11.24 Metallic Minerals Processing

11.24.1 Process Description[1-6]

Metallic mineral processing typically involves the mining of ore from either open pit or underground mines; the crushing and grinding of ore; the separation of valuable minerals from matrix rock through various concentration steps; and at some operations, the drying, calcining, or pelletizing of concentrates to ease further handling and refining. Figure 11.24-1 is a general flow diagram for metallic mineral processing. Very few metallic mineral processing facilities will contain all of the operations depicted in this figure, but all facilities will use at least some of these operations in the process of separating valued minerals from the matrix rock.

The number of crushing steps necessary to reduce ore to the proper size vary with the type of ore. Hard ores, including some copper, gold, iron, and molybdenum ores, may require as much as a tertiary crushing. Softer ores, such as some uranium, bauxite, and titanium/zirconium ores, require little or no crushing. Final comminution of both hard and soft ores is often accomplished by grinding operations using media such as balls or rods of various materials. Grinding is most often performed with an ore/water slurry, which reduces particulate matter (PM) emissions to negligible levels. When dry grinding processes are used, PM emissions can be considerable.

After final size reduction, the beneficiation of the ore increases the concentration of valuable minerals by separating them from the matrix rock. A variety of physical and chemical processes is used to concentrate the mineral. Most often, physical or chemical separation is performed in an aqueous environment, which eliminates PM emissions, although some ferrous and titaniferous minerals are separated by magnetic or electrostatic methods in a dry environment.

The concentrated mineral products may be dried to remove surface moisture. Drying is most frequently done in natural gas-fired rotary dryers. Calcining or pelletizing of some products, such as alumina or iron concentrates, is also performed. Emissions from calcining and pelletizing operations are not covered in this section.

11.24.2 Process Emissions[7-9]

Particulate matter emissions result from metallic mineral plant operations such as crushing and dry grinding ore, drying concentrates, storing and reclaiming ores and concentrates from storage bins, transferring materials, and loading final products for shipment. Particulate matter emission factors are provided in Tables 11.24-1 and 11.24-2 for various metallic mineral process operations including primary, secondary, and tertiary crushing; dry grinding; drying; and material handling and transfer. Fugitive emissions are also possible from roads and open stockpiles, factors for which are in Section 13.2.

The emission factors in Tables 11.24-1 and 11.24-2 are for the process operations as a whole. At most metallic mineral processing plants, each process operation requires several types of equipment. A single crushing operation likely includes a hopper or ore dump, screen(s), crusher, surge bin, apron feeder, and conveyor belt transfer points. Emissions from these various pieces of equipment are often ducted to a single control device. The emission factors provided in Tables 11.24-1 and 11.24-2 for primary, secondary, and tertiary crushing operations are for process units that are typical arrangements of the above equipment.

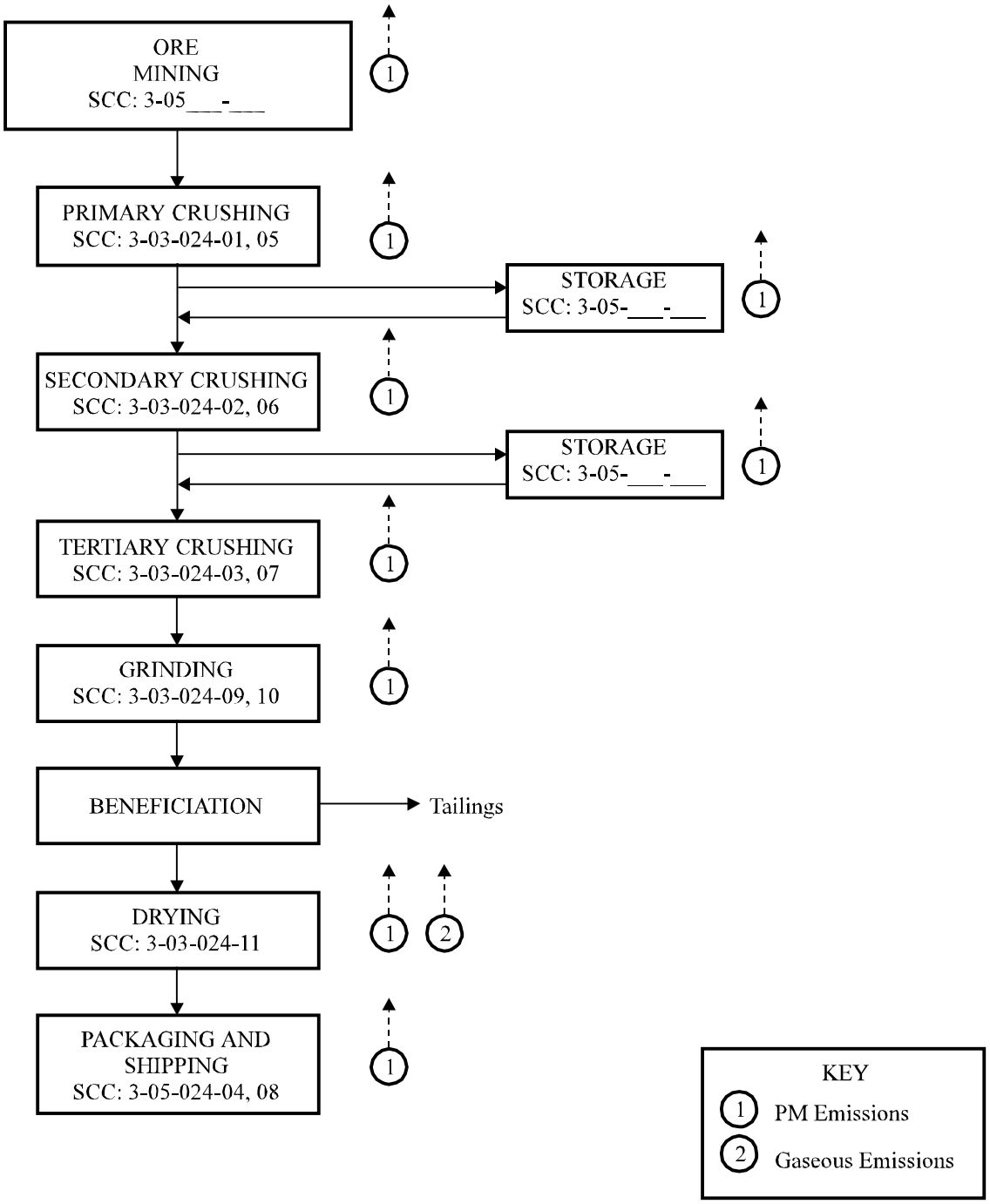

Figure 11.24-1. Process flow diagram for metallic mineral processing.

of the above equipment.

Table 11.24-1 (Metric Units). EMISSION FACTORS FOR METALLIC MINERALS PROCESSING[a]

EMISSION FACTOR RATINGS: (A-E) Follow The Emission Factor

Source	Filterable[b,c]			
	PM	RATING	PM-10	RATING
Low-moisture ore[c]				
Primary crushing (SCC 3-03-024-01)[d]	0.2	C	0.02	C
Secondary crushing (SCC 3-03-024-02)[d]	0.6	D	ND	
Tertiary crushing (SCC 3-03-024-03)[d]	1.4	E	0.08	E
Wet grinding	Neg		Neg	
Dry grinding with air conveying and/or air classification (SCC 3-03-024-09)[e]	14.4	C	13	C
Dry grinding without air conveying and/or air classification (SCC 3-03-024-10)[e]	1.2	D	0.16	D
Drying--all minerals except titanium/zirconium sands (SCC 3-03-024-11)[f]	9.8	C	5.9	C
Drying--titanium/zirconium with cyclones (SCC 3-03-024-11)[f]	0.3	C	ND	C
Material handling and transfer--all minerals except bauxite (SCC 3-03-024-04)[g]	0.06	C	0.03	C
Material handling and transfer--bauxite/alumina (SCC 3-03-024-04)[g,h]	0.6	C	ND	
High-moisture ore[c]				
Primary crushing (SCC 3-03-024-05)[d]	0.01	C	0.004	C
Secondary crushing (SCC 3-03-024-06)[d]	0.03	D	0.012	D
Tertiary crushing (SCC 3-03-024-07)[d]	0.03	E	0.01	E
Wet grinding	Neg		Neg	
Dry grinding with air conveying and/or air classification (SCC 3-03-024-09)[e]	14.4	C	13	C
Dry grinding without air conveying and/or air classification (SCC 3-03-024-10)[e]	1.2	D	0.16	D
Drying--all minerals except titanium/zirconium sands (SCC 3-03-024-11)[f]	9.8	C	5.9	C
Drying--titanium/zirconium with cyclones (SCC 3-03-024-11)[f]	0.3	C	ND	
Material handling and transfer--all minerals except bauxite (SCC 3-03-024-08)[g]	0.005	C	0.002	C
Material handling and transfer--bauxite/alumina (SCC 3-03-024-08)[g,h]	ND		ND	

[a] References 9-12; factors represent uncontrolled emissions unless otherwise noted; controlled emission factors are discussed in Section 11.24.3. All emission factors are in kg/Mg of material processed unless noted. SCC = Source Classification Code. Neg = negligible. ND = no data.

[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.

[c] Defined in Section 11.24.2.

[d] Based on weight of material entering primary crusher.

[e] Based on weight of material entering grinder; emission factors are the same for both low-moisture and high-moisture ore because material is usually dried before entering grinder.

[f] Based on weight of material exiting dryer; emission factors are the same for both high-moisture and low-moisture ores; SO_x emissions are fuel dependent (see Chapter 1); NO_x emissions depend on burner design and combustion temperature (see Chapter 1).

[g] Based on weight of material transferred; applies to each loading or unloading operation and to each conveyor belt transfer point.

[h] Bauxite with moisture content as high as 15 to 18% can exhibit the emission characteristics of low-moisture ore; use low-moisture ore emission factor for bauxite unless material exhibits obvious sticky, nondusting characteristics.

Table 11.24-2 (English Units). EMISSION FACTORS FOR METALLIC MINERALS PROCESSING[a,b]

EMISSION FACTOR RATINGS: (A-E) Follow The Emission Factor

Source	Filterable[b,c]			
	PM	RATING	PM-10	RATING
Low-moisture ore[c]				
Primary crushing (SCC 3-03-024-01)[d]	0.5	C	0.05	C
Secondary crushing (SCC 303-024-02)[d]	1.2	D	ND	
Tertiary crushing (SCC 3-03-024-03)[d]	2.7	E	0.16	E
Wet grinding	Neg		Neg	
Dry grinding with air conveying and/or air classification (SCC 3-03-024-09)[e]	28.8	C	26	C
Dry grinding without air conveying and/or air classification (SCC 3-03-024-10)[e]	2.4	D	0.31	D
Drying--all minerals except titanium/zirconium sands (SCC 3-03-024-11)[f]	19.7	C	12	C
Drying--titanium/zirconium with cyclones (SCC 3-03-024-11)[f]	0.5	C	ND	C
Material handling and transfer--all minerals except bauxite (SCC 3-03-024-04)[g]	0.12	C	0.06	C
Material handling and transfer--bauxite/alumina (SCC 3-03-024-04)[g,h]	1.1	C	ND	
High-moisture ore[c]				
Primary crushing (SCC 3-03-024-05)[d]	0.02	C	0.009	C
Secondary crushing (SCC 3-03-024-06)[d]	0.05	D	0.02	D
Tertiary crushing (SCC 3-03-024-07)[d]	0.06	E	0.02	E
Wet grinding	Neg		Neg	
Dry grinding with air conveying and/or air classification (SCC 3-03-024-09)[e]	28.8	C	26	C
Dry grinding without air conveying and/or air classification (SCC 3-03-024-10)[e]	2.4	D	0.31	D
Drying--all minerals except titanium/zirconium sands (SCC 3-03-024-11)[f]	19.7	C	12	C
Drying--titanium/zirconium with cyclones (SCC 3-03-024-11)[f]	0.5	C	ND	
Material handling and transfer--all minerals except bauxite (SCC 3-03-024-08)[g]	0.01	C	0.004	C
Material handling and transfer--bauxite/alumina (SCC 3-03-024-08)[g,h]	ND		ND	

[a] References 9-12; factors represent uncontrolled emissions unless otherwise noted; controlled emission factors are discussed in Section 11.24.3. All emission factors are in lb/ton of material processed unless noted. SCC = Source Classification Code. Neg = negligible. ND = no data.

[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.

[c] Defined in Section 11.24.2.

[d] Based on weight of material entering primary crusher.

[e] Based on weight of material entering grinder; emission factors are the same for both low-moisture and high-moisture ore because material is usually dried before entering grinder.

[f] Based on weight of material exiting dryer; emission factors are the same for both high-moisture and low-moisture ores; SO_x emissions are fuel dependent (see Chapter 1); NO_x emissions depend on burner design and combustion temperature (see Chapter 1).

[g] Based on weight of material transferred; applies to each loading or unloading operation and to each conveyor belt transfer point.

[h] Bauxite with moisture content as high as 15 to 18% can exhibit the emission characteristics of low-moisture ore; use low-moisture ore emission factor for bauxite unless material exhibits obvious sticky, nondusting characteristics.

Emission factors are provided in Tables 11.24-1 and 11.24-2 for two types of dry grinding operations: those that involve air conveying and/or air classification of material and those that involve screening of material without air conveying. Grinding operations that involve air conveying and air classification usually require dry cyclones for efficient product recovery. The factors in Tables 11.24-1 and 11.24-2 are for emissions after product recovery cyclones. Grinders in closed circuit with screens usually do not require cyclones. Emission factors are not provided for wet grinders because the high-moisture content in these operations can reduce emissions to negligible levels.

The emission factors for dryers in Tables 11.24-1 and 11.24-2 include transfer points integral to the drying operation. A separate emission factor is provided for dryers at titanium/zirconium plants that use dry cyclones for product recovery and for emission control. Titanium/zirconium sand-type ores do not require crushing or grinding, and the ore is washed to remove humic and clay material before concentration and drying operations.

At some metallic mineral processing plants, material is stored in enclosed bins between process operations. The emission factors provided in Tables 11.24-1 and 11.24-2 for the handling and transfer of material should be applied to the loading of material into storage bins and the transferring of material from the bin. The emission factor will usually be applied twice to a storage operation: once for the loading operation and once for the reclaiming operation. If material is stored at multiple points in the plant, the emission factor should be applied to each operation and should apply to the material being stored at each bin. The material handling and transfer factors do not apply to small hoppers, surge bins, or transfer points that are integral with crushing, drying, or grinding operations.

At some large metallic mineral processing plants, extensive material transfer operations with numerous conveyor belt transfer points may be required. The emission factors for material handling and transfer should be applied to each transfer point that is not an integral part of another process unit. These emission factors should be applied to each such conveyor transfer point and should be based on the amount of material transferred through that point.

The emission factors for material handling can also be applied to final product loading for shipment. Again, these factors should be applied to each transfer point, ore dump, or other point where material is allowed to fall freely.

Test data collected in the mineral processing industries indicate that the moisture content of ore can have a significant effect on emissions from several process operations. High moisture generally reduces the uncontrolled emission rates, and separate emission rates are provided for primary crushers, secondary crushers, tertiary crushers, and material handling and transfer operations that process high-moisture ore. Drying and dry grinding operations are assumed to produce or to involve only low-moisture material.

For most metallic minerals covered in this section, high-moisture ore is defined as ore whose moisture content, as measured at the primary crusher inlet or at the mine, is 4 weight percent or greater. Ore defined as high-moisture at the primary crusher is presumed to be high-moisture ore at any subsequent operation for which high-moisture factors are provided unless a drying operation precedes the operation under consideration. Ore is defined as low-moisture when a dryer precedes the operation under consideration or when the ore moisture at the mine or primary crusher is less than 4 weight percent.

Separate factors are provided for bauxite handling operations because some types of bauxite with a moisture content as high as 15 to 18 weight percent can still produce relatively high emissions

during material handling procedures. These emissions could be eliminated by adding sufficient moisture to the ore, but bauxite then becomes so sticky that it is difficult to handle. Thus, there is some advantage to keeping bauxite in a relatively dusty state, and the low-moisture emission factors given represent conditions fairly typical of the industry.

Particulate matter size distribution data for some process operations have been obtained for control device inlet streams. Since these inlet streams contain PM from several activities, a variability has been anticipated in the calculated size-specific emission factors for PM.

Emission factors for PM equal to or less than 10 μm in aerodynamic diameter (PM-10) from a limited number of tests performed to characterize the processes are presented in Table 11.24-1.

In some plants, PM emissions from multiple pieces of equipment and operations are collected and ducted to a control device. Therefore, examination of reference documents is recommended before applying the factors to specific plants.

Emission factors for PM-10 from high-moisture primary crushing operations and material handling and transfer operations were based on test results usually in the 30 to 40 weight percent range. However, high values were obtained for high-moisture ore at both the primary crushing and the material handling and transfer operations, and these were included in the average values in the table. A similarly wide range occurred in the low-moisture drying operation.

Several other factors are generally assumed to affect the level of emissions from a particular process operation. These include ore characteristics such as hardness, crystal and grain structure, and friability. Equipment design characteristics, such as crusher type, could also affect the emissions level. At this time, data are not sufficient to quantify each of these variables.

11.24.3 Controlled Emissions[7-9]

Emissions from metallic mineral processing plants are usually controlled with wet scrubbers or baghouses. For moderate to heavy uncontrolled emission rates from typical dry ore operations, dryers, and dry grinders, a wet scrubber with pressure drop of 1.5 to 2.5 kilopascals (kPa) (6 to 10 inches of water) will reduce emissions by approximately 95 percent. With very low uncontrolled emission rates typical of high-moisture conditions, the percentage reduction will be lower (approximately 70 percent).

Over a wide range of inlet mass loadings, a well-designed and maintained baghouse will reduce emissions to a relatively constant outlet concentration. Such baghouses tested in the mineral processing industry consistently reduce emissions to less than 0.05 gram per dry standard cubic meter (g/dscm) (0.02 grains per dry standard cubic foot [gr/dscf]), with an average concentration of 0.015 g/dscm (0.006 gr/dscf). Under conditions of moderate to high uncontrolled emission rates of typical dry ore facilities, this level of controlled emissions represents greater than 99 percent removal of PM emissions. Because baghouses reduce emissions to a relatively constant outlet concentration, percentage emission reductions would be less for baghouses on facilities with a low level of uncontrolled emissions.

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