11.3 Brick And Structural Clay Product Manufacturing

11.3.1 General[1-2]

The brick and structural clay products industry is made up primarily of facilities that manufacture structural brick from clay, shale, or a combination of the two. These facilities are classified under standard industrial classification (SIC) code 3251, brick and structural clay tile. Facilities that manufacture structural clay products, such as clay pipe, adobe brick, chimney pipe, flue liners, drain tiles, roofing tiles, and sewer tiles are classified under SIC code 3259, structural clay products, not elsewhere classified.

11.3.2 Process Description[3-6]

The manufacture of brick and structural clay products involves mining, grinding, screening and blending of the raw materials followed by forming, cutting or shaping, drying, firing, cooling, storage, and shipping of the final product. A typical brick manufacturing process is shown in Figure 11.3-1.

The raw materials used in the manufacture of brick and structural clay products include surface clays and shales, which are mined in open pits. The moisture content of the raw materials ranges from a low of about 3 percent at some plants to a high of about 15 percent at other plants. Some facilities have onsite mining operations, while others bring in raw material by truck or rail. The raw material is typically loaded by truck or front-end loader into a primary crusher for initial size reduction. The material is then conveyed to a grinding room, which houses several grinding mills and banks of screens that produce a fine material that is suitable for forming brick or other products. Types of grinding mills typically used include dry pan grinders, roller mills, and hammermills. From the grinding room, the material is conveyed to storage silos or piles, which typically are enclosed. The material is then either conveyed to the mill room for brick forming or conveyed to a storage area.

Most brick are formed by the stiff mud extrusion process, although brick are also formed using the soft mud and dry press processes (there may be no plants in the U.S. currently using the dry press process). A typical stiff mud extrusion line begins with a pug mill, which mixes the ground material with water and discharges the mixture into a vacuum chamber. Some facilities mix additives such as barium carbonate, which prevents sulfates from rising to the surface of the brick, with the raw material prior to extrusion. The moisture content of the material entering the vacuum chamber is typically between 14 and 18 percent. The vacuum chamber removes air from the material, which is then continuously augered or extruded through dies. The resulting continuous "column" is lubricated with oil or other lubricant to reduce friction during extrusion. If specified, various surface treatments, such as manganese dioxide, iron oxide, and iron chromite can be applied at this point. These treatments are used to add color or texture to the product. A wire-cutting machine is used to cut the column into individual bricks, and then the bricks are mechanically or hand set onto kiln cars. All structural tile and most brick are formed by this process. Prior to stacking, some facilities mechanically process the unfired bricks to create rounded imperfect edges that give the appearance of older worn brick.

The soft mud process is usually used with clay that is too wet for stiff mud extrusion. In a pug mill, the clay is mixed with water to a moisture content of 15 to 28 percent, and the bricks are formed in molds and are dried before being mechanically stacked onto kiln cars. In the dry press process, clay is mixed with a small amount of water and formed in steel molds by applying pressure of 500 to 1,500 pounds per square inch (3.43 to 10.28 megapascals).

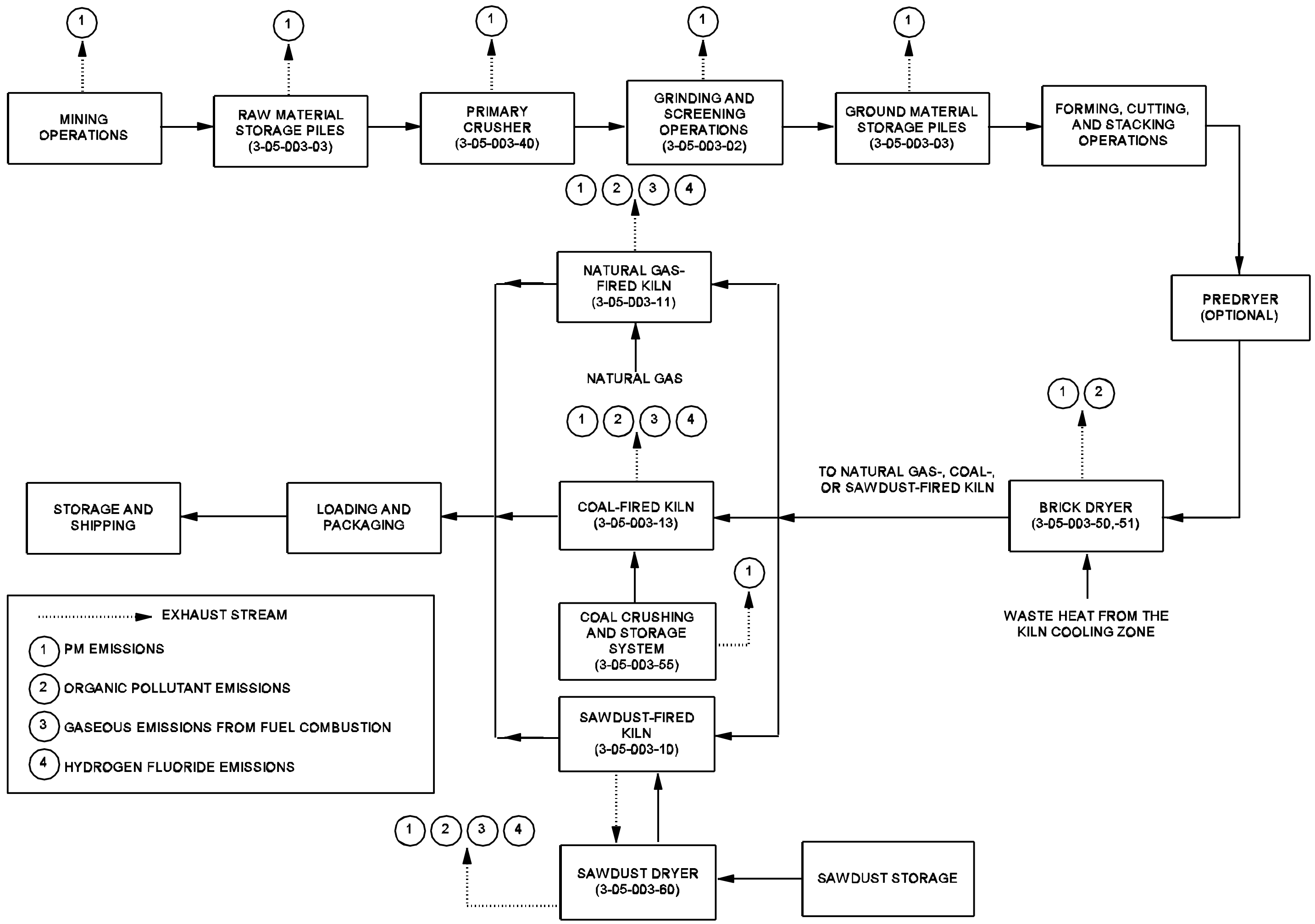

Figure 11.3-1. Typical brick manufacturing process.
(Source Classification Codes in parentheses.)

Following forming and stacking, the brick-laden kiln cars enter a predryer or a holding area and are then loaded into the dryer. Dryers typically are heated to about 400°F (204°C) using waste heat from the cooling zone of the kiln. However, some plants heat dryers with gas or other fuels. Dryers may be in-line or totally separate from the kiln. From the dryer, the bricks enter the kiln. The most common type of kiln used for firing brick is the tunnel kiln, although some facilities operate downdraft periodic kilns or other types of kilns. A typical tunnel kiln ranges from about 340 feet (ft) (104 meters [m]) to 500 ft (152 m) in length and includes a preheat zone, a firing zone, and a cooling zone. The firing zone typically is maintained at a maximum temperature of about 2000°F (1090°C). During firing, small amounts of excess fuel are sometimes introduced to the kiln atmosphere, creating a reducing atmosphere that adds color to the surface of the bricks. This process is called flashing. After firing, the bricks enter the cooling zone, where they are cooled to near ambient temperatures before leaving the tunnel kiln. The bricks are then stored and shipped.

A periodic kiln is a permanent brick structure with a number of fireholes through which fuel enters the furnace. Hot gases from the fuel are first drawn up over the bricks, then down through them by underground flues, and then out of the kiln to the stack.

In all kilns, firing takes place in six steps: evaporation of free water, dehydration, oxidation, vitrification, flashing, and cooling. Natural gas is the fuel most commonly used for firing, followed by coal and sawdust. Some plants have fuel oil available as a backup fuel. Most natural gas-fired plants that have a backup fuel use vaporized propane as the backup fuel. For most types of brick, the entire drying, firing, and cooling process takes between 20 and 50 hours.

Flashing is used to impart color to bricks by adding uncombusted fuel (other materials such as zinc, used tires, or used motor oil are also reportedly used) to the kiln to create a reducing atmosphere. Typically, flashing takes place in a “flashing zone” that follows the firing zone, and the bricks are rapidly cooled following flashing. In tunnel kilns, the uncombusted fuel or other material typically is drawn into the firing zone of the kiln and is burned.

11.3.3 Emissions And Controls[3,7-11,22,24,29-30]

Emissions from brick manufacturing facilities include particulate matter (PM), PM less than or equal to 10 microns in aerodynamic diameter (PM-10), PM less than or equal to 2.5 microns in aerodynamic diameter (PM-2.5) sulfur dioxide (SO_2), sulfur trioxide (SO_3), nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), metals, total organic compounds (TOC) (including methane, ethane, volatile organic compounds [VOC], and some hazardous air pollutants [HAP]), hydrochloric acid (HCl), and fluoride compounds. Factors that may affect emissions include raw material composition and moisture content, kiln fuel type, kiln operating parameters, and plant design. The pollutants emitted from the manufacture of other structural clay products are expected to be similar to the pollutants emitted from brick manufacturing, although emissions from the manufacture of glazed products may differ significantly.

The primary sources of PM, PM-10, and PM-2.5 emissions are the raw material grinding and screening operations and the kilns. Other sources of PM emissions include sawdust dryers used by plants with sawdust-fired kilns, coal crushing systems used by plants with coal-fired kilns, and fugitive dust sources such as paved roads, unpaved roads, and storage piles.

Combustion products, including SO_2, NO_x, CO, and CO_2, are emitted from fuel combustion in brick kilns and some brick dryers. Brick dryers that are heated with waste heat from the kiln cooling zone are not usually a source of combustion products because kilns are designed to prevent combustion gases from entering the cooling zone. Some brick dryers have supplemental gas burners that produce small amounts of NO_x, CO, and CO_2 emissions. These emissions are sensitive to the condition of the burners. The primary source of SO_2 emissions from most brick kilns is the raw material, which sometimes contain sulfur compounds. Some facilities use raw material with a high sulfur content, and have higher SO_2 emissions than facilities that use low-sulfur raw material. In addition, some facilities use additives that contain sulfates, and these additives may contribute to SO_2 emissions. Data are available that indicate that sulfur contents of surface soils are highly variable, and it is likely that sulfur contents of brick raw materials are also highly variable.

Organic compounds, including methane, ethane, VOC, and some HAP, are emitted from both brick dryers and kilns. These compounds also are emitted from sawdust dryers used by facilities that fire sawdust as the primary kiln fuel. Organic compound emissions from brick dryers may include contributions from the following sources: (1) petroleum-based or other products in those plants that use petroleum-based or other lubricants in extrusion, (2) light hydrocarbons within the raw material that vaporize at the temperatures encountered in the dryer, and (3) incomplete fuel combustion in dryers that use supplemental burners in addition to waste heat from the kiln cooling zone. Organic compound emissions from kilns are the result of volatilization of organic matter contained in the raw material and kiln fuel.

Hydrogen fluoride (HF) and other fluoride compounds are emitted from kilns as a result of the release of the fluorine compounds contained in the raw material. Fluorine typically is present in brick raw materials in the range of 0.01 to 0.06 percent. As the green bricks reach temperatures of 930° to 1110°F, (500° to 600°C), the fluorine in the raw material forms HF and other fluorine compounds. Much of the fluorine is released as HF. Because fluorine content in clays and shales is highly variable, emissions of HF and other fluoride compounds vary considerably depending on the raw material used.

A variety of control systems may be used to reduce PM emissions from brick manufacturing operations. Grinding and screening operations are sometimes controlled by fabric filtration systems, although many facilities process raw material with a relatively high moisture content (greater than 10 percent) and do not use add-on control systems. Most tunnel kilns are not equipped with control devices, although fabric filters or wet scrubbers are sometimes used for PM removal. Particulate matter emissions from fugitive sources such as paved roads, unpaved roads, and storage piles can be controlled using wet suppression techniques.

Gaseous emissions from brick dryers and kilns typically are not controlled using add-on control devices. However, dry scrubbers that use limestone as a sorption medium may be used to control HF emissions; control efficiencies of 95 percent or higher have been reported at one plant operating this type of scrubber. Also, wet scrubbers are used at one facility. These scrubbers, which use a soda ash and water solution as the scrubbing liquid, provide effective control of HF and SO_2 emissions. Test data show that the only high-efficiency packed tower wet scrubber operating in the U.S. (at brick plants) achieves control efficiencies greater than 99 percent for SO_2 and total fluorides. A unique "medium-efficiency" wet scrubber operating at the same plant has demonstrated an 82 percent SO_2 control efficiency.

Process controls are also an effective means of controlling kiln emissions. For example, facilities with coal-fired kilns typically use a low-sulfur, low-ash coal to minimize SO_2 and PM emissions. In addition, research is being performed on the use of additives (such as lime) to reduce HF and SO_2 emissions.

Table 11.3-1 presents emission factors for filterable PM, filterable PM-10, condensible inorganic PM, and condensible organic PM emissions from brick and structural clay product manufacturing operations. Two emission factors for uncontrolled grinding and screening operations are presented; one for operations processing relatively dry material (about 4 percent moisture) and the other for operations processing wet material (about 13 percent moisture). Table 11.3-2 presents total PM, total PM-10, and total PM-2.5 emission factors for brick and structural clay product manufacturing. Table 11.3-3 presents emission factors for SO_2, SO_3, NO_x, CO, and CO_2 emissions from brick dryers, kilns (fired with natural gas, coal, and sawdust), and from a combined source--sawdust-fired kiln and sawdust dryer. To estimate emissions of NO_x, and CO from fuel oil-fired kilns, refer to the AP-42 section addressing oil combustion. Table 11.3-4 presents emission factors for HF, total fluorides, and HCl emissions from brick kilns and from a combined source--sawdust-fired kilns and sawdust drying. Table 11.3-5 presents emission factors for TOC as propane, methane, and VOC from brick dryers, kilns, and from a combined source--sawdust-fired kilns and sawdust drying. Tables 11.3-6 and 11.3-7 present emission factors for speciated organic compounds and metals, respectively. Table 11.3-8 presents particle size distribution data for sawdust- and coal-fired kilns. Although many of the emission factors presented in the tables are assigned lower ratings than emission factors in previous editions of AP-42, the new factors are based on higher quality data than the old factors.

Table 11.3-1. PARTICULATE MATTER EMISSION FACTORS FOR BRICK MANUFACTURING OPERATIONS[a]

	Filterable PM[b]						Condensible PM[c]			
Source	PM	EMISSION FACTOR RATING	PM-10	EMISSION FACTOR RATING	PM-2.5	EMISSION FACTOR RATING	Inorganic	EMISSION FACTOR RATING	Organic	EMISSION FACTOR RATING
Primary crusher with fabric filter[d] (SCC 3-05-003-40)	ND	NA	0.00059	E	ND	NA	NA	NA	NA	NA
Grinding and screening operations (SCC 3-05-003-02)										
processing wet material[f]	0.025	E	0.0023	E	ND	NA	NA	NA	NA	NA
processing dry material[e]	8.5	E	0.53	E	ND	NA	NA	NA	NA	NA
with fabric filter[g]	0.0062	E	0.0032	E	ND	NA	NA	NA	NA	NA
Extrusion line with fabric filter[h] (SCC 3-05-003-42)	ND	NA	0.0036	E	ND	NA	NA	NA	NA	NA
Brick dryer (SCC 3-05-003-50, -51)	0.077[j]	E	ND	NA	ND	NA	0.11[k]	E	ND	NA
Natural gas-fired kiln (SCC 3-05-003-11)	0.37[m]	C	0.28[n]	E	ND	NA	0.48[p]	D	0.11[q]	D
Coal-fired kiln (SCC 3-05-003-13)										
uncontrolled	1.2[r]	A	0.76[s]	C	0.28[t]	D	0.48[p]	D	0.11[q]	D
with fabric filter	0.043[v]	E	ND	NA	ND	NA	0.48[u]	D	0.11[q]	D
Sawdust-fired kiln (SCC 3-05-003-10)	0.34[w]	D	0.26[x]	D	0.16[x]	D	0.48[p]	D	0.11[q]	D
Sawdust-fired kiln and sawdust dryer[y] (SCC 3-05-003-61)	1.3	E	0.25	E	ND	NA	0.013	E	0.043	E
Natural gas-fired kiln firing structural clay tile[z] (SCC 3-05-003-70)	1.0	E	ND	NA	ND	NA	ND	NA	ND	NA

[a] Emission factor units are lb of pollutant per ton of fired bricks produced unless noted. Factors represent uncontrolled emissions unless noted. SCC = Source Classification Code. ND = no data. NA = not applicable. To convert from lb/ton to kg/Mg, multiply by 0.5. Total PM can be calculated as the sum of filterable PM and condensible inorganic and organic PM. Total PM-10 can be calculated as the sum of filterable PM-10 and condensible inorganic and organic PM. Total PM-2.5 can be calculated as the sum of filterable PM-2.5 and condensible inorganic and organic PM.

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

Table 11.3-1. (cont.).

[c] Condensible PM is that PM collected in the impinger portion of an EPA Method 5 (or equivalent) sampling train or by EPA Method 202.
[d] Reference 29.
[e] Reference 8. Emission factor units are lb of pollutant per ton of raw material processed. Grinding and screening operations are typically housed in large buildings that can be fully or partially enclosed. Factor is based on measurements at the inlet to a fabric filter and does not take into account the effect of the building enclosure. Based on a raw material moisture content of 4 percent.
[f] Reference 11. Emission factor units are lb of pollutant per ton of raw material processed. Based on a raw material moisture content of 13 percent. Grinding and screening operations are typically housed in large buildings that can be fully or partially enclosed.
[g] References 8-9. Emission factor units are lb of pollutant per ton of raw material processed. Grinding and screening operations are typically housed in large buildings that can be fully or partially enclosed. Average raw material moisture content of 6.5 percent.
[h] Reference 29. Extrusion line with several conveyor drop points processing material with a 5-9 percent moisture content. This emission factor is not applicable to typical extrusion lines.
[j] Reference 21,36-37.
[k] Reference 21.
[m] References 8,12,15,22,25-26,29-30,32-34,36-37. Includes data from a kiln controlled with a dry scrubber.
[n] Reference 25.
[p] References 8-9,11,21,25,29-30,33-34.
[q] References 8-9,11,25,29-30.
[r] References 9,13-14,17-18,21.
[s] References 9,13-14,17-18,21.
[t] Reference 21.
[u] Fabric filter is not expected to control condensible PM emissions. Therefore, the uncontrolled condensible PM emission factors are used.
[v] Reference 19.
[w] References 11,23.
[x] References 11,20,23.
[y] Reference 11. Sawdust dryer heated with the exhaust stream from a sawdust-fired kiln.
[z] References 27-28.

Table 11.3-2. EMISSION FACTORS FOR TOTAL PM, TOTAL PM-10, AND TOTAL PM-2.5 FROM BRICK MANUFACTURING OPERATIONS[a]

Source	Total PM[b]					
	PM	EMISSION FACTOR RATING	PM-10	EMISSION FACTOR RATING	PM-2.5	EMISSION FACTOR RATING
Primary crusher with fabric filter (SCC 3-05-003-40)	ND	NA	0.00059	E	ND	NA
Grinding and screening operations (SCC 3-05-003-02)						
processing dry material[c]	8.5	E	0.53	E	ND	NA
processing wet material[d]	0.025	E	0.0023	E	ND	NA
with fabric filter[e]	0.0062	E	0.0032	E	ND	NA
Extrusion line with fabric filter[f] (SCC 3-05-003-42)	ND	NA	0.0036	E	ND	NA
Natural gas-fired kiln (SCC 3-05-003-11)	0.96	D	0.87	D	ND	NA
Coal-fired kiln (SCC 3-05-003-13)						
uncontrolled	1.8	B	1.4	C	0.87	D
with fabric filter	0.63	E	ND	NA	ND	NA
Sawdust-fired kiln (SCC 3-05-003-10)	0.93	D	0.85	D	0.75	D
Sawdust-fired kiln and sawdust dryer[g] (SCC 3-05-003-61)	1.4	E	0.31	E	ND	NA

[a] Emission factor units are lb of pollutant per ton of fired bricks produced unless noted. Factors represent uncontrolled emissions unless noted. SCC = Source Classification Code. ND = no data. NA = not applicable. To convert from lb/ton to kg/Mg, multiply by 0.5.

[b] Total PM emission factors are the sum of filterable PM and condensible inorganic and organic PM emission factors from Table 11.3-1. Total PM-10 emission factors are the sum of filterable PM-10 and condensible inorganic and organic PM emission factors from Table 11.3-1. Total PM-2.5 emission factors are the sum of filterable PM-2.5 and condensible inorganic and organic PM emission factors from Table 11.3-1.

[c] Emission factor units are lb of pollutant per ton of raw material processed. Grinding and screening operations are typically housed in large buildings that can be fully or partially enclosed. Factor is based on measurements at the inlet to a fabric filter and does not take into account the effect of the building enclosure. Based on a raw material moisture content of 4 percent.

[d] Emission factor units are lb of pollutant per ton of raw material processed. Based on a raw material moisture content of 13 percent. Grinding and screening operations are typically housed in large buildings that can be fully or partially enclosed.

[e] Emission factor units are lb of pollutant per ton of raw material processed. Grinding and screening operations are typically housed in large buildings that can be fully or partially enclosed.

[f] This emission factor is not applicable to typical extrusion lines. Extrusion line with several conveyor drop points processing material with a 5-9 percent moisture content.

[g] Sawdust dryer heated with the exhaust stream from a sawdust-fired kiln.

Table 11.3-3. EMISSION FACTORS FOR BRICK MANUFACTURING OPERATIONS[a]

Source	SO_2[b]	EMISSION FACTOR RATING	SO_3	EMISSION FACTOR RATING	NO_x	EMISSION FACTOR RATING	CO	EMISSION FACTOR RATING	CO_2	EMISSION FACTOR RATING
Brick dryer with supplemental gas burner[c] (SCC 3-05-003-51)	NA	NA	NA	NA	0.098[d]	E	0.31[e]	E	71[f]	E
Natural gas-fired kiln (SCC 3-05-003-11)	0.67[g]	C	0.11[h]	D	0.35[j]	C	1.2[k]	C	400[m]	B
Natural gas-fired kiln firing high-sulfur material[n] (SCC 3-05-003-22)										
uncontrolled	5.1[p]	D	ND	NA	0.35[j]	C	1.2[k]	C	400[m]	B
with medium-efficiency wet scrubber[q]	1.0[q]	C	ND	NA	0.35[j]	C	1.2[k]	C	400[m]	B
with high-efficiency packed-bed scrubber[r]	0.0049[r]	C	ND	NA	0.35[j]	C	1.2[k]	C	400[m]	B
Coal-fired kiln (SCC 3-05-003-13)	1.2[s]	D	ND	NA	0.51[t]	D	0.80[t]	D	300[u]	C
Sawdust-fired kiln (SCC 3-05-003-10)	0.67[g]	C	0.11[h]	D	0.37[v]	E	1.6[x]	D	490[x]	D

[a] Emission factor units are lb of pollutant per ton of fired bricks produced. Factors represent uncontrolled emissions unless noted. SCC = Source Classification Code. ND = no data. NA = not applicable. To convert from lb/ton to kg/Mg, multiply by 0.5.

[b] Because of highly variable percentages of sulfur in raw materials, SO_2 emissions can be more accurately estimated using mass balance procedures. Assuming that all of the sulfur in the raw material is released as SO_2 during firing, each lb of sulfur in the raw material will result in 2 lb of SO_2 emissions. The amount of SO_2 released may be reduced by contact with alkaline components of the raw materials or additives. To develop emission factors based on mass balance, the sulfur percentage should be presented as a percentage of dry raw material, because the emission factor is based on brick production (dry) rather than raw material (wet) use. Because SO_3 emissions are generally a small percentage of total sulfur oxide (SO_X) emissions, assume that all SO_x is SO_2 when performing mass balance calculations. For coal-fired kilns, the contribution of the coal to SO_2 emissions must also be accounted for when performing mass balance calculations.

Table 11.3-3. (cont.).

[c] Brick dryer heated with waste heat from the cooling zone of the kiln and a supplemental gas burner or burners.
[d] Reference 37.
[e] References 8,36-37.
[f] Reference 36-37.
[g] References 12,15,22,25-26,32-33. Sulfur dioxide emissions are the result of pyrites or other sulfur compounds in the brick raw material. A mass balance on sulfur will provide a better estimate of emissions for individual facilities.
[h] References 26,33,36-37.
[j] References 8,12,15,25,29-30,32-34,36-37.
[k] References 8,25,30,32,36-37.
[m] References 8,12,15,22,25,27-30,32-34,36-37. A mass balance based on carbon burned will provide a better estimate of emissions for individual facilities.
[n] Materials that have potentially high percentages of sulfur include fire clays, clays and shales mined in conjunction with coal mining activities, and other types of clay.
[p] References 8,27-30, 36-37. Sulfur dioxide emissions are the result of pyrites or other sulfur compounds in the brick raw material. A mass balance on sulfur will provide a better estimate of emissions for individual facilities.
[q] Reference 29. Medium-efficiency wet scrubber using a soda-ash/water solution (maintained at pH 7) as the scrubbing liquid. Scrubber is not expected to provide significant control of NO_x, CO, or CO_2. This emission factor was developed using data from a unique wet scrubber that is not a standard design air pollution control device.
[r] Reference 30. High-efficiency packed bed scrubber with soda-ash/water solution circulated through the packing section. Scrubber is not expected to provide significant control of NO_x, CO, or CO_2.
[s] References 10,16. Sulfur dioxide emissions are the result of sulfur in the coal and pyrites or other sulfur compounds in the brick raw material. A mass balance on sulfur will provide a better estimate of emissions for individual facilities.
[t] References 9-10.
[u] References 9-10,13-14,16-19,21.
[v] Reference 11. Includes measurements following a sawdust dryer heated with the exhaust stream from a sawdust-fired kiln.
[x] Reference 11,31,35. Includes measurements following a sawdust dryer heated with the exhaust stream from a sawdust-fired kiln.

Table 11.3-4. EMISSION FACTORS FOR HYDROGEN FLUORIDE, TOTAL FLUORIDES, AND HYDROGEN CHLORIDE FROM BRICK MANUFACTURING OPERATIONS[a]

Source	HF[b]	EMISSION FACTOR RATING	Total fluorides[c]	EMISSION FACTOR RATING	HCl[d]	EMISSION FACTOR RATING
Sawdust- or natural gas-fired tunnel kiln (SCC 3-05-003-10,-11)						
uncontrolled	0.37[e]	C	0.59[f]	E	0.17[g]	D
with dry scrubber[h]	ND	NA	0.028	C	ND	NA
with medium-efficiency wet scrubber[j]	ND	NA	0.18	C	ND	NA
with high-efficiency packed-bed scrubber[k]	ND	NA	0.0013	C	ND	NA
Coal-fired tunnel kiln[m] (SCC 3-05-003-13)	0.17	D	ND	NA	ND	NA
Sawdust-fired kiln and sawdust dryer[n] (SCC 3-05-003-61)	0.18	E	ND	NA	ND	NA

[a] Emission factor units are lb of pollutant per ton of fired product. Factors represent uncontrolled emissions unless noted. To convert from lb/ton to kg/Mg, multiply by 0.5. SCC = Source Classification Code. ND = no data. NA = not applicable.

[b] Hydrogen fluoride measured using an EPA Method 26A or equivalent sampling train.

[c] Total fluorides measured using an EPA Method 13B or equivalent sampling train.

[d] Hydrogen chloride measured using an EPA Method 26A or equivalent sampling train.

[e] References 8,11,26-27,32,34. Factor includes data from kilns firing structural clay tile. Data from kilns firing natural gas and sawdust are averaged together because fuel type (except for coal) does not appear to affect HF emissions. However, the raw material fluoride content does effect HF emissions. A mass balance on fluoride will provide a better estimate of emissions for individual facilities. Assuming that all of the fluorine in the raw material is released as HF, each lb of fluorine will result in 1.05 lb of HF emissions.

[f] Reference 26. Factor is 1.6 times the HF factor.

[g] References 8,26.

[h] References 22,33-34. Kiln firing material with a high fluorine content. Dry scrubber using limestone as a sorption medium.

[j] Reference 29. Medium-efficiency wet scrubber using a soda-ash/water solution (maintained at pH 7) as the scrubbing liquid. The design of this scrubber is not typical. Kiln firing material with a high fluorine content.

[k] Reference 30. High-efficiency packed bed scrubber with soda-ash/water solution circulated through the packing section. Kiln firing material with a high fluorine content (uncontrolled emission factor of 2.1 lb/ton).

[m] References 9,26.

[n] Reference 11. Sawdust dryer heated with the exhaust stream from a sawdust-fired kiln.

Table 11.3-5. EMISSION FACTORS FOR TOC, METHANE, AND VOC FROM BRICK MANUFACTURING OPERATIONS[a]

Source	TOC[b]	EMISSION FACTOR RATING	Methane	EMISSION FACTOR RATING	VOC[c]	EMISSION FACTOR RATING
Brick dryer[d] (SCC 3-05-003-50)	0.05[e]	E	0.02[f]	E	0.03	E
Brick dryer w/supplemental gas burner (SCC 3-05-003-51)	0.14[g]	E	0.11[h]	E	0.03	E
Brick kiln[j] (SCC 3-05-003-10,-11,-13)	0.062[k]	C	0.037[m]	E	0.024	D
Sawdust-fired kiln and sawdust dryer[n] (SCC 3-05-003-61)	0.18	E	ND	NA	0.18	E

[a] Emission factor units are lb of pollutant per ton of fired product. Factors represent uncontrolled emissions unless noted. To convert from lb/ton to kg/Mg, multiply by 0.5. SCC = Source Classification Code. ND = no data. ND = not applicable.

[b] Total organic compounds reported "as propane"; measured using EPA Method 25A, unless noted.

[c] VOC as propane; calculated as the difference in the TOC and methane emission factors for this source. If no methane factor is available, VOC emissions are estimated using the TOC emission factor. In addition, emissions of the non-reactive compounds shown in Table 11.3-6 (brick kiln = 0.00094 lb/ton) are subtracted from the TOC factors to calculate VOC.

[d] Brick dryer heated with waste heat from the kiln cooling zone.

[e] References 9-10.

[f] Reference 9. Methane value includes methane and ethane emissions. Most of these emissions are believed to be methane.

[g] References 8,37.

[h] Factor is estimated by assuming that VOC emissions from dryers with and without supplemental burners are equal. The VOC factor is subtracted from the TOC factor to estimate methane emissions.

[j] Includes natural gas-, coal-, and sawdust-fired tunnel kilns.

[k] References 8-11,25,32,36-37. Data from kilns firing natural gas, coal, and sawdust are averaged together because the data indicate that the fuel type does not effect TOC emissions.

[m] References 8-9,25. Data from kilns firing natural gas, coal, and sawdust are averaged together because the data indicate that the fuel type does not effect methane emissions.

[n] Reference 11. Sawdust dryer heated with the exhaust stream from a sawdust-fired kiln.

Table 11.3-6. EMISSION FACTORS FOR ORGANIC POLLUTANT EMISSIONS FROM BRICK MANUFACTURING OPERATIONS[a]

EMISSION FACTOR RATING: E

Source	Pollutant		Emission Factor, lb/ton	Ref. No.
	CASRN	Name		
Coal-fired kiln (SCC 3-05-003-13)	75-34-3	1,1-dichloroethane	$5.0x10^{-6}$	9
	71-55-6	1,1,1-trichloroethane[b]*	BDL ($1.7x10^{-5}$)	9
	106-46-7	1,4-dichlorobenzene	$3.2x10^{-6}$	9
	78-93-3	2-butanone	$2.5x10^{-4}$	9
	591-78-6	2-hexanone[b]	BDL ($9.4x10^{-7}$)	9
	91-57-6	2-methylnaphthalene	$1.7x10^{-6}$	9
	95-48-7	2-methylphenol[b]	BDL ($2.2x10^{-6}$)	9
	67-64-1	Acetone*	$6.8x10^{-4}$	9
	71-43-2	Benzene	$2.9x10^{-4}$	9
	65-85-0	Benzoic acid	$2.5x10^{-4}$	9
	117-81-7	Bis(2-ethylhexy)phthalate	$7.3x10^{-5}$	9
	74-83-9	Bromomethane	$2.4x10^{-5}$	9
	85-68-7	Butylbenzylphthalate	$1.2x10^{-6}$	9
	75-15-0	Carbon disulfide	$2.3x10^{-6}$	9
	56-23-5	Carbon tetrachloride[b]	BDL ($1.0x10^{-7}$)	9
	108-90-7	Chlorobenzene	$2.1x10^{-5}$	9
	75-00-3	Chloroethane	$1.1x10^{-5}$	9
	67-66-3	Chloroform[b]	BDL ($1.0x10^{-7}$)	9
	74-87-3	Chloromethane	$1.1x10^{-4}$	9
	132-64-9	Dibenzofuran[c]	$3.6x10^{-7}$	9
		Di-n-octylphthalate	$1.2x10^{-5}$	9
	84-66-2	Diethylphthalate	$1.4x10^{-6}$	9
	131-11-3	Dimethylphthalate[b]	BDL ($7.8x10^{-7}$)	9
	100-41-4	Ethylbenzene	$2.1x10^{-5}$	9
	78-59-1	Isophorone	$3.0x10^{-5}$	9
	1330-20-7	M-/p-xylene	$1.3x10^{-4}$	9
	75-09-2	Methylene chloride*	$8.0x10^{-7}$	9
	91-20-3	Naphthalene	$6.9x10^{-6}$	9
	95-47-6	O-xylene	$4.7x10^{-5}$	9
	108-95-2	Phenol	$3.5x10^{-5}$	9
	100-42-5	Styrene[b]	BDL ($1.0x10^{-7}$)	9
	127-18-4	Tetrachloroethane[b]	BDL ($1.0x10^{-7}$)	9
	71-55-6	Trichloroethane[b]*	BDL ($1.0x10^{-7}$)	9
	108-88-3	Toluene	$2.5x10^{-4}$	9
	108-05-4	Vinyl acetate[b]	BDL ($1.0x10^{-7}$)	9
	75-69-4	Trichlorofluoromethane*	$1.4x10^{-5}$	9

Table 11.3-6 (cont.).

Source	Pollutant		Emission Factor, lb/ton	Ref. No.
	CASRN	Name		
Natural gas-fired kiln (SCC 3-05-003-11)	71-55-6	1,1,1-Trichloroethane*	$4.7x10^{-6}$	8
	106-46-7	1,4-dichlorobenzene	$4.8x10^{-5}$	8
	91-57-6	2-methylnaphthalene	$5.7x10^{-5}$	8
	78-93-3	2-butanone	0.00022	8
	591-78-6	2-Hexanone	$8.5x10^{-5}$	8
	67-64-1	Acetone*	0.0017	8
	71-43-2	Benzene	0.0029	8
	117-81-7	Bis(2-ethylhexy)phthalate	0.0020	8
	85-68-7	Butylbenzylphthalate	$1.8x10^{-5}$	8
	75-15-0	Carbon disulfide	$4.3x10^{-5}$	8
	7782-50-5	Chlorine	0.0013	8
	75-00-3	Chloroethane	0.00057	8
	74-87-3	Chloromethane	0.00067	8
	84-74-2	Di-n-butylphthalate	0.00014	8
	84-66-2	Diethylphthalate	0.00024	8
	100-41-4	Ethylbenzene	$4.4x10^{-5}$	8
	1330-20-7	M-/p-Xylene	$6.7x10^{-5}$	8
	74-88-4	Iodomethane	$9.3x10^{-5}$	8
	91-20-3	Naphthalene	$6.5x10^{-5}$	8
	95-47-6	o-Xylene	$5.8x10^{-5}$	8
	108-95-2	Phenol	$8.6x10^{-5}$	8
	100-42-5	Styrene	$2.0x10^{-5}$	8
	127-18-4	Tetrachloroethene	$2.8x10^{-6}$	8
	108-88-3	Toluene	0.00016	8
Sawdust-fired kiln (SCC 3-05-003-10)	71-55-6	1,1,1-trichloroethane[b]*	BDL ($3.0x10^{-7}$)	11
	78-93-3	2-butanone[b]	BDL ($6.6x10^{-6}$)	11
	591-78-6	2-hexanone[b]	BDL ($3.0x10^{-7}$)	11
	95-48-7	2-methylphenol[b]	BDL ($2.0x10^{-9}$)	11
	67-64-1	Acetone*	$3.9x10^{-4}$	11
	107-13-1	Acrylonitrile[c]	$1.5x10^{-5}$	11
	71-43-2	Benzene	$5.2x10^{-4}$	11
	117-81-7	Bis(2-ethylhexy)phthalate	$2.9x10^{-5}$	11
	74-83-9	Bromomethane	$5.0x10^{-5}$	11
	75-15-0	Carbon disulfide	$1.6x10^{-5}$	11
	56-23-5	Carbon tetrachloride[b]	BDL ($3.0x10^{-7}$)	11
	67-66-3	Chloroform[b]	BDL ($3.0x10^{-7}$)	11
	74-87-3	Chloromethane	$6.8x10^{-4}$	11
	84-74-2	Di-n-butylphthalate[c]	$6.1x10^{-6}$	11
	132-64-9	Dibenzofuran	$1.5x10^{-5}$	11

Table 11.3-6 (cont.).

Source	Pollutant		Emission Factor, lb/ton	Ref. No.
	CASRN	Name		
Sawdust-fired kiln (SCC 3-05-003-10)	84-74-2	Dimethylphthalate[c]	$1.0x10^{-5}$	11
	100-41-4	Ethylbenzene	$8.5x10^{-6}$	11
	74-88-4	Iodomethane	$2.0x10^{-4}$	11
	1330-20-7	M-/p-xylene	$2.9x10^{-5}$	11
	75-09-2	Methylene chloride*	$7.5x10^{-6}$	11
	91-20-3	Naphthalene[c]	$3.4x10^{-4}$	11
	95-47-6	O-xylene[c]	$3.8x10^{-6}$	11
	108-95-2	Phenol	$7.2x10^{-5}$	11
	100-42-5	Styrene[b]	BDL ($4.4x10^{-7}$)	11
	127-18-4	Tetrachloroethane[b]	BDL ($3.0x10^{-7}$)	11
	108-88-3	Toluene	$1.1x10^{-4}$	11
	71-55-6	Trichloroethane[b]*	BDL ($3.0x10^{-7}$)	11
	75-69-4	Trichlorofluoromethane*	$5.8x10^{-6}$	11
	108-05-4	Vinyl acetate[b]	BDL ($3.0x10^{-7}$)	11
Sawdust-fired kiln and sawdust dryer[d] (SCC 3-05-003-61)	71-55-6	1,1,1-trichloroethane[b]*	BDL ($5.2x10^{-7}$)	11
	78-93-3	2-butanone	$2.2x10^{-4}$	11
	591-78-6	2-hexanone[b]	BDL ($3.8x10^{-7}$)	11
	95-48-7	2-methylphenol[b]	BDL ($2.4x10^{-9}$)	11
	67-64-1	Acetone*	0.0010	11
	107-13-1	Acrylonitrile	$1.9x10^{-5}$	11
	71-43-2	Benzene	$5.6x10^{-4}$	11
	117-81-7	Bis(2-ethylhexy)phthalate	$1.4x10^{-4}$	11
	74-83-9	Bromomethane	$4.4x10^{-5}$	11
	75-15-0	Carbon disulfide	$1.8x10^{-5}$	11
	56-23-5	Carbon tetrachloride[b]	BDL ($3.8x10^{-7}$)	11
	67-66-3	Chloroform[b]	BDL ($3.8x10^{-7}$)	11
	74-87-3	Chloromethane	0.0014	11
	84-74-2	Di-n-butylphthalate	$1.6x10^{-5}$	11
	132-64-9	Dibenzofuran[b]	BDL ($2.4x10^{-9}$)	11
	131-11-3	Dimethylphthalate[b]	BDL ($2.4x10^{-9}$)	11
	100-41-4	Ethylbenzene	$1.0x10^{-5}$	11
	74-88-4	Iodomethane	$2.4x10^{-4}$	11
	1330-20-7	M-/p-xylene	$2.9x10^{-5}$	11
	75-09-2	Methylene chloride*	$6.2x10^{-5}$	11
	91-20-3	Naphthalene[b]	BDL ($2.4x10^{-9}$)	11
	95-47-6	O-xylene	$7.3x10^{-6}$	11
	108-95-2	Phenol	$1.0x10^{-4}$	11
	100-42-5	Styrene[b]	BDL ($4.2x10^{-6}$)	11
	127-18-4	Tetrachloroethane[b]	BDL ($3.8x10^{-7}$)	11

Table 11.3-6 (cont.).

Source	Pollutant		Emission Factor, lb/ton	Ref. No.
	CASRN	Name		
Sawdust-fired kiln and sawdust dryer[d] (SCC 3-05-003-61)	108-88-3	Toluene	$4.3x10^{-4}$	11
	71-55-6	Trichloroethane[b]*	BDL ($3.8x10^{-7}$)	11
	75-69-4	Trichlorofluoromethane*	$1.0x10^{-6}$	11
	108-05-4	Vinyl acetate	$1.9x10^{-7}$	11

[a] Emission factor units are lb of pollutant per ton of fired bricks produced. To convert from lb/ton to kg/Mg, multiply by 0.5. CASRN = Chemical Abstracts Service Registry Number. * = Non-reactive compound as designated in 40 CFR 51.100(s), July 1, 1995. BDL = concentration was below the method detection limit.

[b] The emission factor for this pollutant is shown in parentheses and is based on the detection limit.

[c] Emissions were below the detection limit during two of three test runs. Emission factor is estimated as the average of the single measured quantity and one-half of the detection limit for the two nondetect runs.

[d] These emission factors are based on data from an atypical facility.

[e] Sawdust dryer heated with the exhaust stream from a sawdust-fired kiln.

Table 11.3-7. EMISSION FACTORS FOR METALS EMISSIONS FROM BRICK MANUFACTURING OPERATIONS[a]

Source	Pollutant	Emission Factor, lb/ton	EMISSION FACTOR RATING	Reference Nos.
Kiln[b] (SCC 3-05-003-10,-11,-13)	Antimony	$2.7x10^{-5}$	D	8-9,11,25
	Cadmium	$1.5x10^{-5}$	D	8-9,11,25
	Chromium	$5.1x10^{-5}$	D	9,11,25
	Cobalt	$2.1x10^{-6}$	E	25
	Lead	$1.5x10^{-4}$	D	8-9,11,25
	Nickel	$7.2x10^{-5}$	D	9,11,25
	Selenium	$2.3x10^{-4}$	D	8-9,11,25
Coal-fired kiln (SCC 3-05-003-13)	Arsenic	$1.3x10^{-4}$	E	9
	Beryllium	$1.6x10^{-5}$	E	9
	Manganese	$2.9x10^{-4}$	D	8-9,25
	Mercury	$9.6x10^{-5}$	E	9
	Phosphorus	$9.8x10^{-4}$	E	9,11
Natural gas-fired kiln (SCC 3-05-003-11)	Arsenic	$3.1x10^{-5}$	D	8,11,25
	Beryllium	$4.2x10^{-7}$	D	8,11,25
	Manganese	$2.9x10^{-4}$	D	8-9,25
	Mercury	$7.5x10^{-6}$	D	11,25
Sawdust-fired kiln (SCC 3-05-003-10)	Arsenic	$3.1x10^{-5}$	D	8,11,25
	Beryllium	$4.2x10^{-7}$	D	8,11,25
	Manganese	0.013[c]	E	11
	Mercury	$7.5x10^{-6}$	D	11,25
	Phosphorus	$9.8x10^{-4}$	E	9,11
Sawdust-fired kiln and sawdust dryer[d] (SCC 3-05-003-61)	Antimony	$2.8x10^{-6}$	E	11
	Arsenic	$2.1x10^{-5}$	E	11
	Beryllium	$3.1x10^{-7}$	E	11
	Cadmium	$2.2x10^{-5}$	E	11
	Chromium	$4.8x10^{-5}$	E	11
	Lead	$1.2x10^{-4}$	E	11
	Manganese	$4.8x10^{-4}$	E	11
	Mercury	$1.1x10^{-5}$	E	11
	Nickel	$3.4x10^{-5}$	E	11
	Phosphorus	$5.5x10^{-4}$	E	11
	Selenium	$4.7x10^{-5}$	E	11

[a] Emission factor units are lb of pollutant per ton of fired brick produced. Emission factors for individual facilities will vary based on the metal content of the raw material, metallic colorants used on the face of the bricks, metallic additives mixed into the bodies of the bricks, and the metal content of the fuels used for firing the kilns.
[b] Coal-, natural gas-, or sawdust-fired tunnel kiln.
[c] The facility uses a manganese surface treatment on the bricks. The manganese emission factor for coal- and natural gas-fired kilns is a better estimate for sawdust-fired kilns firing bricks that do not have a manganese surface treatment. Conversely, this emission factor should be used to estimate manganese emissions from coal- or natural gas-fired kilns firing a product with manganese surface treatment.
[d] Sawdust dryer heated with the exhaust stream from a sawdust-fired kiln.

Table 11.3.8. AVERAGE PARTICLE SIZE DISTRIBUTION FOR FILTERABLE PM EMISSIONS FROM KILNS[a]

Source	Aerodynamic Diameter, microns	Percent of Filterable PM Emissions Less Than or Equal to Stated Particle Size	Reference No.
Sawdust-fired kiln	10[b]	75	11,20
	2.5	48	11,20
	1	44	11,20
Coal-fired kiln	10[b]	63	9,21
	2.5	23	21
	1	9.8	21

[a] Particle size distribution based on cascade impactor tests unless noted.
[b] Based on cascade impactor particle size distribution and a comparison of PM-10 (measured using EPA Method 201A) and filterable PM (measured using EPA Method 5) emissions.

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