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INDUSTRIAL PROCESS PROFILES FOR ENVIRONMENTAL USE: Chapter 21. The Cement Industry

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INDUSTRIAL PROCESS PROFILES

FOR ENVIRONMENTAL USE

CHAPTER 21

THE CEMENT INDUSTRY

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CEMENT INDUSTRY

INDUSTRY DESCRIPTION

The cement industry consists of companies producing complex calcium-silicate-aluminate-ferrite materials which when mixed with water form a binding material for aggregates (crushed stone, gravel, and sand) in "concrete." Products include a variety of portland cements, masonry cements and calcium aluminate cement.

The portland cements are dominant in this industry. They account for approximately 95 percent of the total volume. Masonry cement and calcium aluminate cement account for the remaining 5 percent.

Portland cements of several types are manufactured using two processes known as the "dry process" and the "wet process" (see Figure 2). In both processes, the primary raw material, limestone or other calcium carbonate deposit, is mined and crushed. Then the carbonate material is blended and ground with alumina-containing, silica-containing, and iron-containing materials. In the dry process, the raw materials are dried before and/or during grinding. In the wet process, the raw materials are mixed with water before grinding. In both processes, the finely ground and intimately mixed raw materials are heated in a rotary kiln until partially melted. Reactions occur to form a material called "clinker." The clinker exits the kiln, is cooled, and then mixed and ground with approximately 5 percent gypsum into a fine powder known as portland cement.

Masonry cement is made by mixing crushed limestone and gypsum with clinker and grinding to a fine powder. Calcium aluminate cement is made by fusing a mixture of limestone and bauxite in a kiln and then grinding the kiln product.

At the end of 1973, 166 plants in 41 states and Puerto Rico were manufacturing portland cement. Of the 166 plants, 103 used the wet process; 59, the dry process; and 4, both wet and dry processes. In addition to these 166 plants, there were 7 plants which functioned as grinding mills only, using imported, purchased, or interplant transfers of clinker. Masonry cement was manufactured in 116 plants at the end of 1972. However, only 4 plants produced masonry cement exclusively. At the end of 1973, 4 plants were producing calcium aluminate cement.

Size of portland cement plants, gauged by production capacity in 1973, ranged from 68,000 metric tons per year to 2,390,000 metric tons per year. Mean plant production capacity was 480,000 metric tons per year. Total mine and mill employment in the cement industry in 1973 was estimated to be 25,000.

Portland cement production in 1973 was 75 x 10^6 metric tons. This included 2.6 million metric tons produced from imported clinker. Imports of portland cement were 3.6 million metric tons. Masonry cement production was 3.7 million metric tons. It is estimated that calcium aluminate cement production was less than 1 million metric tons.

Cement plants are located in 41 states and Puerto Rico. They are located close to limestone or other calcium carbonate deposits. Because of the relatively low value of portland cement ($23 to $55 per metric ton in 1973 depending on type of cement), the marketing distance is limited. Therefore, cement plants are usually fairly close to an urban market. Approximately 45 percent of the U. S. and Puerto Rico cement production is in California, Pennsylvania, Texas, Michigan, and New York. Transportation of product is by rail, barge, and truck. In 1972, 91.4 percent of cement shipments were bulk while 8.6 percent were in bags.

The portland cement industry is mature and is not experiencing a large growth rate. An annual growth of 3 percent is expected through 1980.

Electric energy usage in the portland cement industry in 1972 was 10.6×10^9 kWh. Approximately 8 percent (0.85×10^9 kWh) was generated at the cement plant while 92 percent (9.7×10^9kWh) was purchased.

Trends in the cement industry include increased used of:

- portable crushers in quarries
- roller mills to grind raw material
- suspension-type preheater kilns
- planetary clinker coolers
- computer control
- the dry process.

Raw Materials

The primary raw materials in cement production are the calcareous minerals of limestone and cement rock. The most restrictive requirement for the limestone material is that it cannot contain more than 3 percent magnesium oxide. Most limestone and cement rock mines are open-pit operations. In recent years, cement manufacturers have increased efforts to landscape stripped areas.

The use of oyster shell as the calcareous mineral has been criticized by some conservation groups. Studies to determine the environmental impact of this practice are underway.

A complete listing of raw material consumption for portland cement in 1973 is found in Appendix A. Generally the argillacious (alumina-containing), siliceous (silica-containing), ferrous (iron-containing), and other materials are supplied to the cement manufacturer by other companies or occur as impurities in the limestone deposit. Occasionally the cement manufacturer mines separate deposits of these secondary materials, using methods similar to those used in the limestone mining operation.

Products

The 78.6 million metric tons of portland cement consumed during 1973 were distributed among customers as follows:

Ready-mixed concrete	52.0 metric tons, 66%
Concrete product manufacturers	10.7 metric tons, 14%
Highway contractors	5.6 metric tons, 7%
Building material dealers	6.4 metric tons, 8%
Other contractors	2.2 metric tons, 3%
Federal, state, & other government agencies	0.3 metric tons, <1%
Miscellaneous	1.4 metric tons, 2%

Masonry cement is used in mortar to bond brick and masonry. Calcium aluminate cement is used primarily in refractory concrete for withstanding temperatures up to 1500°C.

A list of different types of cement products and 1973 shipments is found in Appendix B. The different portland cements have slightly different compositions. These differences may be the result of variations in materials going into the clinker or the result of adding materials to the clinker before grinding.

Companies

Most of the major companies involved in cement manufacture are diversified conglomerates. The diversification has increased in the last ten years because of the low rate of return for cement manufacturers. Rather than reinvesting money in cement, companies manufacturing cement have preferred to diversify into other activities.

A total of 53 companies manufactured portland cement as of 1973. They are listed in Appendix C along with plant locations, production capacities, and type of process used. The twelve largest portland cement producers are listed below. In 1964 the twelve

Company	Plants	Capacity (metric tons/yr.)
Ideal Basic Industries, Inc.	14	6.3×10^6
U.S. Steel (Universal Atlas)	11	4.8×10^6
Lone Star Industries, Inc.	11	4.7×10^6
General Portland Incorporated	9	4.5×10^6
Martin Marietta Corporation	9	4.4×10^6
Marquette Cement Mfg. Co.	12	3.7×10^6
Amcord (American)	5	3.5×10^6
Kaiser Cement & Gypsum Corp.	5	3.3×10^6
Medusa Corporation	6	3.1×10^6
National Gypsum Company	2	3.0×10^6
Lehigh Portland Cement Company	6	2.8×10^6
California Portland Cement Co.	3	2.3×10^6
	93	46.4×10^6
Percent of US plants & capacity	56%	57%

largest producers accounted for 64 percent of the plants and 65 percent of the production capacity. In 1974, they only accounted for 56 percent of the plants and 57 percent of the production. A slight movement toward less concentration in cement production is thus evident.

Companies which operate clinker grinding plants, masonry cement manufacturing plants, and calcium aluminate manufacturing plants are also listed in Appendix C.

Environmental Impact

During the 10-year period through 1971, approximately 216 million dollars were spent by the cement industry on capital equipment for air and water pollution control. Pollution control facilities comprise 10 to 15 percent of the capital cost of a new plant.

The primary air pollution problems are emissions from the kiln and at other points in the cement manufacturing process. Heavy investments primarily in electrostatic precipitators and fabric or glass bag dust collectors are decreasing these problems.

Most techniques for control of particulate emissions from sources other than the kiln involve the capture of dust by drawing ambient air in through a hood or other partial enclosure at the source at a velocity sufficient to entrain the dust and carry it away in the air stream. For most applications in the cement plant, an air intake velocity of 1.0 to 1.25 m/s (200-250 ft/min) is necessary to assure capture of the particulates generated.

The dust-laden air is then transported through a series of ducts to the collectors. Capture and transport systems are designed for optimal fluid flow (round pipe, large radius turns, and acute angle junctions) and the cross-sectional area is matched to flow rate to maintain the air velocity above 18 m/s (3500 ft/min) and preferably about 20-23 m/s (4000-4500 ft/min), thereby preventing dust from falling out within the system.

Selection of a dust collector depends upon a number of factors including particle size, dust loading, flow rate, moisture content, and gas temperature. Table 1 summarizes the applicability of a number of collection systems for use by the cement industry.

The primary water pollution problem is the overflow from slurry concentrating equipment such as thickeners. New plants using the wet process are designed with closed-cycle water systems in which overflow water is returned to the process.

In the cement industry, raw and finish-grinding mills produce noise levels of 102-105 decibels and diesel trucks in quarry operations register 94 decibels. Quantitative information on efforts to decrease this level or reduce employees' exposure is not available.

Table 1. CEMENT PLANT DUST COLLECTOR APPLICABILITY

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	Not Applicable	Successful	Not Applicable	Impractical
Feeders and Belt Conveyors	Not Applicable	Not Applicable	Successful	Not Applicable	Impractical
Packing and Loading	Not Applicable	Not Applicable	Successful	Not Applicable	Impractical
Coal Dryer	Preliminary Cleaning Only	Practicable	Successful	Not Common	Practicable
Kiln Gases	Preliminary Cleaning Only	Impractical	12x30 Glass Successful	Successful	Practicable
Clinker Cooler	Preliminary Cleaning Only	Not Applicable	Successful	Not Common	Successful

Source: Hoon, Harry E., Dust Collection in Portland Cement Manufacture. Flex-Kleen Corp., Division of Research-Cottrell, Inc. Chicago, Illinois (1976).

Strip-mined areas are receiving attention from cement manufactures. Revegetation of quarry sections where mining is complete is being practiced in some cases. Quantitative information is not available.

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INDUSTRY ANALYSIS

The cement industry is competitive and operations are relatively standardized. Pollution emission limitations imposed in the 1970's have forced modernization and replacement of old equipment. The recent rise in fuel prices has also accelerated modernization and replacement of old, inefficient equipment. Information presented in the process descriptions later in this report is believed to be representative of the industry.

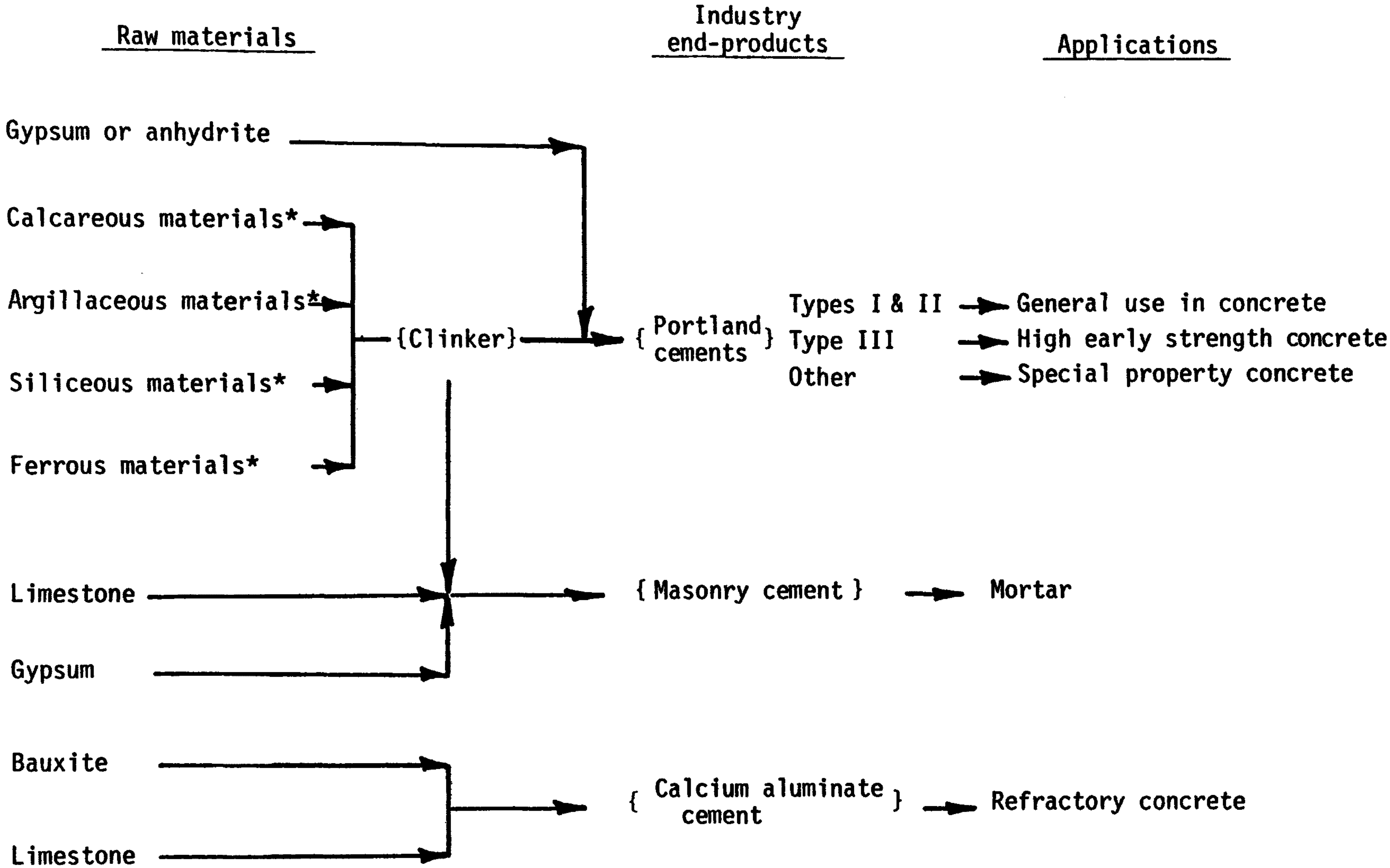
Availability of quantitative information on emissions has in some cases been inadequate. In these cases, the magnitudes have been estimated from qualitative statements on emissions.

The chemical tree of Figure 1 gives a qualitative overview of the cement industry from a raw material-product standpoint. The dominant products are portland cements I and II which account for approximately 88 percent of the total cement volume. Included under other portland cements are sulfate resisting cements, white cement (low iron content), slag cement (steel furnace slag added to "normal" portland before finish grinding), expansive cement (slag and a calcium sulfoaluminate cement added to "normal" portland before finish grinding), oil well cement (portland containing a set retarder), and pozzolan cement (pozzolan added to "normal" portland before finish grinding).

The process flowsheet of Figure 2 shows the process used in manufacturing portland cements and masonry cement. Because of its small sales volume and the lack of processing information, the processes for manufacturing calcium aluminate cement are not included on the flowsheet.

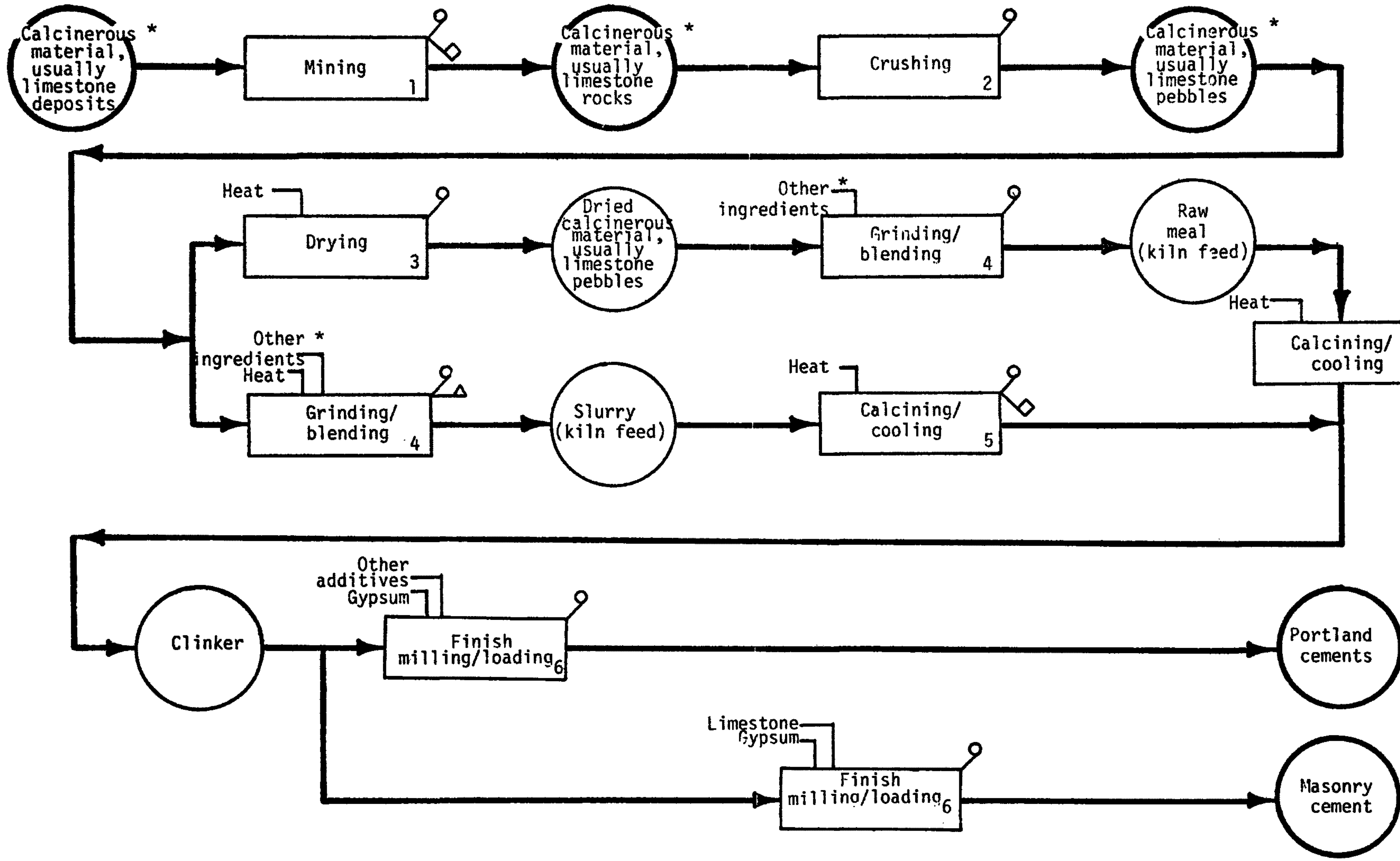
The interior of each of the rectangular "process blocks" appearing on the flowsheet represents at least one of the sequential, real processes of the cement manufacturing operation. A number and title have been placed within each of the process blocks. These identifying symbols are used in the process descriptions later in this report.

Flag symbols at the upper right-hand corner of the process block indicate the nature of the waste streams, if any, discharged from the process. A circle is used for atmospheric emissions, a triangle for liquid wastes, and a rhombus for solid wastes. The flags do not differentiate between inadvertent (fugitive) and designed wastes.



* See Appendix A for more specific identification of raw materials.

Figure 1. CEMENT INDUSTRY CHEMICAL TREE.



* See Appendix A for more specific identification of raw materials.

Figure 2. CEMENT INDUSTRY FLOWSHEET.

Mining

1. Function - This process (See Figure 2) removes primarily deposits of limestone and cement rock from their natural source to the cement plant crushers (Process 2). Other cement raw materials* such as clay or shale are sometimes found close to or intermixed with limestone or cement rock deposits and are removed with them.

   Most deposits are worked through open quarries although some are mined underground. A typical mining process includes removing overburden by shovels or bulldozers, blasting of rock, loading of the blasted rock by front-end loaders or power shovels into trucks or railroad cars, and transporting of the rock to the crushing plant located in the quarry or at the cement plant. Rock size is up to 1 meter diameter.

2. Input Materials

   - 1.3 to 2.0 metric tons of calcareous raw material per metric ton of cement. The calcareous material could be limestone, cement rock, marl, oyster shell, or other.

   - 0.0 to 0.3 metric tons of other raw materials* per metric ton of cement.

3. Operating Parameters

   - Ambient temperature
   - Atmospheric pressure
   - Overburden from 1 to 30 meters deep
   - *Typical equipment:*
     3 1/2 cubic meter shovels
     30-70 ton truck capacities
     10 meter front-end loaders
   - Quarry face height of 10 to 60 meters
   - Variations in deposit composition from layer to layer often require selective quarrying to obtain a fairly uniform quarry product.

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* Raw materials used in North America for cement manufacture include the following:

calcareous materials - limestone, cement rock, marl, alkali waste, oyster shell, coquina shell, chalk, marble.

argillaceous materials - clay, shale, slag, fly ash, copper slag, aluminum ore refuse, staurolite, diaspore clay, granodiorite, kaolin.

siliceous materials - sand, "traprock," calcium silicate, quartzite, Fuller's earth.

ferriferous materials - iron ore, iron calcine, iron dust, iron pyrite, iron sinters, iron oxide, blast furnace flue dust.

4. Utilities

- Fuel for vehicles
  4000 kcal per metric ton cement

- Electrical
  2-3 kWh per metric ton cement

- Explosives
  1000 kcal per metric ton cement

5. Waste Streams

- Dust emissions are released from mining steps such as blasting, earthmoving, truck loading and unloading, and truck movement. Dust from roads can be reduced by wet suppression techniques including watering and treating with an oil emulsion. Most emissions are heavy particles that settle out within the plant.

- Stripped overburden can sometimes be used as a raw material. If not, disposal of the material is usually by local landfill. A gross estimate of overburden used as landfill is from 0 to 3 metric tons per metric ton of cement produced.

6. EPA Source Classification Code - None

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Crushing

1. Function - This process (See Figure 2) decreases the size of mined limestone or cement rock from Process 1.

   Various types of crushers are used depending on the nature of the rock (hardness,lamination, quarry product size). These include gyratory crushers, jaw crushers, impact mills, hammer mills, and roll crushers. Often the crushing plant is located in the quarry and is portable. Screening and conveying of crushed rock to storage is included in this process.

   In a typical crushing plant, a primary crusher may reduce the rock from power shovel size to 0.1 to 0.25 meter and a secondary crusher may again reduce this product to approximately 0.01 to 0.05 meter size. This material is then transported to raw material storage piles or compartments on a belt conveyor. This material will then be conveyed with other raw materials to Process 3 or Process 4.

   In some instances, partial drying of rock is accomplished in the crushing process by passing kiln exhaust gases, clinker cooler exhaust air, or furnace heated air through the crusher.

2. Input Materials

   •Calcareous material
   1.3 to 2.0 metric tons per metric ton of cement depending on purity and composition

   •Other materials
   0.0 to 0.3 metric tons per metric ton of cement

3. Operating Parameters

   •Ambient temperature (usually)
   •Atmospheric pressure
   •Typical modern equipment
   Receiving hopper - 70 to 140 metric ton capacity.
   700 ton per hour portable two-stage impactor crusher with 600 kW and 800 kW motors for driving crusher.
   2.5 meter x 5.5 meter inclined, vibrating screen.
   Enclosed belt conveyors - 0.8 meter to 1.2 meters wide and up to several thousand meters long.
   Cyclone dust collector plus baghouse containing 1000 bags, each one 0.12 meter in diameter x 2.7 meters long.

4. Utilities

- Electrical
  2 to 5 kWh per metric ton cement

5. Waste Streams

- Dust is emitted during crushing, screening, and conveying steps. Most of the emissions are heavy particulates that settle out within the plant. Without emission abatement systems, estimated emissions are 0.01 metric ton per metric ton of cement produced. Dust collection systems reduce the emissions to 0.0005 metric ton per metric ton of cement produced.

6. EPA Source Classification Code - None

7. Bibliography

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Drying

1. Function - This process (See Figure 2) reduces the moisture content of cement raw materials moved by belt conveyor from Process 2 to less than 1 percent. Usually the moisture content of the calcareous raw material is 3 to 8 percent, but it may be as high as 20 percent. The dried material is moved by belt conveyor to storage silos. The drying process is necessary only in the "dry process" cement manufacturing technique.

   Furnace heated air, kiln exhaust gases, or clinker cooler exhaust air are commonly used to dry crushed stone in a cylindrical rotary dryer. In modern installations drying and grinding are frequently combined. Sometimes crushing and drying are combined.

2. Input Materials

   - Calcareous material
     1.3 to 2.0 metric tons per metric ton of cement

   - Other materials
     0.0 to 0.3 metric tons per metric ton of cement

3. Operating Parameters

   - 600°C temperature
   - Atmospheric pressure
   - Typical modern equipment
     4.5 meter x 40 meter rotary dryer revolving at 160 rph

4. Utilities

   - Fuel
     200,000 kcal per metric ton cement

   - Electricity
     1-2 kWh per metric ton cement

5. Waste Streams

   - Dust emissions from dryers are estimated to be 0.01 to 0.05 metric tons per metric ton of cement. This is in addition to the amount that is initially present in the heating medium which could be furnace heated air, kiln exhaust gases, or clinker cooling air. Electrostatic filters and/or fabric filters reduce the emission to 0.0002 metric ton per metric ton of cement.

6. EPA Source Classification Code

3-05-006-02 Dryers/Grinder, etc.

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Grinding/Blending

1. Function - This process (See Figure 2) includes feeding of raw material to the grinding mill, grinding of the materials to a fine size suitable for feeding to a kiln, and blending of the ground material to obtain kiln feed of the correct composition.

   a. The dry process - Raw materials from several piles or bins are withdrawn in carefully proportioned ratios through a weighing machine or table feeder and moved by belt conveyor to the grinding mill. Ball mills and tube mills in series or combined into a single two-stage machine called a compartment mill are usually used. Roller mills use less power and can accept larger size and wetter feed. They are becoming more popular. Air separators are usually used to divide mill discharge into a coarse recycle fraction and a fine product fraction. The product is a powder such that 75 to 90 percent passes through a 200 mesh sieve. Often some drying of raw materials can be accomplished in a compartment ahead of the grinding mill or within the mill itself. This is done by passing kiln exhaust gases, clinker cooler exhaust air, or furnace heated air through the equipment. Finely ground raw meal is conveyed by pneumatic pumps, elevators, or screw conveyors to storage silos. Agitation, circulation, and homogenization techniques are used to obtain a final blend from several silos. The final blend is air or mechanically agitated and homogenized for one or two hours and then pumped to the kiln (Process 5).

   b. The wet process - Water or clay slip (containing minute amounts of chemicals* known as slurry thinners) is fed along with preproportioned crushed raw materials to ball, tube, and compartment mills similar to those used in the dry process. Vibrating screens, rake classifiers, hydroseparators, or thickeners are used to remove oversize mill discharge and return it to the mill. Finished slurry is pumped to slurry basins designated as mixing, correcting, blending and storage. All tanks or basins are agitated by compressed air and/or mechanical agitators. Material from several tanks can be blended and homogenized in the kiln feed storage tank and then pumped to the kiln (Process 5).

2. Input Materials

   a. 1.7 metric tons of raw materials per metric ton cement.

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* Chemicals include waste sulfite liquor, sodium carbonate, sodium silicate, sodium tri-polyphosphate, and tetrasodium pyrophosphate.

b. 1.7 metric tons of raw materials per metric ton cement.
   1 metric ton of process water per metric ton cement.
   .0005 to 0.001 metric ton chemical slurry thinner per metric ton cement.

3. Operating Parameters

a. •Atmospheric pressure
   •Ambient temperature if no drying is required
   •350°C to 700°C temperature if drying is combined with grinding
   •Typical modern equipment
   Compartment mill - 3 meters diameter x 10 meters long with 1100 kW motor.
   5 meters diameter air separator.
   336 bag, 7-zone baghouse dust collector.

b. •Atmospheric pressure
   •Ambient temperature
   •Typical modern equipment
   Compartment mill - 3.5 meters diameter x 10.5 meters long with 1500 kW motor.
   110 metric ton per hour capacity of slurry containing 35 percent water.
   Kiln feed tanks - 16 meters diameter x 13 meters high.

4. Utilities

a. Electrical
   45 kWh per metric ton cement

b. Electrical
   35 kWh per metric ton cement

5. Waste Streams

a. Dust emissions can occur from proportioning equipment, conveyors, grinding mills, and storage silos. Total emissions are estimated to be 0.03 metric tons per metric ton of cement produced. It is estimated that dust collection equipment (such as bag filters) reduces these emissions to less than 0.0003 metric tons per metric ton of cement produced.

b. Dust emissions primarily from proportioning equipment are estimated to be 0.01 metric tons per metric ton of cement. It is estimated that dust collection equipment reduces these emissions to less than 0.0001 metric tons per metric ton of cement produced. Water effluent containing suspended solids is eliminated in a closed cycle water system. If water is not recycled, amounts up to 0.4 metric tons per metric ton of cement produced could be rejected to natural streams. It is estimated that this water could contain 1 percent solids.

6. EPA Source Classification Code

3-05-006-02	Dryers/Grinder, etc.
3-05-007-02	Dryers/Grinder, etc.

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Calcining/Cooling

1. Function - This process (See Figure 2) converts the finely ground kiln feed from Process 4 to portland cement clinker by heating it in a rotary kiln to approximately 1500°C and then cooling it to ambient temperature.

   a. The dry process - Raw meal is pneumatically pumped to the upper end of a steel kiln. The meal flows slowly down through the sloped kiln. Heat is supplied from the lower end of the kiln by the combustion of coal, fuel oil, or natural gas. Hot combustion gases are pulled by forced draft up through the kiln in counter flow to the raw meal. Fire brick refractories line the inside of the kiln in order to protect the steel shell from the heat and to conserve fuel. Lifters are usually located inside the kiln to facilitate heat transfer from the combustion gases to the raw meal. As the raw meal passes through the kiln, it gets hotter. When its temperature reaches 800 to 1000°C, carbon dioxide is released by calcium carbonate. At 1500°C, the raw meal becomes partially sintered and complex compounds are formed. The resulting 0.5 to 1 cm diameter material is called clinker. It is cooled in rotary coolers, planetary coolers, or grate-type coolers by air pulled into the cooler. The heated air is then used as combustion air for the fuel. The cooled clinker is conveyed by drag chains, vibrating troughs, or belt conveyors to storage. Recently, because of increasing fuel costs, suspension gas preheaters have come into use. These allow raw meal to pass through a system of cyclones counter-current to kiln exit gases before entering the kiln.

   b. The wet process - Slurry is pumped to the upper end of a refractory-lined steel kiln and flows down through the kiln. Wet process kilns are somewhat longer than dry process kilns because a portion of the kiln (1/4 to 1/5) is used for evaporation of slurry water. Chain heat exchangers inside the upper section of the kiln increase the surface of slurry exposed to the hot combustion gases and facilitate heat transfer. They also reduce dust emissions. Clinker formation and handling is similar to that described in the dry process.

2. Input Materials

   a. 1.7 metric tons raw meal per metric ton cement

   b. 2.2 to 2.7 metric tons slurry per metric ton cement (contains 20 to 40 percent moisture)

3. Operating Parameters

a,b. •Atmospheric pressure
•Maximum kiln temperature - 1450 to 1600°C
•Equipment size range
Kiln - 20 meters to 230 meters long
2 meters to 7 meters diameter
20 to 60 rph sloped at 0.3 cm per m

a. •Typical modern systems
Long dry process kiln - 5 meters in diameter x 145 meters long with capacity of 1200 metric tons per day.
Four-stage suspension preheater kiln - 4.3 meters in diameter x 65 meters long with capacity of 1200 metric tons per day.
Four-stage suspension preheater height of 60 meters.
Four meters x 22-meter horizontal grate-type clinker cooler with 7 to 10 fans and a total power requirement of 500 kW.
Kiln dust collector system - exit gas temperature from most conventional process kilns exceeds the limits of all bag fiber except glass. For this purpose, field-assembled, insulated baghouses using large 0.3 meter x 9 meter bags are usually employed. In order to prevent condensation of moisture, the exit gas temperature should be kept 45°C higher than the dew point. If the resultant temperature exceeds 287°C, even glass fiber filters are unsuitable because of deterioration. In such applications, electrostatic precipitators are used for dust collection, with gravel filter beds a possible satisfactory alternative. Because of the heavy dust loading in kiln exit gases, mechanical collectors such as cyclones or multi-tube collectors are usually employed to pre-clean the exit gas stream.
Clinker Cooler dust collector system - 12-zone baghouse with 1900 bags measuring 0.12 meter diameter x 2.7 meters long. Pulse-jet type filters using felted fabric find widespread use. Dacron felted fibers may be employed if carefully controlled water spray is used to limit gas temperature, but Nomex is preferred because of its 232°C temperature tolerance. The most common cement industry use of gravel-bed filters occurs in the treatment of clinker cooler off gases.
600 kW motor for kiln fan.

b. •Typical modern systems
Wet process kiln - 5 meters diameter x 160 meters long with a capacity of 1200 metric tons per day.
Dust collection system and motors similar to the dry process.

4. Utilities

a. •Fuel
0.8×10^6 to 2×10^6 kcal per metric ton cement

•Electrical
35 kWh per metric ton cement

b. •Fuel
1.3×10^6 to 2.5×10^6 kcal per metric ton cement

•Electrical
30 kWh per metric ton cement

5. Waste Streams

a. Dust emissions from the kiln* range from 0.06 to 0.23 metric tons per metric ton of cement produced if exiting combustion gases are discharged directly into the air. When exiting kiln gases pass through highly efficient electrostatic precipitators and/or fabric filters, the dust discharge is reduced to 0.0002 metric tons per metric ton of cement produced.

a,b. Clinker cooler air containing particulates may be discharged to the atmosphere. It contains particulates in a quantity up to 0.10 metric ton per metric ton of cement produced. Ten to fifteen percent of these dust particles are below 10 microns diameter. When this air is passed through highly efficient electrostatic precipitators, fabric filters or gravel bed filters, the dust discharge is reduced to less than 0.00007 metric tons per metric ton of cement produced.

b. Dust emissions from the kiln* range from 0.04 to 0.13 metric tons per metric ton of cement produced if exiting combustion gases are discharged directly into the air. When exiting kiln gases pass through highly efficient electrostatic precipitators, fabric filters, or in one case venturi scrubbers, the dust discharge is reduced to 0.0002 metric tons per metric ton of cement produced.

a,b. Some collected kiln dust* cannot be reintroduced into the kiln because of high alkali content. It then can be used as a substitute for agricultural limestone, fertilizer, or mineral filler.

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* Size distribution of kiln dust has been determined as follows:

93 percent less than 60 micron diameter
90 percent less than 50 micron diameter
84 percent less than 40 micron diameter
74 percent less than 30 micron diameter
58 percent less than 20 micron diameter
38 percent less than 10 micron diameter
23 percent less than 5 micron diameter
3 percent less than 1 micron diameter

If no use can be found, it is often disposed of in abandoned quarries or storage piles. If this is done, the dust piles should be covered, enclosed, or sprayed with water to form a surface crust. Dust collected could be as much as 0.2 metric tons per metric ton of cement produced.

a,b. SO_2 emissions can occur if high sulfur coal is used as fuel to heat the kiln. However, sulfur oxides passing through a cement kiln are to a large extent removed from the combustion gases and become part of the clinker.

6. EPA Source Classification Code

3-05-006-01	Kilns
3-05-006-03	Kilns - Oil Fired
3-05-006-04	Kilns - Gas Fired
3-05-006-05	Kilns - Coal Fired
3-05-007-01	Kilns
3-05-007-03	Kilns - Oil Fired
3-05-007-04	Kilns - Gas Fired
3-05-007-05	Kilns - Coal Fired

7. Bibliography

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Finish Milling/Loading

1. Function

a. Portland cements - This process (See Figure 2) receives clinker from clinker storage, grinds it along with a 5 percent gypsum addition to a fine powder (generally 94 to 98 percent will pass through 325 mesh sieve), forwards the resulting portland cement to cement storage, and loads it into bulk carriers or packages it into bags. Other additives may be included along with the gypsum to give specialty portland cements.

b. Masonry cement - This process (See Figure 2) receives clinker from clinker storage, grinds it along with a 5 percent gypsum addition plus a crushed limestone addition to a fine powder (generally 94 to 98 percent will pass through 325 mesh sieve), and forwards the resulting masonry cement to storage.

a,b. Clinker and additives are drawn from storage using weigh feeders to proportion the cement ingredients. Belt conveyors deliver the ingredients usually to a two-compartment ball mill. The mill may be rubber lined. An air separator usually recycles oversize product and forwards correct size product to storage silos. Either air or water cooling in the grinding step is employed to prevent dehydration of the gypsum. Cement is transferred from storage silos to trucks, railroad cars, or boats using airslide conveyors. Approximately 9 percent of the cement produced is packaged into multi-layer paper bags using automatic machines. These bags hold 42.7 kg of cement.

2. Input Materials

a. 0.95 metric tons clinker per metric ton normal portland cement. 0.05 metric tons gypsum per metric ton normal portland cement. Specialty portland cements include pozzolan cement which contains 15 to 30 percent pozzolan, slag cement which contains 25 to 65 percent slag, expansion cement which contains 20 percent slag and 10 percent calcium sulfoaluminate cement, and oil well cement which contains a set retarder.

b. 0.5 to 0.8 metric tons clinker per metric ton masonry cement.
0.02 to 0.04 metric tons gypsum per metric ton masonry cement.
0.5 to 0.2 metric tons limestone per metric ton masonry cement.

3. Operating Parameters

a,b. •Atmospheric pressure
•Approximately 60°C temperature

•Typical equipment

Two-compartment ball mill - 3 to 4.5 meters diameter, 6 to 16 meters long.
Motor - 1000 kW to 5000 kW.
Capacity 30 to 120 metric tons per hour.
2-meter-diameter x 5-meter-long cooler.
Storage silos - 10 meters diameter x 60 meters high.

4. Utilities

a,b. •Electrical

75 kWh per metric ton of cement produced

•Cooling water

0 to 1 metric ton per metric ton cement produced

5. Waste Streams

a,b. •Dust emitted from the grinding/loading process is collected by multi-cyclone plus electrostatic precipitator systems or fabric cloth systems. Estimated emissions to the atmosphere are less than 0.00001 metric tons per metric ton cement.

6. EPA Source Classification Code

3-05-006-02	Dryers/Grinder, etc.
3-05-007-02	Dryers/Grinder, etc.

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APPENDIX A

RAW MATERIAL LIST

Table A-1. LIST OF RAW MATERIALS

Raw Material	Quantity** (million metric tons)	%	
Calcareous			85%
Limestone (includes aragonite)	78.9	62%	
Cement rock (includes marl)	23.7	19%	
Oyster shell	4.7	4%	
Argillaceous			9%
Clay	7.2	6%	
Shale	3.7	3%	
Other*	0.2	--	
Siliceous			2%
Sand	1.9	1.5%	
Sandstone and quartz	0.7	.5%	
Ferrous			.7%
Iron ore, pyrites, mill scale and other iron-bearing material	0.9	.7%	
Other			4%
Gypsum and anhydrite	3.9	3%	
Blast furnace slag	0.6	.5%	
Fly ash	0.3	.2%	
Other	0.0	--	
Total	126.7		

* Includes staurolite, bauxite, aluminum dross, pumice, and volcanic material.

** For the year 1973.

APPENDIX B

PRODUCT LIST

Table B-1. LIST OF PRODUCTS

Cement	1973 shipments in million metric tons	(%)
Portland cements		
Types I & II (general use and moderate heat)	72.5	88
Type III (high early strength)	2.6	3
Type V (sulfate resisting)	0.6	.7
Oil-well	0.6	.7
White (low iron)	0.5	.6
Slag and pozzolan	0.9	1
Expansive	0.1	.1
Other	0.9	1
Masonry cement	3.7	4
Calcium aluminate cement	<1.0*	1

* Estimated.

APPENDIX C

COMPANY/PRODUCT LIST

Table C-1. COMPANY/PRODUCT LIST

Company/location	Capacity (metric tons/year)	Process
Alpha Portland Industries, Inc.		
Alpha Portland Cement Co. Div.		
Birmingham, Alabama	307,000	Wet
Lime Kiln, Maryland	393,000	Wet
St. Louis, Missouri	444,000	Wet
Cementon, New York	462,000	Wet
Jamesville, New York	154,000	Wet
Orange, Texas	427,000	Wet
	2,187,000	
Amcord, Inc.		
Hercules Cement Co. Div.		
Stockerton, Pennsylvania	598,000	Dry
Peerless Cement Co. Div.		
Detroit, Michigan	1,111,000	Wet
Phoenix Cement Co. Div.		
Clarkdale, Arizona	600,000	Dry
Riverside Cement Co. Div.		
Crestmore, California	769,000*	Dry
Oro Grande, California	1,128,000	Dry
	4,206,000	
Arkansas Cement Corp.		
Foreman, Arkansas	854,000	Wet
Ash Grove Cement Co.		
Chanute, Kansas	478,000	Wet
Louisville, Nebraska	581,000	Wet
	1,059,000	
Atlantic Cement Co., Inc.		
Ravena, New York	1,452,000	Wet
California Portland Cement Co.		
Colton, California	769,000	Dry
Mojave, California	1,025,000	Dry
Arizona Portland Cement Co., Div.		
Rillito, Arizona	905,000	Dry
	2,699,000	

Continued

Table C-1. (Continued) COMPANY/PRODUCT LIST

Company/location	Capacity (metric tons/year)	Process
Capitol Aggregates, Inc.		
Capitol Cement Div.		
San Antonio, Texas	299,000	Wet
Centex Cement Corp. (Centex Corp.)		
Corpus Christi, Texas	239,000	Wet
Century Cement Manufacturing Co., Inc.		
Rosendale, New York	154,000	Dry
Columbia Cement Corp. (subs. Filtrol Corp.)		
Barberton, Ohio	257,000	Wet
Zanesville, Ohio	598,000	Wet
Bellingham, Washington	324,000	Wet
	1,179,000	
Citadel Cement Corp.		
Birmingham, Alabama	307,000	Wet
Demopolis, Alabama	205,000	Dry
Roanoke, Virginia	667,000	Dry
	1,179,000	
Coplay Cement Manufacturing Co.		
Coplay, Pennsylvania	718,000	Dry
Nazareth, Pennsylvania	513,000	Dry
	1,231,000	
Dundee Cement Co.		
Dundee, Michigan	1,025,000	Wet
Clarksville, Missouri	1,196,000	Wet
	2,221,000	
Flintkote Co.		
Calaveras Cement Div.		
San Andreas, California	854,000	Wet
Redding, California	273,000	Dry
Diamond-Kosmos Cement Div.		
Kosmodale, Kentucky	600,000	Dry
Middlebranch, Ohio	513,000	Dry
Glen Falls Cement Div.		
Glen Falls, New York	513,000	Dry
	2,753,000	

Continued

Table C-1. (Continued) COMPANY/PRODUCT LIST

Company/location	Capacity (metric tons/year)	Process
General Portland Co.		
Peninsular Div.		
Paulding, Ohio	452,000	Wet
Southeastern Div.		
Tampa, Florida	1,196,000*	Wet
Miami Florida	462,000	Wet
Chattanooga, Tennessee	462,000	
Trinity Div.		
Dallas, Texas	598,000	Wet
Fredonia, Kansas	393,000	Wet
Houston, Texas	427,000*	Wet
Fort Worth, Texas	622,000	Wet
California Division		
Lebee, California	542,000	Dry
	5,154,000	
Giant Portland Cement Co.		
Harleyville, South Carolina	684,000	Wet
Gifford-Hill Portland Cement Co.		
Southwest Div.		
Midlothian, Texas	769,000	Wet
Eastern Div.		
Harleyville, South Carolina	513,000	Dry
	1,282,000	
Gulf Coast Portland Cement Co.		
Div. McDonough Co.		
Houston, Texas	257,000	Wet
Hudson Cement Co. Div.		
Colonial Sand & Stone Co.		
Kingston, New York	684,000	Wet
Hawaiian Cement Corp.		
Ewa Beach, Hawaii	171,000	Dry
Ideal Cement Co. Div.		
Ideal Basic Industries, Inc.		
Mobile, Alabama	478,000	Wet
Okay, Arkansas	324,000	Wet
Boettcher, Colorado	427,000	Dry
Portland, Colorado	377,000	Wet
Houston, Texas	649,000*	Wet

Continued

Table C-1. (Continued) COMPANY/PRODUCT LIST

Company/location	Capacity (metric tons/year)	Process
Baton Rouge, Louisiana	513,000	Wet
Trident, Montana	291,000	Wet
Superior, Nevada	341,000	Wet
Tijeras, New Mexico	462,000	Dry
Castle Hayne, North Carolina	598,000	Wet
Seattle, Washington	427,000	Wet
Ada, Oklahoma	598,000	Wet
Devil's Slide, Utah	324,000	Wet
Knoxville, Tennessee	478,000	Wet
	6,287,000	
Illinois Cement Co. (Centex Corp.)		
LaSalle, Illinois	341,000	Dry
Kaiser Cement & Gypsum Corp.		
Permanente, California	1,368,000	Wet
Lucerne Valley, California	891,000	Wet
Nanakuli, Hawaii	273,000	Wet
Montana City, Montana	240,000	Wet
San Antonio, Texas	409,000	Wet
	3,181,000	
Keystone Portland Cement Co.		
Bath, Pennsylvania	564,000	Wet
Lehigh Portland Cement Co.		
Alsen, New York	462,000	Dry
Mason City, Iowa	564,000	Dry
Metaline Falls, Washington	205,000	Dry
Miami, Florida	462,000	Wet
Mitchell, Indiana	462,000	Dry
Union Bridge, Maryland	837,000	Dry
	2,992,000	
Lone Star Industries, Inc.		
Nazareth, Pennsylvania	615,000	Dry
Greencastle, Indiana	684,000	Wet
Bonner Springs, Kansas	410,000	Wet
Houston, Texas	564,000	Wet
Maryneal, Texas	547,000	Wet
New Orleans, Louisiana	377,000	Wet
Seattle, Washington	684,000	Wet
Davenport, California	769,000	Dry
	4,650,000	

Continued

Table C-1. (Continued) COMPANY/PRODUCT LIST

Company/location	Capacity (metric tons/year)	Process
Louisville Cement Co.		
Speed, Indiana	889,000	Dry
Logansport, Indiana	274,000	Wet
Bessemer, Pennsylvania	804,000	Wet
	1,967,000	
Marquette Cement Manufacturing Co.		
Branden, Mississippi	222,000	Wet
Cape Girardeau, Missouri	257,000	Wet & Dry
Catskill, New York	564,000	Wet
Cowan, Tennessee	171,000	Wet
Des Moines, Iowa	377,000	Wet
Hagerstown, Maryland	427,000	Wet
Milwaukee, Wisconsin	222,000	Dry
Nashville, Tennessee	205,000	Wet
Oglesby, Illinois	684,000	Dry
Pittsburgh, Pennsylvania	341,000	Wet
Rockmart, Georgia	222,000	Dry
Superior, Ohio	222,000	Dry
	3,914,000	
Martin Marietta Cement		
Eastern Div.		
Martinsburg, West Virginia	820,000	Wet
Northampton, Pennsylvania	410,000	Dry
Thomaston, Maine	427,000	Wet
Great Lakes Div.		
Essexville, Michigan	171,000	Wet
Midwest Div.		
Davenport, Iowa	513,000	Wet
Southern Div.		
Atlanta, Georgia	581,000	Dry
Roberta, Alabama	495,000	Dry
Western Div.		
Lyons, Colorado	393,000	Dry
Tulsa, Oklahoma	581,000	Dry
	4,391,000	
Maule Industries, Inc.		
Miami, Florida	958,000	Wet
Medusa Cement Co.		
Div. Medusa Corp.		
Clinchfield, Georgia	718,000	Dry

Continued

Table C-1. (Continued) COMPANY/PRODUCT LIST

Company/location	Capacity (metric tons/year)	Process
Dixon, Illinois	598,000	Dry
Charlevoix, Michigan	684,000	Wet
Sylvania, Ohio	257,000	Dry
Wampum, Pennsylvania	701,000	Dry
York, Pennsylvania	444,000*	Wet
Manitowoc, Wisconsin	68,000*	Wet
	3,470,000	
Missouri Portland Cement Co.		
Joppa, Illinois	595,000	Dry
Kansas City, Missouri	513,000	Dry
St. Louis, Missouri	855,000	Wet
	1,963,000	
Monarch Cement Co.		
Humboldt, Kansas	431,000	Dry
Monolith Portland Cement Co.		
Laramie, Wyoming	182,000	Wet
Monolith, California	1,200,000	Wet
	1,382,000	
National Cement Co. Div.		
Mead Co.		
Ragland, Alabama	341,000	Dry
National Gypsum Co.		
Allentown Portland Cement Co.		
Evansville, Pennsylvania	855,000	Dry
Huron Cement Div.		
Alpena, Michigan	2,391,000	Dry
	3,246,000	
National Portland Cement Co., Inc.		
Bethlehem, Pennsylvania	341,000	Wet
Nevada Cement Co. (Centex Corp.)		
Fernley, ~~New York~~ Nevada	377,000	Dry
Northwestern States Portland Cement Co.		
Mason City, Iowa	727,000	Dry
OKC Corp.		
Oklahoma Cement Co. Div		
Pryor, Oklahoma	410,000	Dry

Continued

Table C-1. (Continued) COMPANY/PRODUCT LIST

Company/location	Capacity (metric tons/year)	Process
Louisiana Cement Div.		
New Orleans, Louisiana	613,000	Wet
	1,123,000	
Oregon Portland Cement Co.		
Lake Oswego, Oregon	171,000	Wet
Lime, Oregon	547,000	Wet
Idaho Portland Cement Co. Div.		
Inkom, Idaho	200,000	Wet
	918,000	
Penn-Dixie Industries, Inc.		
West Des Moines, Iowa	393,000	Wet
Petoskey, Michigan	598,000	Wet
Howes Cave, New York	307,000	Dry
Nazareth, Pennsylvania	307,000	Dry
West Winfield, Pennsylvania	324,000	Wet
Kingsport, Tennessee	274,000	Wet
Richard City, Tennessee	274,000	Wet
	2,477,000	
Portland Cement Co. of Utah		
Salt Lake City, Utah	171,000	Wet
Puerto Rican Cement Co.		
Ponce, Puerto Rico	1,454,000	Wet
San Juan, Puerto Rico	513,000	Wet
	1,967,000	
River Cement Co. Div.		
River Corp.		
Selma, Missouri	1,064,000	Dry
San Antonio Portland Cement Co.		
Cementville, Texas	427,000	Wet
San Juan Cement Co., Inc.		
Dorado, Puerto Rico	427,000	Wet
Santee Portland Cement Co.		
Holly Hill, South Carolina	1,025,000	Wet & Dry
South Dakota Cement Commission		
Rapid City, South Dakota	410,000	Wet

Continued

Table C-1. (Continued) COMPANY/PRODUCT LIST

Company/location	Capacity (metric tons/year)	Process
Southdown, Inc.		
Southwestern Portland Cement Co.		
California Div.		
Victorville, California	1,025,000	Wet & Dry
Eastern Div.		
Fairborn, Ohio	597,000	Wet
Southwestern Div.		
El Paso, Texas	307,000	Dry
Odessa, Texas	274,000	Dry
Amarillo, Texas	222,000	Wet
	2,425,000	
Texas Industries, Inc.		
Midlothian, Texas	1,094,000	Wet
United Cement Co.		
Artesia, Michigan	341,000	Wet
	1,435,000	
Universal Atlas Cement Div.		
United States Steel Corp.		
Hudson, New York	684,000	Dry
Northampton, Pennsylvania	393,000*	Wet
Universal, Pennsylvania	444,000	Dry
Fairborn, Ohio	531,000	Wet
Buffington, Indiana	547,000	Dry
Duluth, Minnesota	291,000	Dry
Hannibal, Missouri	632,000	Wet
Independence, Kansas	377,000	Dry
Leeds, Alabama	307,000	Wet
Waco, Texas	341,000*	Dry
	4,547,000	
Whitehall Cement Manufacturing Co.		
Cementon, Pennsylvania	427,000	Dry

* Includes white portland cement manufacturing facilities as follows:

Amcord, Inc.		
Crestmore, California	103,000	Dry
General Portland, Inc.		
Houston, Texas	86,000	Wet
Tampa, Florida	128,000	Wet
Ideal Cement Co. Div.		
Houston, Texas	68,000	Wet

Continued

Table C-1. (Continued) COMPANY/PRODUCT LIST

Company/location	Capacity (metric tons/year)	Process
*Medusa Cement Co. Div.		
Manitowoc, Wisconsin	68,000	Wet
York, Pennsylvania	136,000	Wet
Universal Atlas Cement Div.		
Northampton, Pennsylvania	77,000	Wet
Waco, Texas	86,000	Dry

Table C-2. CLINKER GRINDING PLANTS - 1974

G. & W. H. Corson, Inc.
(International Utilities)
Plymouth Meeting, Pennsylvania

M. J. Grove Lime Co. Div.
(Flintkote Co.)
Frederick, Maryland

Edward C. Levy Co.
Detroit, Michigan

Lone Star Industries, Inc.
Norfolk, Virginia

Martin Marietta Corp.
North Birmingham, Alabama

National Sypsum Co.
W. Conshohocken, Pennsylvania
Superior, Wisconsin

National Portland Cement Co. of Florida
Bradenton, Florida

Riverton Corp.
Riverton, Virginia

Universal Atlas Cement Div.
Milwaukee, Wisconsin

Table C-3. MASONRY CEMENT MANUFACTURING PLANT

Riverton Lime & Stone Co., Inc. Riverton, Virginia
M. J. Grove Lime Co. Div. (Flintkote Co.) Frederick, Maryland
Cheney Lime and Cement Co. Allgood, Alabama
Martin Marietta Cement Birmingham, Alabama

Table C-4. CALCIUM ALUMINATE MANUFACTURING PLANTS

Aluminum Co. of America Bauxite, Arkansas
Universal Atlas Cement Div. Buffington, Indiana
Lone Star Lafarge Co. Norfolk, Virginia
Riverton Corp. Riverton, Virginia

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

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16. ABSTRACT

The catalog of Industrial Process Profiles for Environmental Use was developed as an aid in defining the environmental impacts of industrial activity in the United States. Entries for each industry are in consistent format and form separate chapters of the study. The cement industry consists of companies producing complex calcium-silicate-aluminate-ferrite materials which when mixed with water form a binding material for aggregates in "concrete." One chemical tree, one process flow sheet, and six process descriptions have been prepared to characterize the industry. Within each process description available data have been presented on input materials, operating parameters, utility requirements and waste streams. Data related to the subject matter, including company, product and raw material data, are included as appendices.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution; Process Description; Calcium-Silicate; Aluminate-Ferrite; Concrete; Pozzolana; Lime; Fabric Filters	Air Pollution Control; Water Pollution Control; Solid Waste Control; Stationary Sources; Building Materials	07B; 13B; 13C; 13M

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