11.5 Refractory Manufacturing

11.5.1 Process Description[1-2]

Refractories are materials that provide linings for high-temperature furnaces and other processing units. Refractories must be able to withstand physical wear, high temperatures (above 538°C [1000°F]), and corrosion by chemical agents. There are two general classifications of refractories, clay and nonclay. The six-digit source classification code (SCC) for refractory manufacturing is 3-05-005. Clay refractories are produced from fireclay (hydrous silicates of aluminum) and alumina (57 to 87.5 percent). Other clay minerals used in the production of refractories include kaolin, bentonite, ball clay, and common clay. Nonclay refractories are produced from a composition of alumina (<87.5 percent), mullite, chromite, magnesite, silica, silicon carbide, zircon, and other nonclays.

Refractories are produced in two basic forms, formed objects, and unformed granulated or plastic compositions. The preformed products are called bricks and shapes. These products are used to form the walls, arches, and floor tiles of various high-temperature process equipment. Unformed compositions include mortars, gunning mixes, castables (refractory concretes), ramming mixes, and plastics. These products are cured in place to form a monolithic, internal structure after application.

Refractory manufacturing involves four processes: raw material processing, forming, firing, and final processing. Figure 11.5-1 illustrates the refractory manufacturing process. Raw material processing consists of crushing and grinding raw materials, followed if necessary by size classification and raw materials calcining and drying. The processed raw material then may be dry-mixed with other minerals and chemical compounds, packaged, and shipped as product. All of these processes are not required for some refractory products.

Forming consists of mixing the raw materials and forming them into the desired shapes. This process frequently occurs under wet or moist conditions. Firing involves heating the refractory material to high temperatures in a periodic (batch) or continuous tunnel kiln to form the ceramic bond that gives the product its refractory properties. The final processing stage involves milling, grinding, and sandblasting of the finished product. This step keeps the product in correct shape and size after thermal expansion has occurred. For certain products, final processing may also include product impregnation with tar and pitch, and final packaging.

Two other types of refractory processes also warrant discussion. The first is production of fused products. This process involves using an electric arc furnace to melt the refractory raw materials, then pouring the melted materials into sand-forming molds. Another type of refractory process is ceramic fiber production. In this process, calcined kaolin is melted in an electric arc furnace. The molten clay is either fiberized in a blowchamber with a centrifuge device or is dropped into an air jet and immediately blown into fine strands. After the blowchamber, the ceramic fiber may then be conveyed to an oven for curing, which adds structural rigidity to the fibers. During the curing process, oils are used to lubricate both the fibers and the machinery used to handle and form the fibers. The production of ceramic fiber for refractory material is very similar to the production of mineral wool.

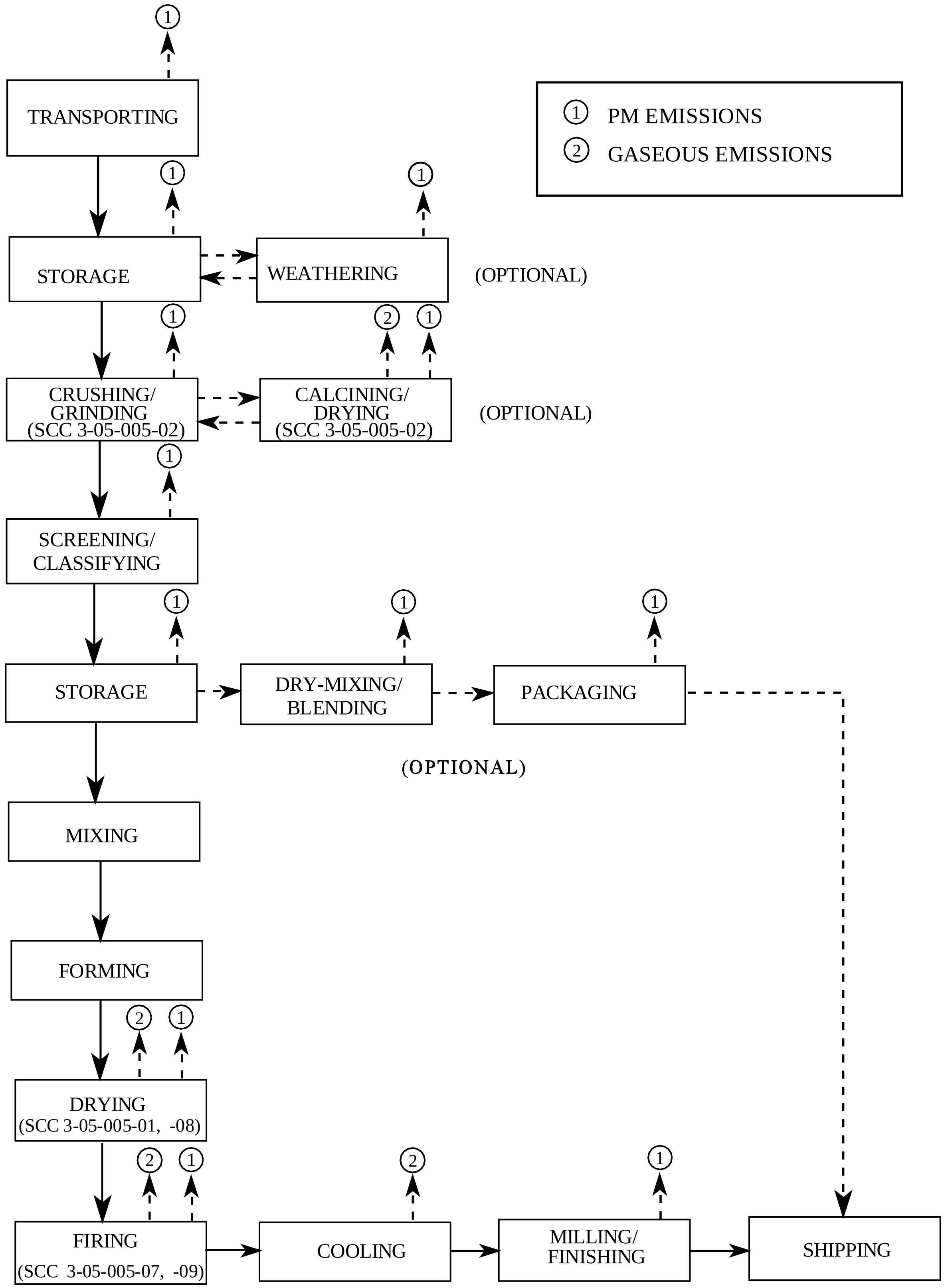

Figure 11.5-1. Refractory manufacturing process flow diagram.[1]
(Source Classification Codes in parentheses.)

11.5.2 Emissions And Controls[2-6]

The primary pollutant of concern in refractory manufacturing is particulate matter (PM). Particulate matter emissions occur during the crushing, grinding, screening, calcining, and drying of the raw materials; the drying and firing of the unfired "green" refractory bricks, tar and pitch operations; and finishing of the refractories (grinding, milling, and sandblasting).

Emissions from crushing and grinding operations generally are controlled with fabric filters. Product recovery cyclones followed by wet scrubbers are used on calciners and dryers to control PM emissions from these sources. The primary sources of PM emissions are the refractory firing kilns and electric arc furnaces. Particulate matter emissions from kilns generally are not controlled. However, at least one refractory manufacturer currently uses a multiple-stage scrubber to control kiln emissions. Particulate matter emissions from electric arc furnaces generally are controlled by a baghouse. Particulate removal of 87 percent and fluoride removal of greater than 99 percent have been reported at one facility that uses an ionizing wet scrubber.

Pollutants emitted as a result of combustion in the calcining and kilning processes include sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), and volatile organic compounds (VOC). The emission of SO_x is also a function of the sulfur content of certain clays and the plaster added to refractory materials to induce brick setting. Fluoride emissions occur during the kilning process because of fluorides in the raw materials. Emission factors for filterable PM, PM-10, SO_2, NO_x, and CO_2 emissions from rotary dryers and calciners processing fire clay are presented in Tables 11.5-1 and 11.5-2. Particle size distributions for filterable particulate emissions from rotary dryers and calciners processing fire clay are presented in Table 11.5-3.

Volatile organic compounds emitted from tar and pitch operations generally are controlled by incineration, when inorganic particulates are not significant. Based on the expected destruction of organic aerosols, a control efficiency in excess of 95 percent can be achieved using incinerators.

Chromium is used in several types of nonclay refractories, including chrome-magnesite, (chromite-magnesite), magnesia-chrome, and chrome-alumina. Chromium compounds are emitted from the ore crushing, grinding, material drying and storage, and brick firing and finishing processes used in producing these types of refractories. Tables 11.5-4 and 11.5-5 present emission factors for emissions of filterable PM, filterable PM-10, hexavalent chromium, and total chromium from the drying and firing of chromite-magnesite ore. The emission factors are presented in units of kilograms of pollutant emitted per megagram of chromite ore processed (kg/Mg CrO_3) (pounds per ton of chromite ore processed [lb/ton CrO_3]). Particle size distributions for the drying and firing of chromite-magnesite ore are summarized in Table 11.5-6.

A number of elements in trace concentrations including aluminum, beryllium, calcium, chromium, iron, lead, mercury, magnesium, manganese, nickel, titanium, vanadium, and zinc also are emitted in trace amounts by the drying, calcining, and firing operations of all types of refractory materials. However, data are inadequate to develop emission factors for these elements.

Emissions of PM from electric arc furnaces producing fused cast refractory material are controlled with baghouses. The efficiency of the fabric filters often exceeds 99.5 percent. Emissions of PM from the ceramic fiber process also are controlled with fabric filters, at an efficiency similar to that found in the fused cast refractory process. To control blowchamber emissions, a fabric filter is used to remove small pieces of fine threads formed in the fiberization stage. The efficiency of fabric filters in similar control devices exceeds 99 percent. Small particles of ceramic fiber are broken off or separated during the handling and forming of the fiber blankets in the curing oven. An oil is used in this process, and higher molecular weight organics may be emitted. However, these emissions generally are controlled with a fabric filter followed by incineration, at an expected overall efficiency in excess of 95 percent.

Table 11.5-1 (Metric Units). EMISSION FACTORS FOR REFRACTORY MANUFACTURING: FIRE CLAY[a]

EMISSION FACTOR RATING: D

Process	SO_2	NO_x	CO_2	Filterable[b]	
				PM	PM-10
Rotary dryer[c] (SCC 3-05-005-01)	ND	ND	15	33	8.1
Rotary dryer with cyclone (SCC 3-05-005-01)	ND	ND	15	5.6	2.6
Rotary dryer with cyclone and wet scrubber[c] (SCC 3-05-005-01)	ND	ND	15	0.052	ND
Rotary calciner (SCC 3-05-005-06)	ND	ND	300[c]	62[d]	14[e]
Rotary calciner with multiclone (SCC 3-05-005-06)	ND	ND	300[c]	31[f]	ND
Rotary calciner with multiclone and wet scrubber (SCC 3-05-005-06)	3.8[d]	0.87[d]	300[c]	0.15[d]	0.031[e]

[a] Factors represent uncontrolled emissions, unless noted. All emission factors in kg/Mg of raw material feed. SCC = Source Classification Code. ND = no data.
[b] Filterable PM is that PM collected on or before the filter of an EPA Method 5 (or equivalent) sampling train. PM-10 values are based on cascade impaction particle size distribution.
[c] Reference 3.
[d] References 4-5.
[e] Reference 4.
[f] Reference 5.

Table 11.5-2 (English Units). EMISSION FACTORS FOR REFRACTORY MANUFACTURING: FIRE CLAY[a]

EMISSION FACTOR RATING: D

Process	SO_2	NO_x	CO_2	Filterable[b]	
				PM	PM-10
Rotary dryer[c] (SCC 3-05-005-01)	ND	ND	30	65	16
Rotary dryer with cyclone[c] (SCC 3-05-005-01)	ND	ND	30	11	5.1
Rotary dryer with cyclone and wet scrubber[c] (SCC 3-05-005-01)	ND	ND	30	0.11	ND
Rotary calciner (SCC 3-05-005-06)	ND	ND	600[c]	120[d]	30[e]
Rotary calciner with multiclone (SCC 3-05-005-06)	ND	ND	600[c]	61[f]	ND
Rotary calciner with multiclone and wet scrubber (SCC 3-05-005-06)	7.6[d]	1.7[d]	ND	0.30[d]	0.062[e]

[a] Factors represent uncontrolled emissions, unless noted. All emission factors in lb/ton of raw material feed. SCC = Source Classification Code. ND = no data.
[b] Filterable PM is that PM collected on or before the filter of an EPA Method 5 (or equivalent) sampling train. PM-10 values are based on cascade impaction particle size distribution.
[c] Reference 3.
[d] References 4-5.
[e] Reference 4.
[f] Reference 5.

Table 11.5-3. PARTICLE SIZE DISTRIBUTIONS FOR REFRACTORY MANUFACTURING: FIRE CLAY[a]

EMISSION FACTOR RATING: D

Diameter (µm)	Uncontrolled	Multiclone Controlled	Cyclone Controlled	Cyclone/Scrubber Controlled
	Cumulative % Less Than Diameter	Cumulative % Less Than Diameter	Cumulative % Less Than Diameter	Cumulative % Less Than Diameter
Rotary Dryers (SCC 3-05-005-01)[b]				
2.5	2.5	ND	14	ND
6.0	10	ND	31	ND
10.0	24	ND	46	ND
15.0	37	ND	60	ND
20.0	51	ND	68	ND
Rotary Calciners (SCC 3-05-005-06)[c]				
1.0	3.1	13	ND	31
1.25	4.1	14	ND	43
2.5	6.9	23	ND	46
6.0	17	39	ND	55
10.0	34	50	ND	69
15.0	50	63	ND	81
20.0	62	81	ND	91

[a] For filterable PM only. ND = no data. SCC = Source Classification Code.
[b] Reference 3.
[c] References 4-5 (uncontrolled). Reference 4 (multiclone-controlled). Reference 5 (cyclone/scrubber-controlled).

Table 11.5-4 (Metric Units). EMISSION FACTORS FOR REFRACTORY MANUFACTURING: CHROMITE-MAGNESITE ORE[a]

EMISSION FACTOR RATING: D (except as noted)

Process	Filterable[b]		Chromium[c]	
	PM	PM-10	Hexavalent	Total
Rotary dryer (SCC 3-05-005-08)	0.83	0.20	3.8×10^{-5}	0.035
Rotary dryer with cyclone and fabric filter (SCC 3-05-005-08)	0.15	ND	1.9×10^{-5}	0.064
Tunnel kiln (SCC 3-05-005-09)	0.41	0.34	0.0087	0.13

[a] Reference 6. Factors represent uncontrolled emissions. Factors for filterable PM are kg/Mg of material processed. Factors for chrominum are kg/Mg of chromite ore processed. SCC = Source Classification Code for chromium. ND = no data.
[b] Filterable PM is that PM collected on or before the filter of an EPA Method 5 (or equivalent) sampling train. PM-10 values are based on cascade impaction particle size distribution and filterable PM emission factor.
[c] EMISSION FACTOR RATING: E.

Table 11.5-5 (English Units). EMISSION FACTORS FOR REFRACTORY MANUFACTURING: CHROMITE-MAGNESITE ORE[a]

EMISSION FACTOR RATING: D (except as noted)

Process	Filterable[b]		Chromium[c]	
	PM	PM-10	Hexavalent	Total
Rotary dryer (SCC 3-05-005-08)	1.7	0.41	7.6×10^{-5}	0.70
Rotary dryer with cyclone and fabric filter (SCC 3-05-005-08)	0.30	ND	3.7×10^{-5}	0.13
Tunnel kiln (SCC 3-05-005-09)	0.82	0.69	0.017	0.27

[a] Reference 6. Factors represent uncontrolled emissions. Factors for filterable PM are lb/ton of material processed. Factors for chromium are lb/ton of chromite ore processed. SCC = Source Classification Code. ND = no data.
[b] Filterable PM is that PM collected on or before the filter of an EPA Method 5 (or equivalent) sampling train. PM-10 values are based on cascade impaction particle size distribution and filterable PM emission factor.
[c] EMISSION FACTOR RATING: E.

Table 11.5-6. PARTICLE SIZE DISTRIBUTIONS FOR REFRACTORY MANUFACTURING: CHROMITE-MAGNESITE ORE DRYING AND FIRING[a]

Diameter (µm)	Filterable PM[b]	Hexavalent Chromium[c]	Total Chromium[c]
	Cumulative % Less Than Diameter	Cumulative % Less Than Diameter	Cumulative % Less Than Diameter
Uncontrolled rotary dryer (SCC 3-05-005-01)			
1	1.2	3.5	0.8
2	13	39	9
10	24	64	19
Uncontrolled tunnel kiln (SCC 3-05-005-07)			
1	71	71	84
5	78	81	91
10	84	84	93

[a] Reference 6. For filterable PM only. SCC = Source Classification Code.
[b] EMISSION FACTOR RATING: D.
[c] EMISSION FACTOR RATING: E.

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