12.5.1 Minimills

12.5.1.1 Process Description

In a minimill, scrap metal is melted and refined in an electric arc furnace (EAF) to make steel products. Generally, molten steel is produced in an EAF and then tapped from the EAF to a ladle. The molten steel is then usually further refined with the addition of alloys. Semifinished product is then produced using continuous casting or ingot casting. Multiple finishing processes may then be used to produce finished steel products. A general flow diagram for a minimill is presented in Figure 12.5-1.

12.5.1.1.1 Electric Arc Furnace

The input material for 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. Some furnaces are charged through a shaft or continuously charged from a conveyor without the removal of the furnace roof. Electric current generates heat between the electrodes and through the scrap to melt the scrap.

The production of steel in an EAF is a batch process. Stages include charging, melting, refining, slagging, and tapping. During the charging stage scrap is introduced into the EAF. The charge can also include lime or carbon. Direct reduced iron (DRI),or other iron bearing material can supplement the scrap steel used as charge material. Components of the DRI production process include a DRI reformer, which prepares the reducing gas, and a metallized briquetter, which forms pellets of the DRI.[1]

After the charging stage, the next step is the melting phase, during which electrical energy is supplied to the furnace interior. Sources such as oxy-fuel burners and oxygen lances may also be used to supply chemical energy. Oxy-fuel burners, which burn natural gas and oxygen, use convection and flame radiation to transfer heat to the scrap. During oxygen lancing, oxygen is injected directly into the melt; exothermic reactions with the iron and other components of the melt provide additional energy to assist in the melting of the scrap and remove excess carbon. Alloying elements may be added to achieve the desired composition.

Refining of the melt can occur simultaneously with melting, especially in EAF operations where oxygen is introduced throughout the heat. During the refining process, impurities such as phosphorus, sulfur, silicon, and carbon are removed from the steel. These elements react with the oxygen to form oxides, which then become slag on top of the steel. The slag is typically removed by tipping the furnace backwards and pouring the slag out through a slag door.[2]

After completion of the heat, the tap hole is opened, and the steel is poured into a ladle for transfer to the next operation.

12.5.1.1.2 Argon Oxygen Decarburization

Argon oxygen decarburization (AOD) is a process used to further refine the steel outside the EAF to produce stainless and speciality steels. In the AOD process, steel from the EAF is transferred into an AOD vessel; gaseous mixtures containing argon and oxygen or nitrogen are

blown into the vessel. The carbon in the steel is reduced by combining it with the oxygen. Argon assists the carbon removal by increasing the affinity of carbon for oxygen[3].

12.5.1.1.3 Ladle Metallurgy

After initial melting and refining of the steel in the EAF, molten steel is refined in a ladle metallurgy process. There are numerous ladle metallurgy processes including ladle temperature control, composition control, deoxidation, degassing, cleanliness control, and others.4 Alloys such as lime, carbon, magnesium, and aluminum may be added to the molten steel to produce the desired metallurgy[5]. Electric arc heating is generally used in the final refining process.

12.5.1.1.4 Finishing

Most steel follows one of two major routes to final processing. The most common finishing method is continuous casting. In this process, a ladle with molten steel is lifted to the top of the continuous caster, where it flows into a reservoir, or tundish, and then into the molds of the continuous casting machine. As the steel passes through the molds and is cooled, a thin skin forms on the outside of the steel. Various designs of the casters shape the steel as it continues to flow. The steel is shaped into semifinished products such as blooms, billets, or slabs, and subsequently into more finished products.

Another finishing route, which is not used as frequently as continuous casting, is ingot casting. Molten steel is poured from the ladle into an ingot mold, where it cools and begins to solidify. The molds are stripped away, and the ingots are transported to a soaking pit or reheat furnace where they are heated to a uniform temperature. The ingots are shaped by rolling into semifinished products, usually blooms, billets, slabs, or by forging. Continuous casting is the preferred method of semifinished product production because the soaking-reheating step is eliminated[3].

The semifinished products may be further processed by a number of different steps, such as hot forming, cold rolling, pickling, galvanizing, coating, or painting. Some of these steps require additional heating or reheating. For example, one type of furnace used for heating is a tunnel furnace, which has cars that are moved slowly through the furnace. Annealing furnaces are another example.

12.5.1.2 Emissions and Controls

12.5.1.2.1 Electric Arc Furnace

The operations which generate emissions during the EAF steelmaking process are charging scrap, melting and refining, dumping slag, and tapping steel. These processes produce metal dusts and gaseous products. The composition of the particulate emitted can vary depending on the scrap composition and furnace additives such as fluxes that are added to aid in slag formation. Iron or iron oxides is the primary component of the particulate, and zinc, chromium, nickel oxides, lead, and cadmium may also be present. Gaseous pollutants such as NOx and CO may also be emitted. Based on well known natural gas combustion relationships, NOx emissions are expected to increase with the use of oxy-fuel burners, though no specific information supporting this assumption was found.

Emissions from EAFs can be captured using direct shell evacuation to a baghouse. This is usually used in conjunction with a canopy hood in the roof that also vents to the baghouse. Some minimills have a common baghouse through which emissions from the EAF processes as well as emissions from the ladle metallurgy process and/or continuous caster are ducted and subsequently controlled. For DRI production processes, a cyclone and scrubber are used to control the DRI reformer; metallized briquetters are also controlled by a scrubber.

12.5.1.2.2 Argon Oxygen Decarburization

The AOD vessel is a potential source of emissions of several pollutants, including particulate, NOx and CO. A baghouse may be used to control particulate emissions from the AOD vessel.

12.5.1.2.3 Ladle Metallurgy

Emission sources in the ladle metallurgy process include the ladle furnace and the ladle heater. At some facilities, a roof canopy hood is used to capture the emissions, which are then vented to a baghouse (which may be the same baghouse used by the EAF).

12.5.1.2.4 Finishing

At some facilities, fugitive particulate emissions may be emitted through a roof monitor during transfer from the ladle to the tundish and the continuous caster. No information is available on any control devices employed for these processes. Other potential sources of emissions, especially NOx and CO, include reheat furnaces, annealing furnaces, and tunnel furnaces used in the finishing processes. Low NOx burners, ultra-low NOx burners, flue gas recirculation, or selective catalytic reduction (SCR) are being used on some of these furnaces to control emissions of NOx.

12.5.1.3 Emission Factors

The emission factors for minimills are the result of an extensive data-gathering effort by EPA. Emissions data for PM, NOx, CO, SO2, lead, VOC, fluoride, and beryllium were gathered for several of the emission sources at minimills. The emission factors are presented in Tables 12.5-1 through 12.5-2 and are in units of pounds per ton (lb/ton) of steel produced or pounds per million British thermal units (lb/MMBtu) of heat input (applicable for furnaces). Where possible, the values have been rounded to two significant figures; however, in some cases, the data on which the emission factors were based contained only one significant figure.

12.5.1-1. FILTERABLE PM EMISSION FACTORS FOR MINIMILLS

Source	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Electric arc furnace Charging, melting, slagging, tapping Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse	B	0.083	lb/ton
Ladle metallurgy Controlled by baghouse	E	0.0009	lb/ton
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse	B	0.053	lb/ton
Electric arc furnace and continuous caster Charging, melting, slagging, tapping, continuous casting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse	E	0.018	lb/ton
Electric arc furnace, ladle metallurgy, and continuous caster Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting, continuous casting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse	E	0.067	lb/ton

12.5.1-1. FILTERABLE PM EMISSION FACTORS (Continued)

Source	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Ladle heating and transfer and continuous casting Uncontrolled leaving roof monitor	E	0.12	lb/ton
Metallized briquetter Controlled by scrubber	E	0.15	lb/ton
Reheat furnace, natural gas-fired Uncontrolled	E	0.036	lb/ton
Reheat furnace, natural gas-fired Controlled by SCR	E	0.0035	lb/MMBtu
Cold reversing mill Controlled by high efficiency mist eliminator	E	0.021	lb/ton
Billet cutting torches, natural gas-fired Uncontrolled	E	0.032	lb/ton

[a] Unit of lb/ton is lb/ton of steel produced. Unit of lb/MMBtu is lb/MMBtu heat input.

12.5.1-2. CONDENSABLE PM EMISSION FACTORS FOR MINIMILLS

Source	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse	D	0.073	lb/ton
Ladle metallurgy Controlled by baghouse	E	0.0039	lb/ton

[a] Unit of lb/ton is lb/ton of steel produced.

12.5.1-3. TOTAL PM (FILTERABLE + CONDENSABLE)
EMISSION FACTORS FOR MINIMILLS

Source	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Electric arc furnace Charging, melting, slagging, tapping Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse	D	0.064	lb/ton
Ladle metallurgy Controlled by baghouse	E	0.0054	lb/ton
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse	E	1.1	lb/ton

a Unit of lb/ton is lb/ton of steel produced.

12.5.1-4. NOx EMISSION FACTORS FOR MINIMILLS

Source	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Electric arc furnace Charging, melting, slagging, tapping Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse without oxygen lancing and oxy-fuel burners	D	0.22	lb/ton
Electric arc furnace Charging, melting, slagging, tapping Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse with oxygen lancing and oxy-fuel burners	E	0.31	lb/ton
Ladle metallurgy Controlled by baghouse	E	0.011	lb/ton
Argon oxygen decarburization vessel Controlled by baghouse	E	0.10	lb/ton
Electric arc furnace and argon oxygen decarburization vessel Fugitive emissions, controlled by roof monitor exhausted to baghouse	E	0.0020	lb/ton
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood without oxygen lancing and oxy-fuel burners	E	0.27	lb/ton

12.5.1-4. NOx EMISSION FACTORS FOR MINIMILLS (Continued)

Source	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood with oxygen lancing	E	0.48	lb/ton
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood with oxy-fuel burners	E	0.32	lb/ton
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood with oxygen lancing and oxy-fuel burners	E	0.30	lb/ton

12.5.1-4. NOx EMISSION FACTORS FOR MINIMILLS (Continued)

Source	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Electric arc furnace, ladle metallurgy, and continuous caster Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting, continuous casting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse with argon oxygen decarburization vessel	E	0.38	lb/ton
Electric arc furnace, ladle metallurgy, and continuous caster Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting, continuous casting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse with oxy-fuel burners and oxygen lancing	E	0.13	lb/ton
Direct reduced iron reformer Controlled by cyclone and scrubber	E	0.96	lb/ton
Reheat furnace, natural gas-fired Controlled by SCR	E	0.085	lb/MMBtu
Reheat furnace, natural gas-fired Controlled by low NOx burners	E	0.068 0.19	lb/ton lb/MMBtu

12.5.1-4. NOx EMISSION FACTORS FOR MINIMILLS (Continued)

Source	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Reheat furnace, natural gas-fired Controlled by ultra-low NOx burners and flue gas recirculation	E	0.17	lb/MMBtu
Annealing furnace, natural gas-fired Uncontrolled	E	0.26	lb/MMBtu
Annealing furnace, natural gas-fired Controlled by low NOx burners	E	0.085	lb/MMBtu
Tunnel furnace, natural gas-fired Controlled by low NOx burners	E	0.072	lb/MMBtu

[a] Unit of lb/ton is lb/ton of steel produced. Unit of lb/MMBtu is lb/MMBtu heat input.

12.5.1-5. CO EMISSION FACTORS FOR MINIMILLS

Source	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Electric arc furnace Charging, melting, slagging, tapping Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse without oxygen lancing and oxy-fuel burners	C	1.6	lb/ton
Electric arc furnace Charging, melting, slagging, tapping Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse with oxygen lancing and oxy-fuel burners	C	1.8	lb/ton
Ladle metallurgy Controlled by baghouse	E	0.016	lb/ton
Argon oxygen decarburization vessel Controlled by baghouse	E	0.60	lb/ton
Electric arc furnace and argon oxygen decarburization vessel Fugitive emissions, controlled by roof monitor exhausted to baghouse	E	0.11	lb/ton

12.5.1-5. CO EMISSION FACTORS FOR MINIMILLS (Continued)

Source	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse without oxygen lancing and oxy-fuel burners	D	2.1	lb/ton
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse with oxy-fuel burners	E	1.5	lb/ton
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse with oxy-fuel burners and oxygen lancing	D	3.8	lb/ton

12.5.1-5. CO EMISSION FACTORS FOR MINIMILLS (Continued)

Source	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Electric arc furnace, argon oxygen decarburization, ladle metallurgy, and continuous caster Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting, continuous casting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse	E	1.0	lb/ton
Reheat furnace, natural gas-fired Controlled by SCR	E	0.00060	lb/MMBtu
Reheat furnace, natural gas-fired Controlled by low NOx burners	E	0.021	lb/MMBtu
Reheat furnace, natural gas-fired Controlled by ultra-low NOx burners and flue gas recirculation	E	0.00011	lb/MMBtu
Annealing furnace, natural gas-fired Controlled by low NOx burners	E	0.0018	lb/MMBtu

[a] Unit of lb/ton is lb/ton of steel produced. Unit of lb/MMBtu is lb/MMBtu heat input.

12.5.1-6. SO2 EMISSION FACTORS FOR MINIMILLS

Source	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Electric arc furnace Charging, melting, slagging, tapping Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse without oxygen lancing and oxy-fuel burners	D	0.090	lb/ton
Electric arc furnace Charging, melting, slagging, tapping Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse with oxygen lancing and oxy-fuel burners	D	0.10	lb/ton
Ladle metallurgy Controlled by baghouse	E	0.035	lb/ton
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse without oxygen lancing and oxy-fuel burners	D	0.36	lb/ton

12.5.1-6. SO2 EMISSION FACTORS FOR MINIMILLS (Continued)

Source	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse with oxygen lancing	D	0.22	lb/ton
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse with oxy-fuel burners	D	0.096	lb/ton
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse with oxygen lancing and oxy-fuel burners	D	0.38	lb/ton

12.5.1-6. SO2 EMISSION FACTORS FOR MINIMILLS (Continued)

Source	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Electric arc furnace, ladle metallurgy, and continuous caster Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting, continuous casting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse with argon oxygen decarburization vessel	E	0.046	lb/ton
Electric arc furnace, ladle metallurgy, and continuous caster Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting, continuous casting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse with oxy-fuel burners	E	0.18	lb/ton
Direct reduced iron reformer Controlled by cyclone and scrubber	E	0.048	lb/ton

[a] Unit of lb/ton is lb/ton of steel produced.

12.5.1-7. LEAD EMISSION FACTORS FOR MINIMILLS

Source	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Electric arc furnace Charging, melting, slagging, tapping Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse without oxygen lancing and oxy-fuel burners	E	0.00066	lb/ton
Electric arc furnace Charging, melting, slagging, tapping Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse with oxygen lancing and oxy-fuel burners	E	0.0003	lb/ton
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse without oxygen lancing and oxy-fuel burners	E	0.00041	lb/ton

12.5.1-7. LEAD EMISSION FACTORS FOR MINIMILLS (Continued)

Source	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse without oxygen lancing and oxy-fuel burners	E	0.032	lb/ton

a Unit of lb/ton is lb/ton of steel produced.

12.5.1-8. VOC EMISSION FACTORS FOR MINIMILLS

Source	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Electric arc furnace Charging, melting, slagging, tapping Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse without oxygen lancing and oxy-fuel burners	E	0.17	lb/ton
Electric arc furnace Charging, melting, slagging, tapping Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse with oxygen lancing and oxy-fuel burners	E	0.057	lb/ton
Ladle metallurgy Controlled by baghouse	E	0.0033	lb/ton
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse without oxygen lancing	D	0.16	lb/ton

12.5.1-8. VOC EMISSION FACTORS FOR MINIMILLS (Continued)

Source	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse with oxygen lancing and oxy-fuel burners	D	1.4	lb/ton
Electric arc furnace, argon oxygen decarburization, ladle metallurgy, and continuous caster Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting, continuous casting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse	E	24	lb/ton

[a] Unit of lb/ton is lb/ton of steel produced.

12.5.1-9. OTHER EMISSION FACTORS FOR MINIMILLS

Source	Pollutant	EMISSION FACTOR RATING	Emission Factor	Unit[a]
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse	Beryllium	E	7.4E-08	lb/ton
Electric arc furnace and ladle metallurgy Charging, melting, slagging, tapping, ladle transfer to ladle furnace, ladle preheater, alloy addition to ladle furnace, ladle furnace melting Controlled by direct shell evacuation and roof canopy hood exhausted to baghouse	Fluoride	E	0.075	lb/ton

a Unit of lb/ton is lb/ton of steel produced.

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