from mold and core production are particulates from sand reclaiming, sand preparation, sand mixing with binders and additives, and mold and core forming. Particulate,

Table 12.13-1 (Metric Units). EMISSION FACTORS FOR STEEL FOUNDRIES

Process	Filterable Particulate[a] (TSP)	EMISSION FACTOR RATING	Nitrogen Oxides	EMISSION FACTOR RATING	Filterable PM-10	EMISSION FACTOR RATING
Melting						
Electric arc[b,c] (SCC 3-04-007-01)	6.5 (2 to 20)	E	0.1	E	ND	NA
Open hearth[d,e] (SCC 3-04-007-02)	5.5 (1 to 10)	E	0.005	E	ND	NA
Open hearth oxygen lanced[f,g] (SCC 3-04-007-03)	5 (4 to 5.5)	E	ND	NA	ND	NA
Electric induction[h] (SCC 3-04-007-05)	0.05	E	ND	NA	0.045	E
Sand grinding/handling in mold and core making[j] (SCC 3-04-007-06)	ND	NA	NA	NA	0.27[k] 3.0	E E
Core ovens[j] (SCC 3-04-007-07)	ND	NA	ND	NA	1.11[k] 0.45	E E
Pouring and casting[j] (SCC 3-04-007-08)	ND	NA	ND	NA	1.4	E
Casting cleaning[j] (SCC 3-04-007-11)	ND	NA	NA	NA	0.85	E
Charge handling[j] (SCC 3-04-007-12)	ND	NA	NA	NA	0.18	E
Casting cooling[j] (SCC 3-04-007-13)	ND	NA	NA	NA	0.7	E

[a] Expressed as kg/Mg of metal processed. If the scrap metal is very dirty or oily, or if increased oxygen lancing is employed, the emission factor should be chosen from the high side of the factor range. SCC = Source Classification Code. ND = no data. NA = not applicable.
[b] Electrostatic precipitator, 92 to 98% control efficiency; baghouse (fabric filter), 98 to 99% control efficiency; venturi scrubber, 94 to 98% control efficiency.
[c] References 2-7.
[d] Electrostatic precipitator, 95 to 98% control efficiency; baghouse , 99.9% control efficiency; venturi scrubber, 96 to 99% control efficiency.
[e] References 2,8-10.
[f] Electrostatic precipitator, 95 to 98% control efficiency; baghouse, 99% control efficiency; venturi scrubber, 95 to 98% control efficiency.
[g] References 5,11.
[h] Usually not controlled.
[j] Reference 13.
[k] Emission factor expressed as kg of pollutant/Mg of sand handled.

Table 12.13-2 (English Units). EMISSION FACTORS FOR STEEL FOUNDRIES

Process	Filterable Particulate[a]	EMISSION FACTOR RATING	Nitrogen Oxides	EMISSION FACTOR RATING	Filterable PM-10	EMISSION FACTOR RATING
Melting						
Electric arc[b,c] (SCC 3-04-007-01)	13 (4 to 40)	E	0.2	E	ND	NA
Open hearth[d,e] (SCC 3-04-007-02)	11 (2 to 20)	E	0.01	E	ND	NA
Open hearth oxygen lanced[f,g] (SCC 3-04-007-03)	10 (8 to 11)	E	ND	NA	ND	NA
Electric induction[h] (SCC 3-04-007-05)	0.1	E	ND	NA	0.09	E
Sand grinding/handling in mold and core making[j] (SCC 3-04-007-06)	ND	NA	NA	NA	0.54[k] 6.0	E E
Core ovens[j] (SCC 3-04-007-07)	ND	NA	ND	NA	2.22[k] 0.90	E E
Pouring and casting[j] (SCC 3-04-007-08)	ND	NA	ND	NA	2.8	E
Casting cleaning[j] (SCC 3-04-007-11)	ND	NA	NA	NA	1.7	E
Charge handling[j] (SCC 3-04-007-12)	ND	NA	NA	NA	0.36	E
Casting cooling[j] (SCC 3-04-007-13)	ND	NA	NA	NA	1.4	E

[a] Expressed as lb/ton of metal processed. If the scrap metal is very dirty or oily, or if increased oxygen lancing is employed, the emission factor should be chosen from the high side of the factor range. SCC = Source Classification Code.

[b] Electrostatic precipitator, 92 to 98% control efficiency; baghouse (fabric filter), 98 to 99% control efficiency; venturi scrubber, 94 to 98% control efficiency.

[c] References 2-7.

[d] Electrostatic precipitator, 95 to 98% control efficiency; baghouse , 99.9% control efficiency; venturi scrubber, 96 to 99% control efficiency.

[e] References 2,8-10.

[f] Electrostatic precipitator, 95 to 98% control efficiency; baghouse, 99% control efficiency; venturi scrubber, 95 to 98% control efficiency.

[g] References 5,11.

[h] Usually not controlled.

[j] Reference 13.

[k] Emission factor expressed as lb of pollutant/ton of sand handled.

VOC, and CO emissions result from core baking and VOC emissions occur during mold drying. Bag filters and scrubbers can be used to control particulates from mold and core production. Afterburners and catalytic incinerators can be used to control VOC and CO emissions.

During casting operations, large quantities of particulates can be generated in the steps prior to pouring. Emissions from pouring consist of fumes, CO, VOCs, and particulates from the mold and core materials when contacted by the molten steel. As the mold cools, emissions continue. A significant quantity of particulate emissions is generated during the casting shakeout operation. The particulate emissions from the shakeout operations can be controlled by either high-efficiency cyclone separators or bag filters. Emissions from pouring are usually uncontrolled.

Emissions from finishing operations consist of particulates resulting from the removal of burrs, risers, and gates and during shot blasting. Particulates from finishing operations can be controlled by cyclone separators.

Nonfurnace emissions sources in steel foundries are very similar to those in iron foundries. Nonfurnace emissions factors and particle size distributions for iron foundry emission sources for criteria and toxic pollutants are presented in Section 12.10, "Gray Iron Foundries".

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