11.17 Lime Manufacturing

11.17.1 Process Description[1-5]

Lime is the high-temperature product of the calcination of limestone. Although limestone deposits are found in every state, only a small portion is pure enough for industrial lime manufacturing. To be classified as limestone, the rock must contain at least 50 percent calcium carbonate. When the rock contains 30 to 45 percent magnesium carbonate, it is referred to as dolomite, or dolomitic limestone. Lime can also be produced from aragonite, chalk, coral, marble, and sea shells. The Standard Industry Classification (SIC) code for lime manufacturing is 3274. The six-digit Source Classification Code (SCC) for lime manufacturing is 3-05-016.

Lime is manufactured in various kinds of kilns by one of the following reactions:

$CaCO_3$ + heat → CO_2 + CaO (high calcium lime)
$CaCO_3 \cdot MgCO_3$ + heat → $2CO_2$ + $CaO \cdot MgO$ (dolomitic lime)

In some lime plants, the resulting lime is reacted (slaked) with water to form hydrated lime. The basic processes in the production of lime are: (1) quarrying raw limestone; (2) preparing limestone for the kilns by crushing and sizing; (3) calcining limestone; (4) processing the lime further by hydrating; and (5) miscellaneous transfer, storage, and handling operations. A generalized material flow diagram for a lime manufacturing plant is given in Figure 11.17-1. Note that some operations shown may not be performed in all plants.

The heart of a lime plant is the kiln. The prevalent type of kiln is the rotary kiln, accounting for about 90 percent of all lime production in the United States. This kiln is a long, cylindrical, slightly inclined, refractory-lined furnace, through which the limestone and hot combustion gases pass countercurrently. Coal, oil, and natural gas may all be fired in rotary kilns. Product coolers and kiln feed preheaters of various types are commonly used to recover heat from the hot lime product and hot exhaust gases, respectively.

The next most common type of kiln in the United States is the vertical, or shaft, kiln. This kiln can be described as an upright heavy steel cylinder lined with refractory material. The limestone is charged at the top and is calcined as it descends slowly to discharge at the bottom of the kiln. A primary advantage of vertical kilns over rotary kilns is higher average fuel efficiency. The primary disadvantages of vertical kilns are their relatively low production rates and the fact that coal cannot be used without degrading the quality of the lime produced. There have been few recent vertical kiln installations in the United States because of high product quality requirements.

Other, much less common, kiln types include rotary hearth and fluidized bed kilns. Both kiln types can achieve high production rates, but neither can operate with coal. The "calcimatic" kiln, or rotary hearth kiln, is a circular kiln with a slowly revolving doughnut-shaped hearth. In fluidized bed kilns, finely divided limestone is brought into contact with hot combustion air in a turbulent zone, usually above a perforated

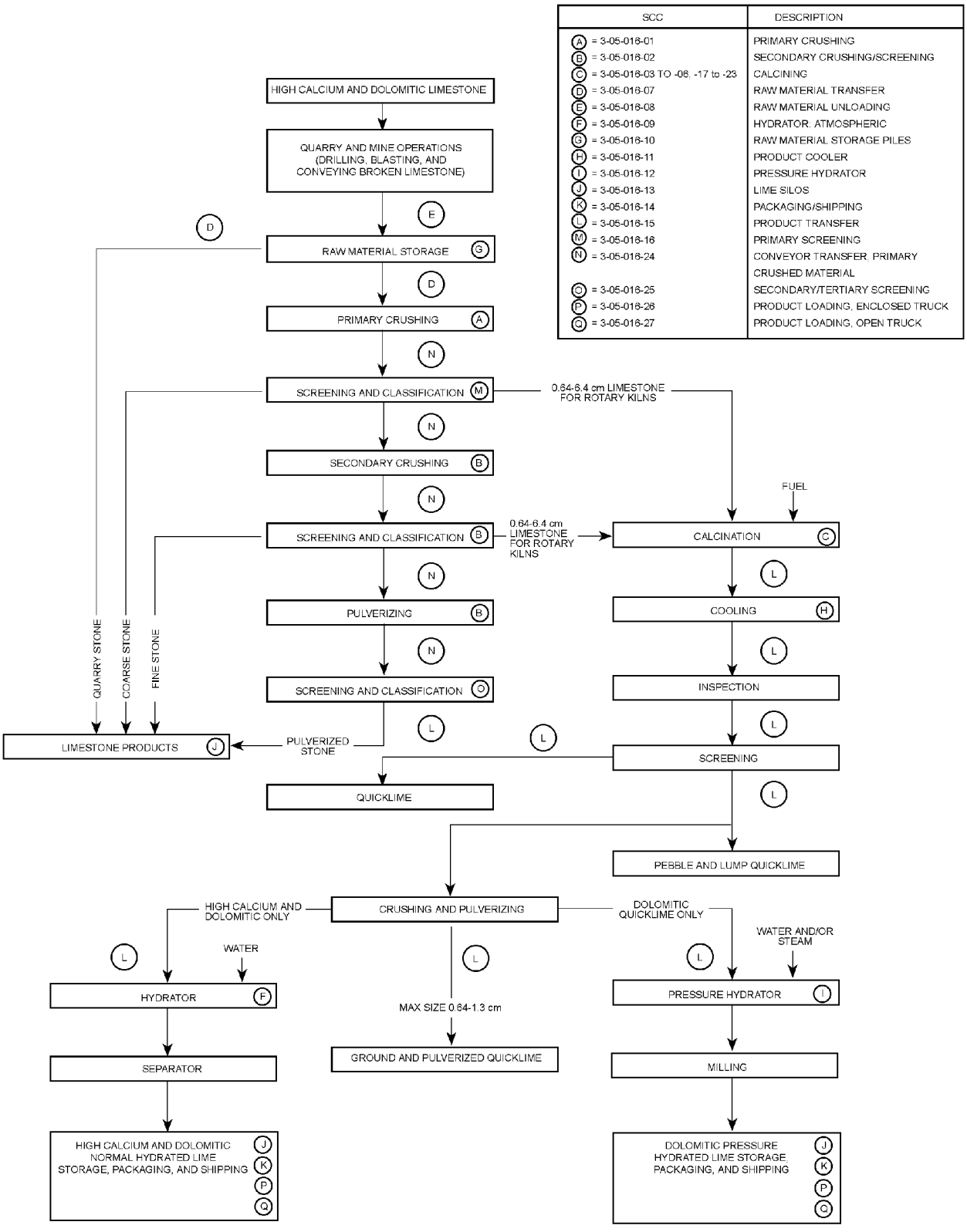

Figure 11.17-1. Process flow diagram for lime manufacturing.[4]
(SCC = Source Classification Code.)

grate. Because of the amount of lime carryover into the exhaust gases, dust collection equipment must be installed on fluidized bed kilns for process economy.

Another alternative process that is beginning to emerge in the United States is the parallel flow regenerative (PR) lime kiln. This process combines 2 advantages. First, optimum heating conditions for lime calcining are achieved by concurrent flow of the charge material and combustion gases. Second, the multiple-chamber regenerative process uses the charge material as the heat transfer medium to preheat the combustion air. The basic PR system has 2 shafts, but 3 shaft systems are used with small size grains to address the increased flow resistance associated with smaller feed sizes.

In the 2-shaft system, the shafts alternate functions, with 1 shaft serving as the heating shaft and the other as the flue gas shaft. Limestone is charged alternatively to the 2 shafts and flows downward by gravity flow. Each shaft includes a heating zone, a combustion/burning zone, and a cooling zone. The 2 shafts are connected in the middle to allow gas flow between them. In the heating shaft, combustion air flows downward through the heated charge material. After being preheated by the charge material, the combustion air combines with the fuel (natural gas or oil), and the air/fuel mixture is fired downward into the combustion zone. The hot combustion gases pass from the combustion zone in the heating shaft to the combustion zone in the flue gas shaft. The heated exhaust gases flow upward through the flue gas shaft combustion zone and into the preheating zone where they heat the charge material. The function of the 2 shafts reverses on a 12-minute cycle. The bottom of both shafts is a cooling zone. Cooling air flows upward through the shaft countercurrently to the flow of the calcined product. This air mixes with the combustion gases in the crossover area providing additional combustion air. The product flows by gravity from the bottom of both shafts.

About 15 percent of all lime produced is converted to hydrated (slaked) lime. There are 2 kinds of hydrators: atmospheric and pressure. Atmospheric hydrators, the more prevalent type, are used in continuous mode to produce high-calcium and dolomitic hydrates. Pressure hydrators, on the other hand, produce only a completely hydrated dolomitic lime and operate only in batch mode. Generally, water sprays or wet scrubbers perform the hydrating process and prevent product loss. Following hydration, the product may be milled and then conveyed to air separators for further drying and removal of coarse fractions.

The major uses of lime are metallurgical (aluminum, steel, copper, silver, and gold industries), environmental (flue gas desulfurization, water softening, pH control, sewage-sludge destabilization, and hazardous waste treatment), and construction (soil stabilization, asphalt additive, and masonry lime).

11.17.2 Emissions And Controls[1-4,6]

Potential air pollutant emission points in lime manufacturing plants are indicated by SCC in Figure 11.17-1. Except for gaseous pollutants emitted from kilns, particulate matter (PM) is the only dominant pollutant. Emissions of filterable PM from rotary lime kilns constructed or modified after May 3, 1977 are regulated to 0.30 kilograms per megagram (kg/Mg) (0.60 pounds per ton [lb/ton]) of stone feed under 40 CFR Part 60, subpart HH.

The largest ducted source of particulate is the kiln. The properties of the limestone feed and the ash content of the coal (in coal-fired kilns) can significantly affect PM emission rates. Of the various kiln types, fluidized beds have the highest levels of uncontrolled PM emissions because of the very small feed rate combined with the high air flow through these kilns. Fluidized bed kilns are well controlled for maximum product recovery. The rotary kiln is second worst in uncontrolled PM emissions because of the small feed rate and relatively high air velocities and because of dust entrainment caused by the rotating chamber. The calcimatic (rotary hearth) kiln ranks third in dust production primarily because of the larger feed rate and the

fact that, during calcination, the limestone remains stationary relative to the hearth. The vertical kiln has the lowest uncontrolled dust emissions due to the large lump feed, the relatively low air velocities, and the slow movement of material through the kiln. In coal-fired kilns, the properties of the limestone feed and the ash content of the coal can significantly affect PM emissions.

Some sort of particulate control is generally applied to most kilns. Rudimentary fallout chambers and cyclone separators are commonly used to control the larger particles. Fabric and gravel bed filters, wet (commonly venturi) scrubbers, and electrostatic precipitators are used for secondary control.

Carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxides (NO_x) are all produced in kilns. Sulfur dioxide emissions are influenced by several factors, including the sulfur content of the fuel, the sulfur content and mineralogical form (pyrite or gypsum) of the stone feed, the quality of lime being produced, and the type of kiln. Due to variations in these factors, plant-specific SO_2 emission factors are likely to vary significantly from the average emission factors presented here. The dominant source of sulfur emissions is the kiln's fuel, and the vast majority of the fuel sulfur is not emitted because of reactions with calcium oxides in the kiln. Sulfur dioxide emissions may be further reduced if the pollution equipment uses a wet process or if it brings CaO and SO_2 into intimate contact.

Carbon dioxide is emitted from the kiln as a result of the carbonate in the limestone being reduced to CO_2 gas, and the carbon in the fuel oxidizing. If CO_2 emissions from the fuel combustion are estimated using data from Chapter 1 (External Combustion Sources) only non-combustion CO_2 emission factors should be used (915 kg/Mg (1830 lb/ton) lime produced for dolomitic limestone and 785 kg/Mg (1570 lb/ton) lime produced for calcitic limestone). These estimates are theoretical, based on the production of two moles of CO_2 for each mole of limestone produced. In some facilities a portion of the CO_2 generated is recovered for use in sugar refining.

In sugar refining, a suspension of hydrated lime in water is used to adjust the pH of the product stream and precipitate colloidal impurities.[7] The lime is then removed by reaction with carbon dioxide.[7]

Product coolers are emission sources only when some of their exhaust gases are not recycled through the kiln for use as combustion air. The trend is away from the venting of product cooler exhaust, however, to maximize fuel use efficiencies. Cyclones, baghouses, and wet scrubbers have been used on coolers for particulate control.

Hydrator emissions are low because water sprays or wet scrubbers are usually installed to prevent product loss in the exhaust gases. Emissions from pressure hydrators may be higher than from the more common atmospheric hydrators because the exhaust gases are released intermittently, making control more difficult.

Other particulate sources in lime plants include primary and secondary crushers, mills, screens, mechanical and pneumatic transfer operations, storage piles, and roads. If quarrying is a part of the lime plant operation, particulate emissions may also result from drilling and blasting. Emission factors for some of these operations are presented in Sections 11.19 and 13.2 of this document.

Tables 11.17-1 (metric units) and 11.17-2 (English units) present emission factors for PM emissions from lime manufacturing calcining, cooling, and hydrating. Tables 11.17-3 (metric units) and 11.17-4 (English units) include emission factors for the mechanical processing (crushing, screening, and grinding) of limestone and for some materials handling operations. Section 11.19, Construction Aggregate Processing, also includes stone processing emission factors that are based on more recent testing, and, therefore, may be more representative of emissions from stone crushing, grinding, and screening. In addition, Section 13.2, Fugitive Dust Sources, includes emission factors for materials handling that may be more representative of materials handling emissions than the emission factors in Tables 11.17-3 and 11.17-4.

Emission factors for emissions of SO_2, NO_x, CO, and CO_2 from lime manufacturing are presented in Tables 11.17-5 and 11.17-6. Particle size distribution for rotary lime kilns is provided in Table 11.17-7.

Because of differences in the sulfur content of the raw material and fuel and in process operations, a mass balance on sulfur may yield a more representative emission factor for a specific facility than the SO_2 emission factors presented in Tables 11.17-5 and 11.17-6. In addition, CO_2 emission factors estimated using a mass balance on carbon may be more representative for a specific facility than the CO_2 emission factors presented in Tables 11.17-5 and 11.17-6. Additional information on estimating emission factors for CO_2 emissions from lime kilns can be found in the background report for this AP-42 section.

11.17.3 Updates Since the Fifth Edition

The Fifth Edition was released in January 1995. Revisions to this section since that date are summarized below. For further detail, consult the memoranda describing each supplement or the background report for this section. These and other documents can be found on the EFIG home page (http://www.epa.gov/ttn/chief).

Supplement D, June 1998

- Revision made to distinguish between the carbon dioxide that is emitted from a kiln as a result of the carbonate in the limestone being reduced to CO2 gas, and the carbon in the fuel oxidizing (based on information already contained in the background report).
- Note added to indicate that some of the CO2 created in lime manufacturing is used in sugar refining.
- The report cited for the above information was added to the reference section as reference number 7. This changed the numbering for the subsequent references.
- The background document was not revised.

Table 11.17-1 (Metric Units). EMISSION FACTORS FOR LIME MANUFACTURING CALCINING, COOLING, AND HYDRATING[a]

Source	Filterable[b]				Condensable PM[c]			
	PM	EMISSION FACTOR RATING	PM-10	EMISSION FACTOR RATING	Inorganic	EMISSION FACTOR RATING	Organic	EMISSION FACTOR RATING
Coal-fired rotary kiln (SCC 3-05-016-18)	180[d]	D	22[e]	D	0.67[f]	D	0.51[g]	E
Coal-fired rotary kiln with large diameter cyclone (SCC 3-05-016-18)	60[h]	D	ND		ND		ND	
Coal-fired rotary kiln with fabric filter (SCC 3-05-016-18)	0.14[j]	D	0.077[k]	D	0.19[m]	E	ND	
Coal-fired rotary kiln with ESP (SCC 3-05-016-18)	4.3[h]	D	2.2[n]	D	ND		ND	
Coal-fired rotary kiln with venturi scrubber (SCC 3-05-016-18)	0.72[p]	D	ND		0.14[q]	D	ND	
Gas-fired rotary kiln with ESP (SCC 3-05-016-19)	0.086[r]	E	ND		0.11[r]	E	ND	
Gas-fired rotary kiln with gravel bed filter (SCC 3-05-016-19)	0.51[s]	E	ND		0.24[s]	E	ND	
Coal- and gas fired rotary kiln (SCC 3-05-016-20)	40[t]	E	ND		ND		ND	
Coal- and gas-fired rotary kiln with venturi scrubber (SCC 3-05-016-20)	0.44[t]	D	ND		0.041[t]	D	ND	
Coal- and coke-fired rotary kiln with venturi scrubber (SCC 3-05-016-21)	0.83[u]	D	ND		ND		ND	
Coal-fired rotary preheater kiln with multiclone (SCC 3-05-016-22)	42[v]	E	ND		0.040[v]	E	ND	
Coal-fired rotary preheater kiln with gravel bed filter (SCC 3-05-016-22)	0.59[w]	E	ND		ND		ND	
Coal-fired rotary preheater kiln with multiclone, water spray, and fabric filter (SCC 3-05-016-22)	0.56[x]	E	ND		0.57[x]	E	0.076[x]	E

Table 11.17-1 (cont.).

Source	Filterable[b]				Condensable PM[c]			
	PM	EMISSION FACTOR RATING	PM-10	EMISSION FACTOR RATING	Inorganic	EMISSION FACTOR RATING	Organic	EMISSION FACTOR RATING
Gas-fired calcimatic kiln (SCC 3-05-016-05)	48[y]	E	ND		0.14[y]	E	ND	
Gas-fired parallel flow regenerative kiln with fabric filter (SCC 3-05-016-23)	0.051[z]	D	ND		ND		ND	
Atmospheric hydrator with wet scrubber (SCC 3-05-016-09)	0.033[aa]	D	ND		0.0067[aa]	D	ND	
Product cooler (SCC 3-05-016-11)	3.4[y]	E	ND		0.011[y]	E	ND	

[a] Factors represent uncontrolled emissions unless otherwise noted. All emission factors in kg/Mg of lime produced unless noted. ND = no data. SCC = Source Classification Code.
[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.
[c] Condensable PM is that PM collected in the impinger portion of a PM sampling train.
[d] References 11-12.
[e] References 4,11-12.
[f] References 11,13.
[g] Reference 11.
[h] Reference 12.
[j] References 12,20,31,33.
[k] References 4,12,20,31,33.
[m] References 9,20-23,33.
[n] References 4,12.
[p] References 8,28-29.
[q] References 8,15-16.
[r] Reference 14.
[s] References 17,32.
[t] Reference 19.
[u] Reference 30.
[v] Reference 12.
[w] Reference 18.
[x] Reference 34.
[y] Reference 25.
[z] Reference 35.
[aa] Reference 24; units are kg/Mg of hydrated lime produced.

Table 11.17-2 (English Units). EMISSION FACTORS FOR LIME MANUFACTURING CALCINING, COOLING, AND HYDRATING[a]

Source	Filterable[b]				Condensable PM[c]			
	PM	EMISSION FACTOR RATING	PM-10	EMISSION FACTOR RATING	Inorganic	EMISSION FACTOR RATING	Organic	EMISSION FACTOR RATING
Coal-fired rotary kiln (SCC 3-05-016-18)	350[d]	D	42[e]	D	1.3[f]	D	1.0[g]	E
Coal-fired rotary kiln with large diameter cyclone (SCC 3-05-016-18)	120[h]	D	ND		ND		ND	
Coal-fired rotary kiln with fabric filter (SCC 3-05-016-18)	0.28[j]	D	0.15[k]	D	0.38[m]	E	ND	
Coal-fired rotary kiln with ESP (SCC 3-05-016-18)	8.5[h]	D	4.3[n]	D	ND		ND	
Coal-fired rotary kiln with venturi scrubber (SCC 3-05-016-18)	1.4[p]	D	ND		0.28[q]	D	ND	
Gas-fired rotary kiln with ESP (SCC 3-05-016-19)	0.17[r]	E	ND		0.22[r]	E	ND	
Gas-fired rotary kiln with gravel bed filter (SCC 3-05-016-19)	0.99[s]	E	ND		0.48[s]	E	ND	
Coal- and gas fired rotary kiln (SCC 3-05-016-20)	80[t]	E	ND		ND		ND	
Coal- and gas-fired rotary kiln with venturi scrubber (SCC 3-05-016-20)	0.87[t]	D	ND		0.082[t]	D	ND	
Coal- and coke-fired rotary kiln with venturi scrubber (SCC 3-05-016-21)	1.7[u]	D	ND		ND		ND	
Coal-fired rotary preheater kiln with multiclone (SCC 3-05-016-22)	84[v]	E	ND		0.081[v]	E	ND	
Coal-fired rotary preheater kiln with gravel bed filter (SCC 3-05-016-22)	1.2[w]	E	ND		ND		ND	
Coal-fired rotary preheater kiln with multiclone, water spray, and fabric filter (SCC 3-05-016-22)	1.1[x]	E	ND		1.1[x]	E	0.15[x]	E
Gas-fired calcimatic kiln (SCC 3-05-016-05)	97[y]	E	ND		0.27[y]	E	ND	

Table 11.17-2 (cont.).

Source	Filterable[b]				Condensable PM[c]			
	PM	EMISSION FACTOR RATING	PM-10	EMISSION FACTOR RATING	Inorganic	EMISSION FACTOR RATING	Organic	EMISSION FACTOR RATING
Gas-fired parallel flow regenerative kiln with fabric filter (SCC 3-05-016-23)	0.026[z]	D	ND		ND		ND	
Atmospheric hydrator with wet scrubber (SCC 3-05-016-09)	0.067[aa]	D	ND		0.013[aa]	D	ND	
Product cooler (SCC 3-05-016-11)	6.8[y]	E	ND		0.023[y]	E	ND	

[a] Factors represent uncontrolled emissions unless otherwise noted. Factors are lb/ton of lime produced unless noted. ND = no data. SCC = Source Classification Code.
[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.
[c] Condensable PM is that PM collected in the impinger portion of a PM sampling train.
[d] References 11-12.
[e] References 4,11-12.
[f] References 9,13.
[g] Reference 11.
[h] Reference 12.
[j] References 12,20,31,33.
[k] References 4,12,20,31,33.
[m] References 8,20-23,33.
[n] References 4,12.
[p] References 10,28-29.
[q] References 10,15-16.
[r] Reference 14.
[s] References 17,32.
[t] Reference 19.
[u] Reference 30.
[v] Reference 13.
[w] Reference 18.
[x] Reference 34.
[y] Reference 25.
[z] Reference 35.
[aa] Reference 24; units are lb/ton of hydrated lime produced.

Table 11.17-3 (Metric Units). EMISSION FACTORS FOR LIME MANUFACTURING RAW MATERIAL AND PRODUCT PROCESSING AND HANDLING[a]

Source	Filterable[b]			
	PM	EMISSION FACTOR RATING	PM-10	EMISSION FACTOR RATING
Primary crusher[c] (SCC 3-05-016-01)	0.0083	E	ND	
Scalping screen and hammermill (secondary crusher)[c] (SCC 3-05-016-02)	0.31	E	ND	
Primary crusher with fabric filter[d] (SCC 3-05-016-01)	0.00021	D	ND	
Primary screen with fabric filter[e] (SCC 3-05-016-16)	0.0030	D	ND	
Crushed material conveyor transfer with fabric filter[f] (SCC 3-05-016-24)	4.4×10^{-5}	D	ND	
Secondary and tertiary screen with fabric filter[g] (SCC 3-05-016-25)	6.5×10^{-5}	D	ND	
Product transfer and conveying (SCC 3-05-016-15)[h]	1.1	E	ND	
Product loading, enclosed truck (SCC 3-05-016-26)[h]	0.31	D	ND	
Product loading, open truck (SCC 3-05-016-27)[h]	0.75	D	ND	

[a] Factors represent uncontrolled emissions unless otherwise noted. Factors are kg/Mg of material processed unless noted. ND = no data. SCC = Source Classification Code.

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

[c] Reference 8; units of kg/Mg of stone processed.

[d] Reference 35. Emission factors in units of kg/Mg of material processed. Includes scalping screen, scalping screen discharges, primary crusher, primary crusher discharges, and ore discharge.

[e] Reference 35. Emission factors in units of kg/Mg of material processed. Includes primary screening, including the screen feed, screen discharge, and surge bin discharge.

[f] Reference 35. Emission factors in units of kg/Mg of material processed. Based on average of three runs each of emissions from two conveyor transfer points on the conveyor from the primary crusher to the primary stockpile.

[g] Reference 35. Emission factors in units of kg/Mg of material processed. Based on sum of emissions from two emission points that include conveyor transfer point for the primary stockpile underflow to the secondary screen, secondary screen, tertiary screen, and tertiary screen discharge.

[h] Reference 12; units of kg/Mg of product loaded.

Table 11.17-4 (English Units). EMISSION FACTORS FOR LIME MANUFACTURING RAW MATERIAL AND PRODUCT PROCESSING AND HANDLING[a]

Source	Filterable[b]			
	PM	EMISSION FACTOR RATING	PM-10	EMISSION FACTOR RATING
Primary crusher[c] (SCC 3-05-016-01)	0.017	E	ND	
Scalping screen and hammermill (secondary crusher) (SCC 3-05-016-02)[c]	0.62	E	ND	
Primary crusher with fabric filter[d] (SCC 3-05-016-01)	0.00043	D	ND	
Primary screen with fabric filter[e] (SCC 3-05-016-16)	0.00061	D	ND	
Crushed material conveyor transfer with fabric filter[f] (SCC 3-05-016-24)	8.8×10^{-5}	D	ND	
Secondary and tertiary screen with fabric filter[g] (SCC 3-05-016-25)	0.00013	D	ND	
Product transfer and conveying (SCC 3-05-016-15)[h]	2.2	E	ND	
Product loading, enclosed truck (SCC 3-05-016-26)[h]	0.61	D	ND	
Product loading, open truck (SCC 3-05-016-27)[h]	1.5	D	ND	

[a] Factors represent uncontrolled emissions unless otherwise noted. Factors are lb/ton of material processed unless noted. ND = no data. SCC = Source Classification Code.

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

[c] Reference 8; factors are lb/ton.

[d] Reference 35. Factors are lb/ton of material processed. Includes scalping screen, scalping screen discharges, primary crusher, primary crusher discharges, and ore discharge.

[e] Reference 35. Factors are lb/ton of material processed. Includes primary screening, including the screen feed, screen discharge, and surge bin discharge.

[f] Reference 35. Factors are lb/ton of material processed. Based on average of three runs each of emissions from two conveyor transfer points on the conveyor from the primary crusher to the primary stockpile.

[g] Reference 35. Emission factors in units of kg/Mg of material processed. Based on sum of emissions from two emission points that include conveyor transfer point for the primary stockpile underflow to the secondary screen, secondary screen, tertiary screen, and tertiary screen discharge.

[h] Reference 12; units are lb/ton of product loaded.

Table 11.17-5 (Metric Units). EMISSION FACTORS FOR LIME MANUFACTURING[a]

Source	SO_2[b]	EMISSION FACTOR RATING	SO_3	EMISSION FACTOR RATING	NO_x	EMISSION FACTOR RATING	CO	EMISSION FACTOR RATING	CO_2[c]	EMISSION FACTOR RATING
Coal-fired rotary kiln (SCC 3-05-016-18)	2.7[d]	D	ND		1.6[e]	C	0.74[f]	D	1,600[g]	C
Coal-fired rotary kiln with fabric filter (SCC 3-05-016-18)	0.83[h]	D	ND		ND		ND		ND	
Coal-fired rotary kiln with wet scrubber (SCC 3-05-016-18)	0.15[j]	D	0.11[k]	E	ND		ND		ND	
Gas-fired rotary kiln (SCC 3-05-016-19)	ND		ND		1.7[m]	E	1.1[m]	E	ND	
Coal- and gas-fired rotary kiln with venturi scrubber (SCC 3-05-016-20)	ND		ND		1.4[n]	D	0.41[n]	D	1,600[n]	D
Coal- and coke-fired rotary kiln with venturi scrubber (SCC 3-05-016-21)	ND		ND		ND		ND		1,500[p]	D
Coal-fired rotary preheater kiln with dry PM controls (SCC 3-05-016-22)	1.1[q]	E	ND		ND		ND		ND	
Coal-fired rotary preheater kiln with multiclone, water spray, and fabric filter (SCC 3-05-016-22)	3.2[r]	E	ND		ND		3.2[r]	E	1,200[r]	E
Gas-fired calcimatic kiln (SCC 3-05-016-05)	ND		ND		0.076[s]	D	ND		1,300[s]	E
Gas-fired parallel flow regenerative kiln with fabric filter (SCC 3-05-016-23)	0.0060[t]	D	ND		0.12[t]	D	0.23[t]	D	ND	
Product cooler (SCC 3-05-016-11)	ND	ND			ND		ND		3.9[s]	E

[a] Factors represent uncontrolled emissions unless otherwise noted. Factors are kg/Mg of lime produced unless noted. ND = no data. SCC = Source Classification Code.

[b] Mass balance on sulfur may yield a more representative emission factor for a specific facility.

[c] Mass balance on carbon may yield a more representative emission factor for a specific facility.

[d] References 11,20.

[e] References 11,13,20,31,33.

[f] References 20,27.

[g] References 10-11,26-29,31.

Table 11.17-5 (cont.).

[h] References 20,31,33.
[j] Reference 27.
[k] Reference 15.
[m] Reference 14.
[n] Reference 19.
[p] Reference 30.
[q] References 18,26.
[r] Reference 34.
[s] Reference 25.
[t] Reference 35.

Table 11.17-6 (English Units). EMISSION FACTORS FOR LIME MANUFACTURING[a]

Source	SO_2[b]	EMISSION FACTOR RATING	SO_3	EMISSION FACTOR RATING	NO_x	EMISSION FACTOR RATING	CO	EMISSION FACTOR RATING	CO_2[c]	EMISSION FACTOR RATING
Coal-fired rotary kiln (SCC 3-05-016-18)	5.4[d]	D	ND		3.1[e]	C	1.5[f]	D	3,200[g]	C
Coal-fired rotary kiln with fabric filter (SCC 3-05-016-18)	1.7[h]	D	ND		ND		ND		ND	
Coal-fired rotary kiln with wet scrubber (SCC 3-05-016-18)	0.30[j]	D	0.21[k]	E	ND		ND		ND	
Gas-fired rotary kiln (SCC 3-05-016-19)	ND		ND		3.5[m]	E	2.2[m]	E	ND	
Coal- and gas fired rotary kiln with venturi scrubber (SCC 3-05-016-20)	ND		ND		2.7[n]	D	0.83[n]	D	3,200[n]	D
Coal- and coke-fired rotary kiln with venturi scrubber (SCC 3-05-016-21)	ND		ND		ND		ND		3,000[p]	D
Coal-fired rotary preheater kiln with dry PM controls (SCC 3-05-016-22)	2.3[q]	E	ND		ND		ND		ND	
Coal-fired rotary preheater kiln with multiclone, water spray, and fabric filter (SCC 3-05-016-22)	6.4[r]	E	ND		ND		6.3[r]	E	2,400[r]	E
Gas-fired calcimatic kiln (SCC 3-05-016-05)	ND		ND		0.15[s]	D	ND		2,700[s]	E
Gas-fired parallel flow regenerative kiln with fabric filter (SCC 3-05-016-23)	0.0012[t]	D	ND		0.24[t]	D	0.45[t]	D	ND	
Product cooler (SCC 3-05-016-11)	ND		ND		ND		ND		7.8[s]	E

[a] Factors represent uncontrolled emissions unless otherwise noted. Factors are lb/ton of lime produced unless noted. ND = no data. SCC = Source Classification Code.

[b] Mass balance on sulfur may yield a more representative emission factor for a specific facility.

[c] Mass balance on carbon may yield a more representative emission factor for a specific facility.

[d] References 11,20.

[e] References 11,13,20,31,33.

[f] References 20,27.

Table 11.17-6 (cont.).

[h] References 20,31,33.
[j] Reference 27.
[k] Reference 15.
[m] Reference 14.
[n] Reference 19.
[p] Reference 30.
[q] References 18,26.
[r] Reference 34.
[s] Reference 25.
[t] Reference 35.

Table 11.17-7. AVERAGE PARTICLE SIZE DISTRIBUTION FOR ROTARY LIME KILNS[a]

Particle Size (μm)	Cumulative Mass Percent Less Than Stated Particle Size			
	Uncontrolled Rotary Kiln	Rotary Kiln With Multiclone	Rotary Kiln With ESP	Rotary Kiln With Fabric Filter
2.5	1.4	6.1	14	27
5.0	2.9	9.8	ND	ND
10.0	12	16	50	55
15.0	31	23	62	73
20.0	ND	31	ND	ND

[a] Reference 4, Table 4-28; based on A- and C-rated particle size data. Source Classification Codes 3-05-016-04, and -18 to -21. ND = no data.

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AP-42 Section 11.17 - Lime Manufacturing
Section and Background document information

The file b11s17.zip located under \programs\misc\ on this CD, contains the original files that were used to create the final AP-42 section and Background report for Lime Manufacturing. Much of the information contained in the following files are presented in the Adobe Acrobat versions of these reports. However, users wishing additional detail can use the spreadsheet files to understand the factor development more thoroughly and to perform additional analysis with the data or additional data where available. The following files are contained in the compressed zip file.

c11s17.wpd
AP-42 Section for Lime Manufacturing in WordPerfect 6.1 for Windows format

LIMEBKGD
Background Report for Lime Manufacturing in WordPerfect 5.1 for DOS.

LIME_APF.TIF
LIME_BKF.TIF
These are Graphics files used in the AP-42 section and background report. They are Tagged Image format files.

Limer5.wk4
This is a Lotus 1,2,3 release 5 for Windows file that contains summary statistical information on the factors presented in the AP-42 section