

12.5 Iron And Steel Production

12.5.1 Process Description¹⁻³

The production of steel at an integrated iron and steel plant is accomplished using several interrelated processes. The major operations are: (1) coke production, (2) sinter production, (3) iron production, (4) iron preparation, (5) steel production, (6) semifinished product preparation, (7) finished product preparation, (8) heat and electricity supply, and (9) handling and transport of raw, intermediate, and waste materials. The interrelation of these operations is depicted in a general flow diagram of the iron and steel industry in Figure 12.5-1. Coke production is discussed in detail in Section 12.2 of this publication, and more information on the handling and transport of materials is found in Chapter 13.

12.5.1.1 Sinter Production -

The sintering process converts fine-sized raw materials, including iron ore, coke breeze, limestone, mill scale, and flue dust, into an agglomerated product, sinter, of suitable size for charging into the blast furnace. The raw materials are sometimes mixed with water to provide a cohesive matrix, and then placed on a continuous, travelling grate called the sinter strand. A burner hood, at the beginning of the sinter strand ignites the coke in the mixture, after which the combustion is self supporting and it provides sufficient heat, 1300 to 1480°C (2400 to 2700°F), to cause surface melting and agglomeration of the mix. On the underside of the sinter strand is a series of windboxes that draw combusted air down through the material bed into a common duct, leading to a gas cleaning device. The fused sinter is discharged at the end of the sinter strand, where it is crushed and screened. Undersize sinter is recycled to the mixing mill and back to the strand. The remaining sinter product is cooled in open air or in a circular cooler with water sprays or mechanical fans. The cooled sinter is crushed and screened for a final time, then the fines are recycled, and the product is sent to be charged to the blast furnaces. Generally, 2.3 Mg (2.5 tons) of raw materials, including water and fuel, are required to produce 0.9 Mg (1 ton) of product sinter.

12.5.1.2 Iron Production -

Iron is produced in blast furnaces by the reduction of iron bearing materials with a hot gas. The large, refractory lined furnace is charged through its top with iron as ore, pellets, and/or sinter; flux as limestone, dolomite, and sinter; and coke for fuel. Iron oxides, coke and fluxes react with the blast air to form molten reduced iron, carbon monoxide (CO), and slag. The molten iron and slag collect in the hearth at the base of the furnace. The byproduct gas is collected through offtakes located at the top of the furnace and is recovered for use as fuel.

The production of 1 ton of iron requires 1.4 tons of ore or other iron bearing material; 0.5 to 0.65 tons of coke; 0.25 tons of limestone or dolomite; and 1.8 to 2 tons of air. Byproducts consist of 0.2 to 0.4 tons of slag, and 2.5 to 3.5 tons of blast furnace gas containing up to 100 pounds (lb) of dust.

The molten iron and slag are removed, or cast, from the furnace periodically. The casting process begins with drilling a hole, called the taphole, into the clay-filled iron notch at the base of the hearth. During casting, molten iron flows into runners that lead to transport ladles. Slag also flows into the clay-filled iron notch at the base of the hearth. During casting, molten iron flows into runners that lead to transport ladles. Slag also flows from the furnace, and is directed through separate runners to a slag pit adjacent to the casthouse, or into slag pots for transport to a remote slag

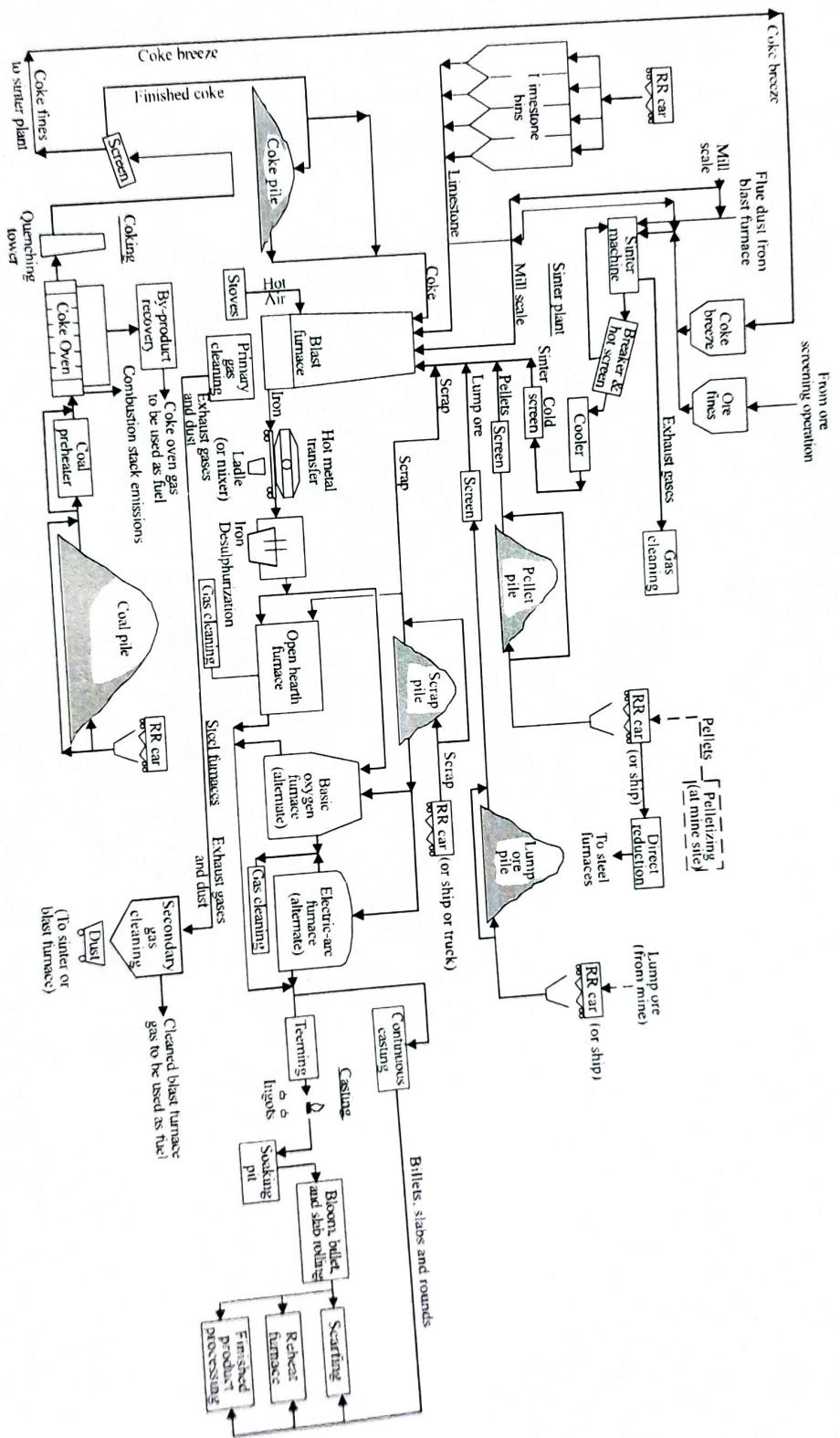


Figure 12.5-1. General flow diagram for the iron and steel industry.

the opposite polarity electrodes generates heat between the electrodes and through the scrap. After melting and refining periods, the slag and steel are poured from the furnace by tilting.

The production of steel in an EAF is a batch process. Cycles, or "heats", range from about 1-1/2 to 5 hours to produce carbon steel and from 5 to 10 hours or more to produce alloy steel. Scrap steel is charged to begin a cycle, and alloying agents and slag materials are added for refining. Stages of each cycle normally are charging and melting operations, refining (which usually includes oxygen blowing), and tapping.

12.5.1.6 Steelmaking Process — Open Hearth Furnaces -

The open hearth furnace (OHF) is a shallow, refractory-lined basin in which scrap and molten iron are melted and refined into steel. Scrap is charged to the furnace through doors in the furnace front. Hot metal from the blast furnace is added by pouring from a ladle through a trough positioned in the door. The mixture of scrap and hot metal can vary from all scrap to all hot metal, but a half-and-half mixture is most common. Melting heat is provided by gas burners above and at the side of the furnace. Refining is accomplished by the oxidation of carbon in the metal and the formation of a limestone slag to remove impurities. Most furnaces are equipped with oxygen lances to speed up melting and refining. The steel product is tapped by opening a hole in the base of the furnace with an explosive charge. The open hearth steelmaking process with oxygen lancing normally requires from 4 to 10 hours for each heat.

12.5.1.7 Semifinished Product Preparation -

After the steel has been tapped, the molten metal is teemed (poured) into ingots which are later heated and formed into other shapes, such as blooms, billets, or slabs. The molten steel may bypass this entire process and go directly to a continuous casting operation. Whatever the production technique, the blooms, billets, or slabs undergo a surface preparation step, scarfing, which removes surface defects before shaping or rolling. Scarfing can be performed by a machine applying jets of oxygen to the surface of hot semifinished steel, or by hand (with torches) on cold or slightly heated semifinished steel.

12.5.2 Emissions And Controls

12.5.2.1 Sinter -

Emissions from sinter plants are generated from raw material handling, windbox exhaust, discharge end (associated sinter crushers and hot screens), cooler, and cold screen. The windbox exhaust is the primary source of particulate emissions, mainly iron oxides, sulfur oxides, carbonaceous compounds, aliphatic hydrocarbons, and chlorides. At the discharge end, emissions are mainly iron and calcium oxides. Sinter strand windbox emissions commonly are controlled by cyclone cleaners followed by a dry or wet ESP, high pressure drop wet scrubber, or baghouse. Crusher and hot screen emissions, usually controlled by hooding and a baghouse or scrubber, are the next largest emissions source. Emissions are also generated from other material handling operations. At some sinter plants, these emissions are captured and vented to a baghouse.

12.5.2.2 Blast Furnace -

The primary source of blast furnace emissions is the casting operation. Particulate emissions are generated when the molten iron and slag contact air above their surface. Casting emissions also are generated by drilling and plugging the taphole. The occasional use of an oxygen lance to open a clogged taphole can cause heavy emissions. During the casting operation, iron oxides, magnesium oxide and carbonaceous compounds are generated as particulate. Casting emissions at existing blast furnaces are controlled by evacuation through retrofitted capture hoods to a gas cleaner, or by suppression techniques. Emissions controlled by hoods and an evacuation system are usually vented to

pit. At the conclusion of the cast, the taphole is replugged with clay. The area around the base of the furnace, including all iron and slag runners, is enclosed by a casthouse. The blast furnace byproduct gas, which is collected from the furnace top, contains CO and particulate. Because of its high CO content, this blast furnace gas has a low heating value, about 2790 to 3350 joules per liter (J/L) (75 to 90 British thermal units per cubic foot [Btu/ft³]) and is used as a fuel within the steel plant. Before it can be efficiently oxidized, however, the gas must be cleaned of particulate. Initially, the gases pass through a settling chamber or dry cyclone to remove about 60 percent of the particulate. Next, the gases undergo a 1- or 2-stage cleaning operation. The primary cleaner is normally a wet scrubber, which removes about 90 percent of the remaining particulate. The secondary cleaner is a high-energy wet scrubber (usually a venturi) or an electrostatic precipitator, either of which can remove up to 90 percent of the particulate that eludes the primary cleaner. Together these control devices provide a clean fuel of less than 0.05 grams per cubic meter (g/m³) (0.02 grains per cubic foot [g/ft³]). A portion of this gas is fired in the blast furnace stoves to preheat the blast air, and the rest is used in other plant operations.

12.5.1.3 Iron Preparation Hot Metal Desulfurization -

Sulfur in the molten iron is sometimes reduced before charging into the steelmaking furnace by adding reagents. The reaction forms a floating slag which can be skimmed off. Desulfurization may be performed in the hot metal transfer (torpedo) car at a location between the blast furnace and basic oxygen furnace (BOF), or it may be done in the hot metal transfer (torpedo) ladle at a station inside the BOF shop.

The most common reagents are powdered calcium carbide (CaC_2) and calcium carbonate (CaCO_3) or salt-coated magnesium granules. Powdered reagents are injected into the metal through a lance with high-pressure nitrogen. The process duration varies with the injection rate, hot metal chemistry, and desired final sulfur content, and is in the range of 5 to 30 minutes.

12.5.1.4 Steelmaking Process — Basic Oxygen Furnaces -

In the basic oxygen process (BOP), molten iron from a blast furnace and iron scrap are refined in a furnace by lancing (or injecting) high-purity oxygen. The input material is typically 70 percent molten metal and 30 percent scrap metal. The oxygen reacts with carbon and other impurities to remove them from the metal. The reactions are exothermic, i. e., no external heat source is necessary to melt the scrap and to raise the temperature of the metal to the desired range for tapping. The large quantities of CO produced by the reactions in the BOF can be controlled by combustion at the mouth of the furnace and then vented to gas cleaning devices, as with open hoods, or combustion can be suppressed at the furnace mouth, as with closed hoods. BOP steelmaking is conducted in large (up to 363 Mg [400 ton] capacity) refractory lined pear shaped furnaces. There are 2 major variations of the process. Conventional BOFs have oxygen blown into the top of the furnace through a water-cooled lance. In the newer, Quelle Basic Oxygen process (Q-BOP), oxygen is injected through tuyeres located in the bottom of the furnace. A typical BOF cycle consists of the scrap charge, hot metal charge, oxygen blow (refining) period, testing for temperature and chemical composition of the steel, alloy additions and reblooms (if necessary), tapping, and slagging. The full furnace cycle typically ranges from 25 to 45 minutes.

12.5.1.5 Steelmaking Process — Electric Arc Furnace -

Electric arc furnaces (EAF) are used to produce carbon and alloy steels. The input material to an EAF is typically 100 percent scrap. Cylindrical, refractory lined EAFs are equipped with carbon electrodes to be raised or lowered through the furnace roof. With electrodes retracted, the furnace roof can be rotated aside to permit the charge of scrap steel by overhead crane. Alloying agents and fluxing materials usually are added through the doors on the side of the furnace. Electric current of

a baghouse. The basic concept of suppression techniques is to prevent the formation of pollutants by excluding ambient air contact with the molten surfaces. New furnaces have been constructed with evacuated runner cover systems and local hooding ducted to a baghouse.

Another potential source of emissions is the blast furnace top. Minor emissions may occur during charging from imperfect bell seals in the double bell system. Occasionally, a cavity may form in the blast furnace charge, causing a collapse of part of the burden (charge) above it. The resulting pressure surge in the furnace opens a relief valve to the atmosphere to prevent damage to the furnace by the high pressure created and is referred to as a "slip".

12.5.2.3 Hot Metal Desulfurization -

Emissions during the hot metal desulfurization process are created by both the reaction of the reagents injected into the metal and the turbulence during injection. The pollutants emitted are mostly iron oxides, calcium oxides, and oxides of the compound injected. The sulfur reacts with the reagents and is skimmed off as slag. The emissions generated from desulfurization may be collected by a hood positioned over the ladle and vented to a baghouse.

12.5.2.4 Steelmaking -

The most significant emissions from the BOF process occur during the oxygen blow period. The predominant compounds emitted are iron oxides, although heavy metals and fluorides are usually present. Charging emissions will vary with the quality and quantity of scrap metal charged to the furnace and with the pour rate. Tapping emissions include iron oxides, sulfur oxides, and other metallic oxides, depending on the grade of scrap used. Hot metal transfer emissions are mostly iron oxides.

BOFs are equipped with a primary hood capture system located directly over the open mouth of the furnaces to control emissions during oxygen blow periods. Two types of capture systems are used to collect exhaust gas as it leaves the furnace mouth: closed hood (also known as an off gas, or O. G., system) or open, combustion-type hood. A closed hood fits snugly against the furnace mouth, ducting all particulate and CO to a wet scrubber gas cleaner. CO is flared at the scrubber outlet stack. The open hood design allows dilution air to be drawn into the hood, thus combusting the CO in the hood system. Charging and tapping emissions are controlled by a variety of evacuation systems and operating practices. Charging hoods, tapside enclosures, and full furnace enclosures are used in the industry to capture these emissions and send them to either the primary hood gas cleaner or a second gas cleaner.

12.5.2.5 Steelmaking — Electric Arc Furnace -

The operations which generate emissions during the electric arc furnace steelmaking process are melting and refining, charging scrap, tapping steel, and dumping slag. Iron oxide is the predominant constituent of the particulate emitted during melting. During refining, the primary particulate compound emitted is calcium oxide from the slag. Emissions from charging scrap are difficult to quantify, because they depend on the grade of scrap utilized. Scrap emissions usually contain iron and other metallic oxides from alloys in the scrap metal. Iron oxides and oxides from the fluxes are the primary constituents of the slag emissions. During tapping, iron oxide is the major particulate compound emitted.

Emission control techniques involve an emission capture system and a gas cleaning system. Five emission capture systems used in the industry are fourth hold (direct shell) evacuation, side draft hood, combination hood, canopy hood, and furnace enclosures. Direct shell evacuation consists of ductwork attached to a separate or fourth hole in the furnace roof which draws emissions to a gas cleaner. The fourth hole system works only when the furnace is up-right with the roof in place. Side

draft hoods collect furnace off gases from around the electrode holes and the work doors after the gases leave the furnace. The combination hood incorporates elements from the side draft and fourth hole ventilation systems. Emissions are collected both from the fourth hole and around the electrodes. An air gap in the ducting introduces secondary air for combustion of CO in the exhaust gas. The combination hood requires careful regulation of furnace interval pressure. The canopy hood is the least efficient of the 4 ventilation systems, but it does capture emissions during charging and tapping. Many new electric arc furnaces incorporate the canopy hood with one of the other 3 systems. The full furnace enclosure completely surrounds the furnace and evacuates furnace emissions through hooding in the top of the enclosure.

12.5.2.6 Steelmaking — Open Hearth Furnace -

Particulate emissions from an open hearth furnace vary considerably during the process. The use of oxygen lancing increases emissions of dust and fume. During the melting and refining cycle, exhaust gas drawn from the furnace passes through a slag pocket and a regenerative checker chamber, where some of the particulate settles out. The emissions, mostly iron oxides, are then ducted to either an ESP or a wet scrubber. Other furnace-related process operations which produce fugitive emissions inside the shop include transfer and charging of hot metal, charging of scrap, tapping steel, and slag dumping. These emissions are usually uncontrolled.

12.5.2.7 Semifinished Product Preparation -

During this activity, emissions are produced when molten steel is poured (teamed) into ingot molds, and when semifinished steel is machine or manually scarfed to remove surface defects. Pollutants emitted are iron and other oxides (FeO, Fe₂O₃, SiO₂, CaO, MgO). Teeming emissions are rarely controlled. Machine scarfing operations generally use an ESP or water spray chamber for control. Most hand scarfing operations are uncontrolled.

12.5.2.8 Miscellaneous Combustion -

Every iron and steel plant operation requires energy in the form of heat or electricity. Combustion sources that produce emissions on plant property are blast furnace stoves, boilers, soaking pits, and reheat furnaces. These facilities burn combinations of coal, No. 2 fuel oil, natural gas, coke oven gas, and blast furnace gas. In blast furnace stoves, clean gas from the blast furnace is burned to heat the refractory checker work, and in turn, to heat the blast air. In soaking pits, ingots are heated until the temperature distribution over the cross-section of the ingots is acceptable and the surface temperature is uniform for further rolling into semifinished products (blooms, billets, and slabs). In slab furnaces, a slab is heated before being rolled into finished products (plates, sheets, or strips). Emissions from the combustion of natural gas, fuel oil, or coal in the soaking pits or slab furnaces are estimated to be the same as those for boilers. (See Chapter 1 of this document.) Emission factor data for blast furnace gas and coke oven gas are not available and must be estimated. There are 3 facts available for making the estimation. First, the gas exiting the blast furnace passes through primary and secondary cleaners and can be cleaned to less than 0.05 g/m³ (0.02 g/ft³). Second, nearly one-third of the coke oven gas is methane. Third, there are no blast furnace gas constituents that generate particulate when burned. The combustible constituent of blast furnace gas is CO, which burns clean. Based on facts 1 and 3, the emission factor for combustion of blast furnace gas is equal to the particulate loading of that fuel, 0.05 g/m³ (2.9 lb/10⁶ ft³) having an average heat value of 3092 J/L (83 Btu/ft³).

Emissions for combustion of coke oven gas can be estimated in the same fashion. Assume that cleaned coke oven gas has as much particulate as cleaned blast furnace gas. Since one-third of the coke oven gas is methane, the main component of natural gas, it is assumed that the combustion of this methane in coke oven gas generates 0.06 g/m³ (3.3 lb/10⁶ ft³) of particulate. Thus, the emission factor for the combustion of coke oven gas is the sum of the particulate loading and that generated by

the methane combustion, or 0.1 g/m^3 ($6.2 \text{ lb}/10^6 \text{ ft}^3$) having an average heat value of $19,222 \text{ J/L}$ (516 Btu/ft^3).

The particulate emission factors for processes in Table 12.5-1 are the result of an extensive investigation by EPA and the American Iron and Steel Institute.³ Particle size distributions for controlled and uncontrolled emissions from specific iron and steel industry processes have been calculated and summarized from the best available data.¹ Size distributions have been used with particulate emission factors to calculate size-specific factors for the sources listed in Table 12.5-1 for which data are available. Table 12.5-2 presents these size-specific particulate emission factors. Particle size distributions are presented in Figure 12.5-2, Figure 12.5-3, and Figure 12.5-4. CO emission factors are in Table 12.5-3.⁶

12.5.2.9 Open Dust Sources -

Like process emission sources, open dust sources contribute to the atmospheric particulate burden. Open dust sources include vehicle traffic on paved and unpaved roads, raw material handling outside of buildings, and wind erosion from storage piles and exposed terrain. Vehicle traffic consists of plant personnel and visitor vehicles, plant service vehicles, and trucks handling raw materials, plant deliverables, steel products, and waste materials. Raw materials are handled by clamshell buckets, bucket/ladder conveyors, rotary railroad dumps, bottom railroad dumps, front end loaders, truck dumps, and conveyor transfer stations, all of which disturb the raw material and expose fines to the wind. Even fine materials, resting on flat areas or in storage piles are exposed and are subject to wind erosion. It is not unusual to have several million tons of raw materials stored at a plant and to have in the range of 9.7 to 96.7 hectares (10 to 100 acres) of exposed area there.

Open dust source emission factors for iron and steel production are presented in Table 12.5-4. These factors were determined through source testing at various integrated iron and steel plants.

As an alternative to the single-valued open dust emission factors given in Table 12.5-4, empirically derived emission factor equations are presented in Section 13.2 of this document. Each equation was developed for a source operation defined on the basis of a single dust generating mechanism which crosses industry lines, such as vehicle traffic on unpaved roads. The predictive equation explains much of the observed variance in measured emission factors by relating emissions to parameters which characterize source conditions. These parameters may be grouped into 3 categories: (1) measures of source activity or energy expended (e. g., the speed and weight of a vehicle traveling on an unpaved road), (2) properties of the material being disturbed (e. g., the content of suspendable fines in the surface material on an unpaved road) and (3) climatic parameters (e. g., number of precipitation free days per year, when emissions tend to a maximum).⁴

Because the predictive equations allow for emission factor adjustment to specific source conditions, the equations should be used in place of the factors in Table 12.5-4, if emission estimates for sources in a specific iron and steel facility are needed. However, the generally higher-quality ratings assigned to the equations are applicable only if (1) reliable values of correction parameters have been determined for the specific sources of interest and (2) the correction parameter values lie within the ranges tested in developing the equations. Section 13.2 lists measured properties of aggregate process materials and road surface materials in the iron and steel industry, which can be used to estimate correction parameter values for the predictive emission factor equations, in the event that site-specific values are not available.

Use of mean correction parameter values from Section 13.2 reduces the quality ratings of the emission factor equation by one level.