

CEMENT INDUSTRIES

A. PROCESS DESCRIPTION

Cement industries typically produce portland cement, although they also produce masonry cement (which is also manufactured at portland cement plants). Portland cement is a fine, typically gray powder comprised of dicalcium silicate, tricalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite, with the addition of forms of calcium sulfate. Different types of portland cements are created based on the use and chemical and physical properties desired. Portland cement types I - V are the most common. Portland cement plants can operate continuously for long time periods (i.e., 6 months) with minimal shut down time for maintenance. The air pollution problems related to the production, handling, and transportation of portland cement are caused by the very fine particles in the product.

Exhibit 1 illustrates the stages of cement production at a portland cement plant:

1. Procurement of raw materials
2. Raw Milling - preparation of raw materials for the pyroprocessing system
3. Pyroprocessing - pyroprocessing raw materials to form portland cement clinker
4. Cooling of portland cement clinker
5. Storage of portland cement clinker
6. Finish Milling
7. Packing and loading

1. Raw Material Acquisition

Most of the raw materials used are extracted from the earth through mining and quarrying and can be divided into the following groups: lime (calcareous), silica (siliceous), alumina (argillaceous), and iron (ferriferous). Since a form of calcium carbonate, usually limestone, is the predominant raw material, most plants are situated near a limestone quarry or receive this material from a source via inexpensive transportation. The plant must minimize the transportation cost since one third of the limestone is converted to CO_2 during the pyroprocessing and is subsequently lost. Quarry operations consist of drilling, blasting, excavating, handling, loading, hauling, crushing, screening, stockpiling, and storing.

2. Raw Milling

Raw milling involves mixing the extracted raw materials to obtain the correct chemical configuration, and grinding them to achieve the proper particle-size to ensure optimal fuel efficiency in the cement kiln and strength in the final concrete product. Three types of processes may be used: the dry process, the wet process, or the semidry process. If the dry process is used, the raw materials are dried using impact dryers, drum dryers, paddle-equipped

Exhibit 1

rapid dryers, air separators, or autogenous mills, before grinding, or in the grinding process itself. In the wet process, water is added during grinding. In the semidry process the materials are formed into pellets with the addition of water in a pelletizing device.

3. Pyroprocessing

In pyroprocessing, the raw mix is heated to produce portland cement clinkers. Clinkers are hard, gray, spherical nodules with diameters ranging from 0.32 - 5.0 cm (1/8 - 2") created from the chemical reactions between the raw materials. The pyroprocessing system involves three steps: drying or preheating, calcining (a heating process in which calcium oxide is formed), and burning (sintering). The pyroprocessing takes place in the burning/kiln department. The raw mix is supplied to the system as a slurry (wet process), a powder (dry process), or as moist pellets (semidry process). All systems use a rotary kiln and contain the burning stage and all or part of the calcining stage. For the wet and dry processes, all pyroprocessing operations take place in the rotary kiln, while drying and preheating and some of the calcination are performed outside the kiln on moving grates supplied with hot kiln gases.

4. Clinker Cooling

The clinker cooling operation recovers up to 30% of kiln system heat, preserves the ideal product qualities, and enables the cooled clinker to be maneuvered by conveyors. The most common types of clinker coolers are reciprocating grate, planetary, and rotary. Air sent through the clinker to cool it is directed to the rotary kiln where it nourishes fuel combustion. The fairly coarse dust collected from clinker coolers is comprised of cement minerals and is restored to the operation. Based on the cooling efficiency and desired cooled temperature, the amount of air used in this cooling process is approximately 1-2 kg/kg of clinker. The amount of gas to be cleaned following the cooling process is decreased when a portion of the gas is used for other processes such as coal drying.

5. Clinker Storage

Although clinker storage capacity is based on the state of the market, a plant can normally store 5 - 25% of its annual clinker production capacity. Equipment such as conveyors and bucket elevators is used to transfer the clinkers from coolers to storage areas and to the finish mill. Gravity drops and transfer points typically are vented to dust collectors.

6. Finish Milling

During the final stage of portland cement production known as finish milling, the clinker is ground with other materials (which impart special characteristics to the finished product) into a fine powder. Up to 5% gypsum and/or natural anhydrite is added to regulate the setting time of the cement. Other chemicals, such as those which regulate flowability or air entrainment, may also be added. Many plants use a roll crusher to achieve a preliminary size reduction of the clinker and gypsum. These materials are then sent through ball or tube mills (rotating, horizontal steel cylinders containing steel alloy balls) which perform the remaining grinding. The grinding process occurs in a closed system with an air separator that divides the cement particles according to size. Material that has not been completely ground is sent through the system again.

7. Packing and Loading

Once the production of portland cement is complete, the finished product is transferred using bucket elevators and conveyors to large, storage silos in the shipping department. Most of the portland cement is transported in bulk by railway, truck, or barge, or in 43 kg (94 pound) multiwalled paper bags. Bags are used primarily to package masonry cement. Once the cement leaves the plant, distribution terminals are sometimes used as an intermediary holding location prior to customer distribution. The same types of conveyor systems used at the plant are used to load cement at distribution terminals.

B. SOURCES OF POLLUTION

Although portland cement plants generate the same final product using similar processes, plant layouts vary according to fuels and raw materials used, location, climate, site topography, and the manufacturer of the equipment. The flow diagram in Exhibit 1 depicts the manufacturing process at a portland cement plant and indicates emission points throughout the process.

C. POLLUTANTS AND THEIR CONTROL

This section briefly discusses the nature of the pollutants generated from, and controls used at, several sources in the cement manufacturing process. Air pollutants are typically of greater concern than solid or liquid wastes.

1. Air Pollutants

Air pollutants generated during the cement manufacturing process consist primarily of particulates from the raw and finished materials, and fuel combustion by-products. Exhibit 2 indicates sources of air pollution, and differentiates between particulates and other air pollutants.

Controlling particulate emissions from sources other than the kiln usually entails capturing the dust using a hood or other partial enclosure and transporting it through a series of ducts to the collectors. The type of dust collector used is based on factors such as particle size, dust loading, flow rate, moisture content, and gas temperature. The best disposal method for collected dust is to send it through the kiln creating the clinker. However, if the alkali content

Exhibit 2: Air Pollution and Control at Cement Production Facilities

Emission Point (gr/acf ¹)	Pollutants	Emission Rate Percent	Control Device
Quarries	Particulates	5-40	Fabric Filter:
• Pulse Jet			
• Reverse Air/Shaker		99.6	
Raw Mill Systems	Particulates	5-20	Fabric Filter:
• Pulse Jet			
• Reverse Air/Shaker			
• Cartridge	99.6		
Kiln System	Particulates	4-18	Dust Collectors:
• Reverse Air			

• Precipitator	99.5		
Clinker Coolers	Particulates	5-10	Fabric Filters:
• Pulsed Plenum/Pulse Jet			
• Reverse Air			
• Precipitator	99.6		
Finish Mill			
Systems	Particulates		
5-20	Fabric Filter:		
• Reverse Air/Shaker		99.6	
Finish Mill			
Systems	Particulates	5-100	Fabric Filters:
• Pulse Jet			
• Pulsed Plenum	99.6		
For use with			
High-Efficiency			
Separators	Particulates	150-300	Fabric Filters:
• Pulse Jet			
• Pulsed Plenum	99.9		
Packing and			
Loading			
Departments	Particulates	5-40	Fabric Filters:
• Pulse Jet			
• Reverse/Air Shaker			
• Cartridge	99.6		

¹ gr/acf = grains/actual cubic foot

of the raw materials is too high, the dust must be discarded, or must be pretreated before introduction into the kiln. The highest allowable alkali content is 0.6 percent (as sodium oxide). Exhibit 3 summarizes the general applicability of a number of collection systems for use by the cement industry.

Exhibit 3: Applicability of Emission Control Methods

Operation	Mechanical	
Collector	Wet	
Scrubber	Fabric	
Collector	Electrostatic	Gravel Bed
Filter		
Primary		
grinding	Unsatisfactory	
efficiency	Not	
applicable	Successful	Not
applicable	None in use	
Air		
separators	Not	
applicable	Not	
applicable	Successful	A few
installations	Questionable	
application		
Mills	Not	
applicable	Not	
applicable	Successful	A few
installations	Questionable	
application		

Storage silos	Not applicable			
applicable	Not applicable			
applicable	Successful	Not		
applicable	Impractical			
Feeders and belt conveyors	Not applicable			
applicable	Not applicable			
applicable	Successful	Not		
applicable	Impractical			
Packing and loading	Not applicable			
applicable	Not applicable			
applicable	Successful	Not		
applicable	Impractical			
Coal dryer	Preliminary			
cleaning only	Practicable	Successful	Not	
common	Practicable			
Kiln gases	Preliminary			
cleaning only	Impractical	12 x 30 Glass		
Successful	Successful	Practicable		
Clinker cooler	Preliminary			
cleaning only	Not applicable			
applicable	Successful	Not		
common	Successful			

Additional air pollutants emitted include such materials as sulfur oxides and nitrogen oxides generated from the kiln and drying processes. Sulfur dioxide is generated from the sulfur compounds in the ores and the combusted fuel and varies in amount produced from plant to plant. The efficiency of particulate control devices is inconclusive as the result of variables such as feed sulfur content, temperature, moisture, and feed chemical composition, in addition to alkali and sulfur content of the raw materials and fuel. The combustion of fuel in rotary cement kilns generates nitrogen oxides from the nitrogen in the fuel and incoming combustion air. The amount emitted depends on several factors including fuel type, nitrogen content, and combustion temperature. Both sulfur dioxide and some of the nitrogen oxide react with the alkaline cement and are removed from the gas stream.

a. Raw Material Acquisition

During raw material acquisition the primary air pollutant emitted is particulate matter. Particulate matter is also emitted from the handling, loading, unloading, and transport of raw materials, such as coal, purchased from another source. In certain areas, exhaust from portable equipment may also be a consideration.

The following methods are used to control particulate emissions generated from the quarry and handling of purchased raw materials:

- fabric filters (pulse-jet or reverse-air/shaker)
- equipment enclosures
- water sprays (with and without surfactants)
- enclosures
- silos (with and without exhaust venting to
- wind screens fabric filters)
- foams
- mechanical collectors
- bins
- chemical dust suppressants
- paving
- material storage buildings

Dust that is collected by these means is restored to the process. For quarry operations, newer plants typically use the pulse-jet fabric filters while older plants employ the reverse-air or shaker-type fabric filters.

b. Raw Milling

Fugitive dust is emitted from raw material feeders, stackers, blenders, reclaimers, conveyor belt transfer points, and bucket elevators used for transferring materials to the mill department from storage. Particulate emissions from the dry raw mills and subsequent equipment occur during temporary failure or from improperly designed or maintained seals. The following devices are used to collect particulate matter in the raw mill and raw mix storage areas:

- mechanical cyclones (usually used in series with another control)
- fabric filters (pulse jet or reverse air/shaker)
- electrostatic precipitators (rarely used)

Newer plants typically use the pulse-jet fabric filters while older plants employ the reverse-air or shaker type fabric filters.

c. Pyroprocessing

The main pyroprocessing system emissions are nitrogen, carbon dioxide, water, oxygen, nitrogen oxides, sulfur oxides, carbon monoxide, and hydrocarbons. Cement kiln dust (CKD) is also produced.

The cement kiln itself has been designated as best available control technology (BACT) for the control of SO₂. The highly alkaline conditions of the kiln system enable it to capture up to 95% of the possible SO₂ emissions. However, if sulfide sulfur (pyrites) is present in the kiln feed, this absorption rate can decline to as low as 50%. Therefore, sulfur emissions can be decreased through careful selection of raw materials.

No device to control cement kiln NO_x emissions has been developed, but there are several prospects:

- stable kiln operation (reduces long term NO_x emissions);

- burner configurations for the rotary kiln (efficiency varies);
- staged combustion for precalciner kilns;
- recirculation of the flue gas (oxygen deficient air in the rotary kiln); and
- alternative/low-nitrogen fuels.

Cement kiln dust (CKD) is the powder retrieved from the exiting gases and is either all or partly returned to the operation or removed entirely. The type of system, the chemical makeup of the raw materials and fuel, and the condition of the system operations all affect the chemical configuration of the CKD. Portland cement specifications usually limit the amounts of sodium and potassium. Because bypass CKD contains a large quantity of these minerals, CKD is usually removed from the process. The CKD from a preheater tower is composed of the same general elements as the kiln feed and therefore is returned to the process. The handling, storage, and deposition of CKD can generate fugitive dust emissions.

The following methods are used to control particulate emissions from the kiln system:

- reverse-air fabric filters
- electrostatic precipitators (ESPs)
- acoustic horns (sometimes used in conjunction with the two devices above)

d. Clinker Cooling

Reciprocating grate clinker coolers most often employ fabric filters, but ESPs and gravel bed filters are also used with a mechanical cyclone or multiclone dust collector sometimes placed in front. Newer plants typically use pulse-jet or pulsed-plenum fabric filters and older plants use reverse-air type fabric filters which may simply be a smaller form of a kiln fabric filter. Gravel bed filters, which are also used by the cement industry, contain quartz granules; contaminated gas passes through this filter and the dust settles to the bottom of the bed.

e. Clinker Storage

The devices used to control dust emissions from clinker storage areas are similar to those used in the raw milling process. The particulate emissions generated by dropping clinkers onto storage piles can be reduced by using a rock ladder or variable-height, automatic, stacker belt conveyor systems. Fugitive dust generated from open storage piles is tempered by rain and snow, wind breaks, and pile covers. Clinker in open piles is moved using front-end loaders; in storage halls overhead bucket cranes are used. Fugitive clinker dust emitted from open storage piles is common and very difficult to control.

f. Finish Milling

Particulate matter is emitted from mill vents, air separator vents, and material-handling system vents. Newer plants usually use pulse-jet or pulsed-plenum fabric filters with high-efficiency separators, while older plants use reverse-air/shaker fabric filters. The cement dust collected by the fabric filter is restored to the system. In cold weather, a plume may develop at the baghouse vent; this may be mistaken for particulate matter, but actually is condensed water vapor from the cooling system.

g. Packing and Loading

In the shipping department particulate matter is emitted from the silos and the handling and loading operations. Active and passive fabric filters are used to collect this dust. During loading of the product, particulate emissions are controlled by a fabric filter connected to the transport vessel; collected dust is restored to the shipment. To ensure dust-free loading onto the transport vessel, a flexible loading spout consisting of concentric tubes is used. The outermost tube seals the delivery spout to the transport vehicle. The product is then delivered through the inner tube and displaced air drawn up the outer tube to a filter. At distribution terminals, fabric filters are again used and the collected dust is returned to the product. New plants typically use pulse-jet fabric filters while older plants use reverse-air or shaker-type fabric filters.

2. Liquid and Solid Wastes

The overflow from slurry concentrating equipment (i.e. thickeners) constitutes the main water pollution problem. For new plants that process slurry, closed-cycle water systems are used to return the overflow water to the process. Another source of waste is the stripped overburden, which is used as a raw material or disposed of in a local landfill. An estimate of overburden deposited in a landfill varies from 0 - 3 metric tons per metric ton of cement produced.

The combustion processes of cement kilns and rotary kilns have been used to dispose of hazardous waste material. For the cement kiln, waste material is burned with a primary fuel. For a wet process kiln, the raw materials are introduced into the top of the kiln and exit at the bottom as cement clinker. The burner is located at the lower end of the kiln where the fuel and waste are ignited. The hot gases move up the kiln and heat the raw materials, exit the kiln, and are then cleaned in a baghouse prior to exiting through a stack. When waste is fired, any ash generated becomes a part of the cement product.

D. REFERENCES

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