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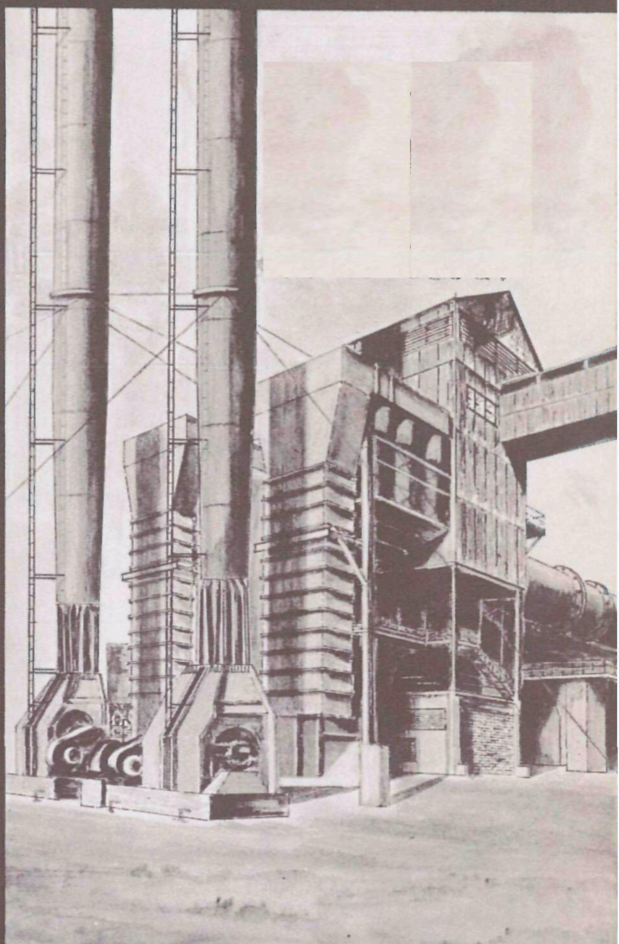

ATMOSPHERIC EMISSIONS FROM THE MANUFACTURE OF PORTLAND CEMENT

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

ATMOSPHERIC EMISSIONS FROM THE MANUFACTURE OF PORTLAND CEMENT

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CONTENTS

ABSTRACT

This report summarizes published and unpublished information on actual and potential atmospheric emissions resulting from the manufacture of cement. Raw materials, process equipment, and production processes are described, as well as the location of plants, and process trends. Emission and related operating data are presented, along with methods normally employed to limit or control emissions from the dry, semi-dry, and wet processes.

ATMOSPHERIC EMISSIONS FROM THE MANUFACTURE OF PORTLAND CEMENT

INTRODUCTION

This report has been prepared to provide reliable information on actual and potential atmospheric emissions from portland cement manufacturing plants and on methods and equipment normally employed to limit these emissions to satisfactory levels.

Background information has been included to define the importance of the cement industry in the United States. Basic characteristics of the industry are discussed, including projected growth rates, types of raw materials, and the number and location of cement manufacturing sites in the United States.

Process descriptions are given for both the wet process and the dry process to provide a basic understanding of these processes for those interested in dust emissions originating from the manufacture of cement. Emissions from both processes are reviewed in detail, normal ranges are given, and methods of emission control and recovery are described.

Because the cement industry in the United States has been a basic industry for many years with well-established manufacturing procedures, and indications are that the industry growth in recent years closely parallels the growth curve of the general economy, the information provided in this report on emissions and their control may likely provide characteristic information for a period of 5 to 10 years.

Although this review of the industry has been prepared primarily for public officials concerned with the control of air pollution, the information may also be useful to cement plant management and technical staffs and to other professional people interested in emissions from portland cement manufacturing plants.

SUMMARY

In 1964, production of portland cement in the United States was approximately 361,000,000 barrels. Cement production is expected to increase at the rate of about 5 percent per year, with a comparable increase in the construction of new plants. (See Figure 1.)[1,2,3]

All portland cement is made by either the wet process or the dry process. Almost all new plants utilize long kilns (greater than 400 feet) with chain or other preheating systems.

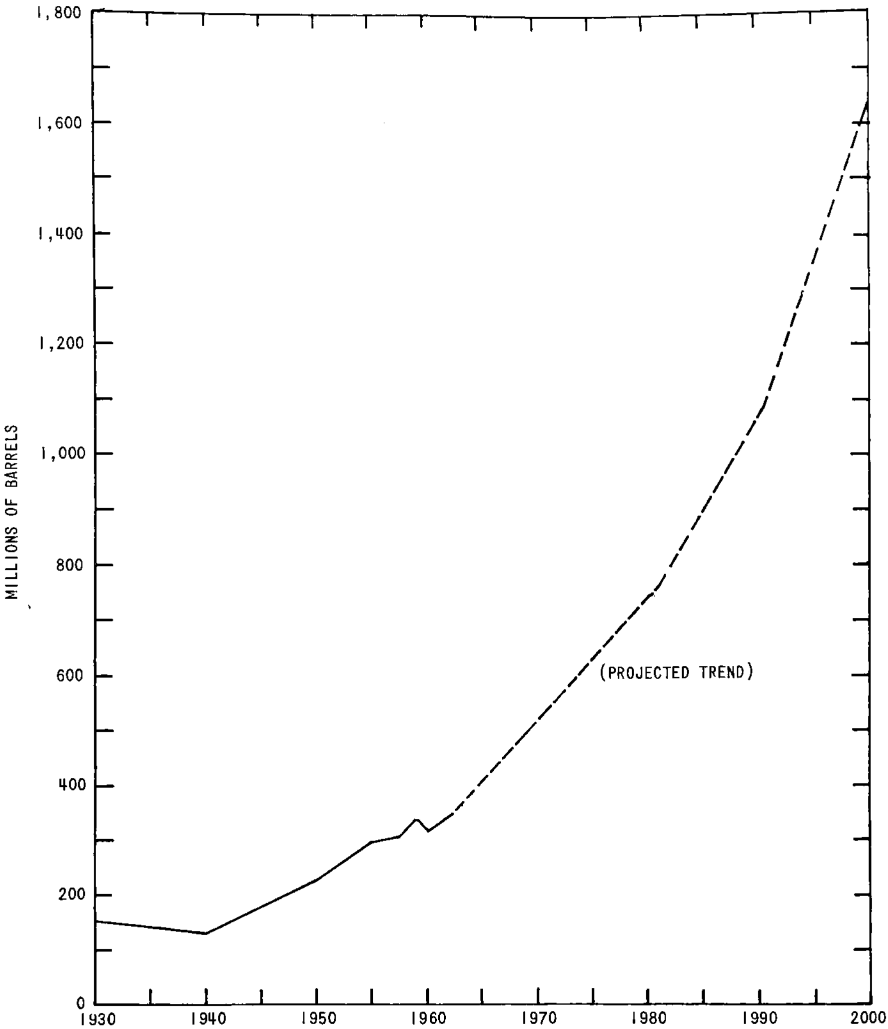

Figure 1. Portland cement production in the United States (References 1, 2, and 3).

The main source of emissions in the cement industry is the kiln operation. Dust generated in the dry-process kiln may vary from 1 to 25 percent expressed in terms of finished cement; from the wet process, 1 to 33 percent. Sulfur dioxide emissions from the kiln operation are generally minor; most of the oxides of sulfur in the kiln gases combine with the alkalies as condensed sulfates. In the wet process, an odor problem may arise from heating certain types of raw material such as marine shells, marl, clay, or shale.

Another important source of dust emissions in the cement industry is the dryer normally used in dry process plants.

Dust can be adequately arrested in the cement industry by proper plant layout and proper selection of high-efficiency multicyclones, electrostatic precipitators, or fabric filters. Electrostatic precipitators or fiber-glass fabric filters that have been properly designed, installed, operated, and maintained will adequately collect the dust from the hot kiln gases. In many plant designs, multicyclones precede the precipitator or fabric filter. Precipitators or low-temperature fabric filters alone may be adequate on other unit operations such as handling, crushing, grinding, drying, and packaging. Dust emissions as low as 0.03 to 0.05 grains per standard cubic foot have been obtained in newly designed well-controlled plants.

INDUSTRY CHARACTERISTICS

LOCATION OF CEMENT PLANTS

The availability of markets and raw materials determines the location of a cement plant. The more important considerations are: (1) a potential market nearby or within the range of low cost transportation; (2) suitable raw materials sufficient to supply a plant for 50 to 100 years; (3) adequate transportation facilities for shipping the finished product to its destination; (4) adequate fresh water of a quality suitable for process use, cooling, cleaning, and washing; (5) adequate uniform-quality fuels available at attractive prices; (6) available skilled and unskilled labor; and (7) available electric power at an attractive rate. To meet these conditions, cement plants are concentrated in certain groups or patterns (Figure 2): (1) eastern Pennsylvania and the Hudson River Valley, serving the eastern metropolitan areas; (2) Birmingham, Alabama, area, serving the central south; (3) St. Louis and Kansas City, Missouri, areas, serving the midwest; (4) central Texas; (5) California; and (6) the Pacific Northwest. In addition to these concentrations, cement plants are located convenient to other markets and available materials. For example some plants are located in the Appalachian Mountains because of the availability of a certain type of limestone, and other plants are located in West Texas, Oklahoma, Kansas, and Louisiana to take advantage of available natural gas as fuel.

Table 1 lists districts in which portland cement manufacturing plants were located in the United States as of December 31, 1964, and their approximate total capacities.

PRODUCTION

In 1964, the United States produced 361,000,000 barrels of portland cement, a 4.3 percent growth over 1963 (see Figure 1). This is 75.5 percent of the 1964 rated capacity of 478,000,000 barrels.[4] The production rates for 1963, estimated percentage of utilization in 1963, and capacity rates for 1964 are summarized by area location in Table 1.[1]

Table 1. PORTLAND CEMENT MANUFACTURING CAPACITY OF THE UNITED STATES BY DISTRICTS, 1964 (References 4,5, and 6)

District	Active plants	Approximate capacity in thousands of barrels, Dec. 31, 1964	Production in thousands of barrels, 1963	Estimated percent utilized, 1963
New York, Maine	14	43,406	24,033	76
Eastern Pennsylvania	14	36,118	30,480	84
Western Pennsylvania	5	11,758	7,956	68
Maryland, West Virginia	4	12,150	10,277	84
Ohio	9	19,700	16,375	72
Michigan	9	35,472	24,388	67
Illinois	4	12,250	9,588	94
Indiana, Kentucky, Wisconsin	8	28,600	19,166	85
Alabama	9	19,540	12,575	73
Tennessee	6	10,024	8,793	83
Virginia, North Carolina, South Carolina	5	13,790	8,562	78
Georgia, Florida	7	20,472	11,288	76
Louisiana, Mississippi	5	9,800	8,304	79
Iowa	5	15,680	12,790	87
Minnesota, South Dakota, Nebraska	4	10,100	7,856	84
Kansas	6	13,440	8,248	64
Missouri	5	15,800	12,624	76
Oklahoma, Arkansas	5	15,200	11,282	70
Texas	17	42,650	29,089	60
Colorado, Arizona, Utah, New Mexico, Nevada	8	19,600	13,488	84
Wyoming, Montana, Idaho	4	4,800	3,614	83
Northern California	6	20,800	17,973	86
Southern California	7	38,650	28,120	72
Oregon, Washington	9	11,410	7,799	75
Hawaii	2	2,700	1,429	50
Total	177	483,910	346,097	73.8

Figure 2. Portland cement plant locations in the United States (1965).

Portland cement is produced by either the dry or the wet process. In 1964 there were 110 wet-process and 69 dry-process plants in the United States (see Figure 2). The number of both wet- and dry-process plants may be expected to increase at a comparable rate. A comparison of cement production by the two processes is shown in Table 2.

The individual plants, their locations, process types, and capacities are listed in the Appendix. Although the plant capacities range from less than 1,000,000 barrels to almost 14,000,000 barrels per year, over 50 percent of them have capacities ranging from 2,000,000 to 4,000,000 barrels per year.

Table 2. COMPARISON OF WET AND DRY PROCESS PRODUCTION OF PORTLAND CEMENT (Reference 1)

	Wet Process	Dry Process
No. of plants[a]	110	69
1964 approximate total capacity, 1,000 bbl	285,270	198,640
Percent of total capacity	58.9	41.1
1963 total production, 1,000 bbl	202,097	144,000
Percent of total production	58.4	41.6

[a]Two plants use both wet and dry processes.

RAW MATERIALS

The raw materials required to make cement may be divided into the following components: lime (calcareous), silica (siliceous), alumina (argillaceous), and iron (ferriferous). In the United States more than 30 different types or classes of raw materials are used to manufacture cement. To produce one barrel of cement weighing 376 pounds, approximately 600 pounds of raw materials (not including fuel) are required.[1] (Approximately 35 percent of the raw material by weight is volatilized as carbon dioxide and water vapor.) The total tonnages of raw materials used in producing portland cement in the United States are shown in Table 3.

Approximately 73 percent of the domestic output of portland cement in 1962 was made from a combination of limestone and clay or shale.

Cement rock (argillaceous limestone), a low-magnesium limestone-containing clay, was used in about 19 percent of the portland cement produced.[1] The Jacksonburg limestone of the Lehigh Valley area of

Pennsylvania is a well-known source of cement rock. Quarry materials are corrected to the desired composition for kiln feed by adding small amounts of clay or high-calcium limestone.

Along the Gulf Coast of the United States, oyster or clam shells are used as sources of calcareous material; in San Francisco oyster shells occurring in brackish water deposits have been found suitable for cement manufacture. Other forms of calcium carbonate of relatively high purity, such as coral rock in Florida, chalk in Alabama and Arkansas, and alkali waste in certain parts of the United States may be used.

Where alumina, silica, and iron oxide are not present in the limestone in sufficient amounts, and this is true in most cases, clay, shale, or iron ore must be added to adjust the composition. Both clays and shales display wide variations in mineralogical and chemical content; some consist essentially of aluminum silicates and others may contain more than 50 percent free silica or quartzite. Adjustment of the silica content may be necessary.

Table 3. RAW MATERIALS USED IN PRODUCING PORTLAND CEMENT IN THE UNITED STATES DURING 1962 (Reference 1)

Raw material	Thousands of tons
Cement rock	20,829
Limestone (including oyster shell)	69,456
Marl	1,689
Clay and shale	9,943
Blast-furnace slag	1,119
Gypsum	2,826
Sand and sandstone (including silica and quartz)	1,423
Iron materials	659
Miscellaneous	105
Total	108,049

Basic blast-furnace slag may be substituted in part for the raw materials used in the production of portland cement. Where the slag is used, the fluxing stone charged to the blast furnace must necessarily be limestone with high calcium content and not dolomite with its objectionable magnesium content. The slag is mixed with limestone and serves to introduce a part of the lime, silica, alumina, and iron oxide. Another raw material is fly ash from coal-fired power stations.

FUEL CONSUMPTION

In the United States, coal, oil, and natural gas are used, singly or in combination with one fuel as the main supply and the other as a standby. Cost, availability, and convenience of handling determine the fuels used.

Only coal requires extensive preparation; a supply is kept in covered storage bins or in piles out in the open to ensure against supply interruption, and to permit blending for the sake of uniformity. As in the grinding of dry-process raw materials, coal may be dried in separate driers or in a combined drying-grinding mill. After being ground to a fineness of about 80 to 90 percent minus 200 mesh, the coal may be stored in bins and withdrawn by automatic feeders for injection into the kilns with a stream of preheated primary air. Most plants use direct-firing-unit pulverizers, with which the dried and powdered coal is swept through and out of the grinding mills by the heated air stream and blown directly into the kiln. Any dust released from the coal-handling system can be efficiently controlled by a fabric filter.

Heated fuel oil is injected into the kilns with or without the primary air by means of compressed air or fluid-pressure-steam atomizers. Natural gas is simply reduced in pressure before passing directly into a kiln with or without the addition of primary air.

The amount of fuel used to manufacture cement varies with the efficiency of the kiln, the composition of raw materials, the process used, and many other operational factors. In 1963, on the average, one barrel of finished cement required about 92.3 pounds of coal, or 8.27 gallons of fuel oil, or 1140 cubic feet of natural gas--the equivalent of approximately 1,200,000 Btu per barrel of cement produced.[1] This figure is the statistical mean of data compiled on all makes and models of kilns used today. Modern plants would be expected to consume much less fuel. Long-dry-process kilns utilize about 900,000 Btu per barrel, short-dry-process kilns with vertical suspension preheaters utilize 540,000 to 640,000 Btu per barrel, and grate-preheater-process kilns utilize approximately 600,000 Btu per barrel.[1] Although the wet-process kiln has a higher heat requirement than the dry-process kiln, the fuel consumption difference, in many cases, is partially offset by the heat consumed in the dryers preceding the dry-process kiln. This is not the case in instances where dryers do not precede dry-process kilns.

CEMENT PRODUCTION PROCESS

There are four major steps in the production of portland cement: quarrying and crushing, grinding and blending, clinker production, and finish grinding and packaging. Flow charts depicting the various steps in cement production are shown in Figures 3-A, B, C, and D.

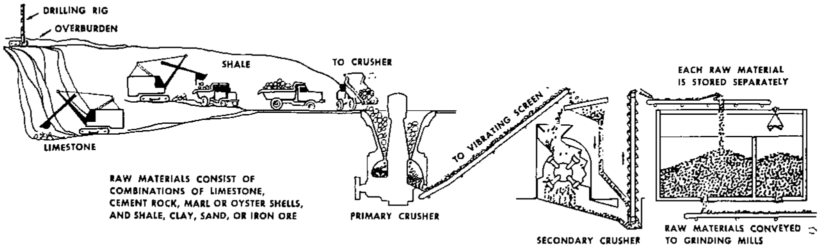

Figure 3A. Quarrying and crushing operation of portland cement production.

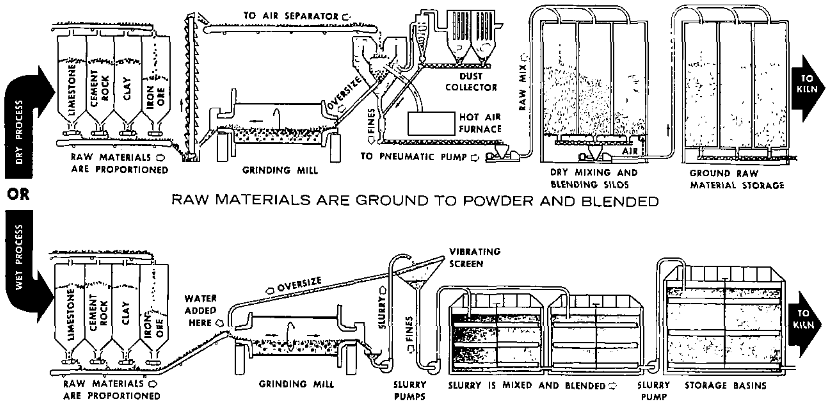

Figure 3B. Grinding and blending operation of portland cement production.

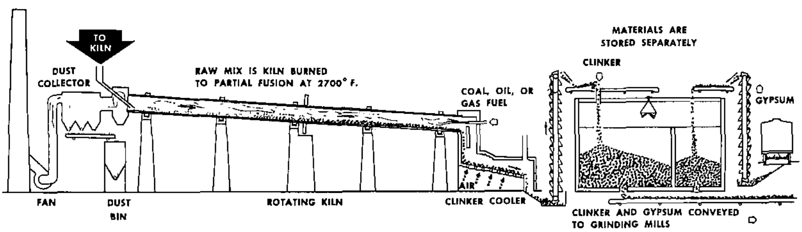

Figure 3C. Kiln operation of portland cement production.

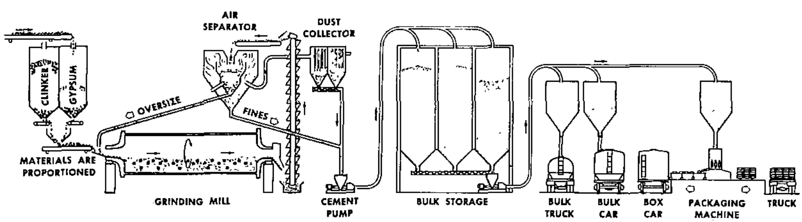

Figure 3D. Fine grinding and packaging operation of portland cement production.

QUARRYING AND CRUSHING

The production of cement begins in the quarry. Although there are numerous methods of obtaining the cement rock, limestone, clay, and shale from the earth, most deposits are worked in open quarries with a face height ranging from 30 to 200 feet. In many cases, heavy overburden, which may run as much as 50 to 100 feet in depth, requires extensive stripping and must be relocated.

Rock must be transported to crushing plants located either at or remote from the quarry. The types of primary crushers used depend on the hardness, lamination, and size of rock produced at the quarry, and include gyratory crushers, jaw crushers, roll crushers, and heavy hammer mills or impact mills.

After the rock has been broken in the primary crusher, it is carried by conveyors to the secondary crusher where crushing may be completed in one, two, or three steps. Typical crushers are hammer mills that reduce the rock to a maximum of 3/4 inch.

In a typical crushing plant a primary crusher may reduce the rock from as large as 4 to 5 feet across to 6 to 10 inches, and the secondary crusher may again reduce this product to 3/4 to 1 inch. Crushed material is generally transported to the raw material storage area by elevator and belt-conveyor systems and deposited in piles or compartments.

MIXING AND GRINDING

The various crushed raw materials must be properly proportioned, mixed, and pulverized to prepare them for heat treatment or clinkering in the kiln. The crushed materials are generally proportioned prior to the grinding operation, following which the finely ground raw mix is blended as required. In some plants, principal raw material components are ground separately, with both proportioning and blending accomplished after grinding. Product of the raw grinding circuit is so fine that 70 to 90 percent will pass through a 200-mesh sieve. Two grinding processes are used--dry and wet.

Dry Process

In the dry process, free moisture content of crushed materials is reduced to less than 1 percent prior to or during grinding. The drying may take place in direct-contact cylindrical rotary dryers, typically 6 to 8 feet in diameter and 60 to 150 feet long, or in "dry-in-the-mill" combined drying and grinding units that utilize a mill drying compartment or air separator for heat transfer. The hot gases may be provided by direct dryer firing, from separately fired furnaces, or by hot-kiln exit gases (waste heat). Pulverized coal, oil, or gas fuels are used.

The dried materials are ground to final product fineness in one or more stages. Preliminary or first stage grinding may utilize a cylindrical ball mill, rod mill, or ring-roller mill. The second- or final-stage unit is usually a ball mill or a "tube" mill, which is a ball mill with a higher length-to-diameter ratio. Most of the more recent installations follow the secondary or tertiary crushing operation with single-stage grinding with a combined ball-tube mill unit known as a compartment mill. Some plants operate single-stage vertical ball-race mills.

Modern dry-process grinding units are usually operated in a closed circuit with air separators that split the mill output into coarse and fine fractions. The coarse fraction is returned to the mill for further grinding, and the fine fraction becomes finished raw-mix. Various types of closed circuits have been used, with units in parallel, or series, or combinations thereof, but the basic purpose is to minimize objectionable oversize and develop a product fineness best suited for effective combinations in the kiln.

This finished finely ground raw mix is conveyed by pneumatic pumps or by mechanical means to blending, homogenizing, and/or storage silos from which it is withdrawn as kiln feed.

Wet Process

Wet-process grinding uses ball mills or compartment mills that are essentially the same as those used in the dry process except for feeding and discharge arrangements. Water is added to the mill with the crushed feed to form a slurry. Where clay is used as a raw material, it is generally added in suspension as a slip. Grinding may be done in one or two stages. Some installations are closed circuited with bowl-rake classifiers that return the oversize to the mill as "sands" and discharge the finished product as a very dilute overflow. Excess water in this overflow is removed in thickeners.

In other plants, mills are closed circuited with cyclones or screens that produce a final more viscous slurry that does not require thickeners. The various crushed materials may be proportioned ahead of grinding, as in the dry process, or each major component may be ground into separate slurries that are then proportioned and blended. Finished slurry fed to kilns may contain 30 to 40 percent water, or it may be further de-watered in vacuum filters and fed to the kiln as a "cake" containing about 20 percent water.[7]

CLINKER PRODUCTION

Clinker production is one of the most important functions in a cement plant; the quality of the finished cement largely depends upon proper burning conditions in the kiln.

The rotary kiln used in most plants in the United States is a steel cylinder with a refractory lining. Kilns may be 6 feet in diameter by 60 feet in length (a size almost extinct) to as large as 25 feet in diameter by 760 feet in length. The kiln is erected horizontally with a gentle slope of 3/8 to 3/4 inch per foot of length, and rotates on its longitudinal axis.

The kiln feed, commonly referred to as "slurry" for wet-process kilns or "raw meal" for dry-process kilns, is fed into the upper end of the revolving sloped kiln. As the feed flows slowly toward the lower end, it is exposed to increasing temperatures. During passage through the kiln (1 to 4 hours), the raw materials are heated, dried, calcined, and finally heated to a point of incipient fusion at about 2,900° F, a temperature at which a new mineralogical substance called clinker is produced. At the lower end of the kiln, the combustion of coal, fuel oil, or gas must produce a process temperature of 2,600° to 3,000° F. The combustion gases pass through the kiln counterflow to the material, and leave the kiln, along with carbon dioxide driven off during calcination, at temperatures of 300° to 1,800° F, depending on the kiln length and the process used.

In the grate preheater system or "semidry" system, which was developed in Europe as the Lepol system, the feed is composed of raw meal mixed with 10 to 12 percent water and is formed into pellets of about 1-inch maximum size. These pellets are dried and preheated on a slowly traveling grate through which the hot gases from the rotary kiln are passed. The pellets are then fed directly into the rotary kiln.

As the hot waste gases pass through the kiln exit, they are sometimes utilized in preheat systems. These preheat systems can affect the quantity of emissions released from the kiln. The grate preheater method uses a double-pass system whereby the gaseous effluents pass countercurrently through the wet (12 percent water) mix twice: first to preheat the mix and second to dry and partially calcine the mix.

The suspension preheater system has been adapted to short, dry-process kilns. In this system, the dry mix is preheated by direct contact with waste gases in a multistage cyclone-suspension process. The waste gases pass through one or more cyclones through which the mix passes countercurrently.

Two basic types of wet-process kilns are in use in the United States. Around 1930, short wet-process kilns were installed with waste-heat boilers similar to the waste-heat boilers in the short (250 feet) dry kilns. Shortly thereafter, the construction of short wet-process kilns yielded to the building of long (350 feet) wet-process kilns with internal chain preheaters. Most of the new wet-process kilns utilize a chain system to heat and convey the feed. The system consists of a large number of chains suspended in the drying zone of the kiln and so arranged that, in addition to lifting the slurry into the path of the hot gases, they convey the raw material to the burning zone. The feed on the large exposed surface of the chains is in intimate contact with the combustion gases.[1]

As the clinker is discharged from the lower end of the kiln it is passed through a clinker cooler that serves the dual purpose of reducing the temperature of the clinker before it is stored and recovering the sensible heat for reuse inside the kiln as preheated primary or secondary combustion air. Rotary, planetary, vibrating, or grate type air-quenching coolers are used to permit a blast of cooling air to pass through a slowly moving bed of hot clinkers. The cooled clinker is then conveyed by drag chains, vibrating troughs, or conveyor belts to storage.

FINISH GRINDING AND PACKAGING

In the final stage of cement manufacture, the clinker is ground into cement. Interground with the clinker is a small amount of gypsum (4 to 6 percent), which regulates the setting time of the cement when it is mixed with water and aggregate to make mortar or concrete.

Various grinding circuits are in use. The system may be two stage, with preliminary and secondary mills, or the entire process may be performed in a single compartment mill. Ball mills or tube mills normally are used. Crushers may be used ahead of the ball or tube mills. The grinding system may be open circuit, but most of the mills are closed-circuited with air separators. The final product has a fineness of 90 to 100 percent minus 325 mesh. The average size of a cement particle reportedly is about 10 microns.[8] The finished cement is transported by screws, belt conveyors, or pneumatic pumps to silos for storage until it is shipped.

Some portland cement is packaged in 94-pound bags, which is one-quarter of the 376-pound "barrel." In bulk, however, most cement is transported in trucks, hopper cars, railway box cars, barges, and ships.

EMISSIONS AND THEIR CONTROL

Particulate matter is the primary emission in the manufacture of portland cement. There are also the normal combustion products of the fuel used to supply heat for the kiln and drying operations, including oxides of nitrogen and small amounts of oxides of sulfur.

For dust control, the cement industry generally uses mechanical collectors, electrical precipitators, and fabric filter (baghouse) collectors or combinations thereof, depending upon the emission and the temperatures of the effluents in the plant in question and the particulate emission standards in the community. Gaseous emissions are controlled only when an odor problem arises.

CRUSHING

Dust production in the crusher area depends on the type and moisture content of the raw material, and the characteristics and type of crusher. If the material has a high moisture content, it may not be necessary to provide dust control for plants located in a relatively isolated location. Where dust generation from crushing is a problem, the entrained dust is normally collected by centrifugal collectors or cloth filters. In some cases dust-suppressive aqueous solutions are applied to control dust in the crushing circuit.

In the process of conveying the crushed material to storage silos, sheds, or open piles, dust is generated at various conveyor transfer points. A hood is normally placed over each of these points to control particulate emissions (see Figure 4). A face velocity of 200 feet per minute is normally necessary to control the dust emitted at the transfer points.[9] Cloth filters have been used extensively and are very effective in recovering the dust.

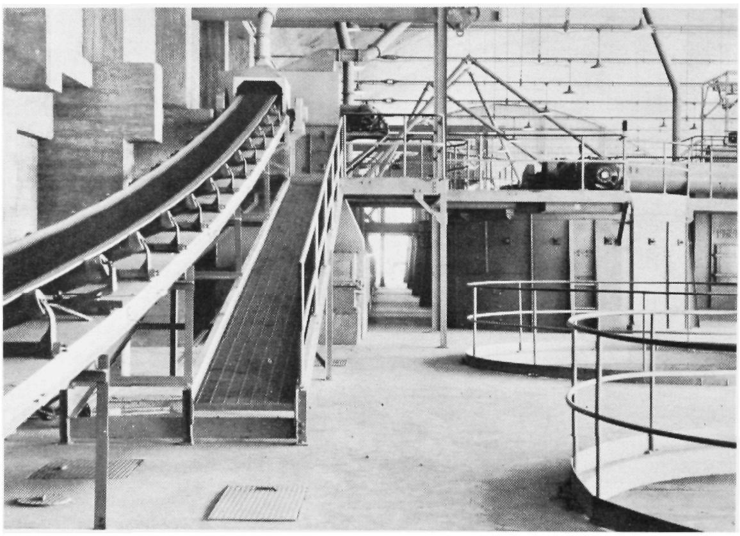

Figure 4. Arrangement of dust collectors at transfer points of belt conveyors and screw conveyors.

Storage silos are under slight pressure as a result of material displacing air during the filling operation. In modern installations displaced dust-laden air is normally vented to a bag-type dust collector. This is especially true for silos with pneumatic loading and circulating systems.

Where sheds are used for the storage of raw materials, and dust emission is a problem, they should be as completely enclosed as possible. Dust-suppression methods on open or semi-open piles include spraying the pile with water or dust-suppressive aqueous solutions, (e.g., wetting agents or detergents), discharging the contents of the conveyors onto the piles through telescoping spouts close to the top of the pile rather than with a long free fall, and placing wind breakers such as trees and fences around the piles.

RAW DRYING AND GRINDING - DRY PROCESS

The hot gases passing through a rotating cylindrical dryer will entrain dust from the limestone, shale, or other materials being dried. The concentration of dust in the exit gases is related to the velocity of the gases, the quantity and size of the fine particles, and their degree of dispersion in the gas stream. A heavier dust concentration may be expected in dryers utilizing kiln exit gases (waste-heat dryers) because of the dust carry-over from the kilns.

Dust concentrations of 5 to 10 grains per cubic foot of rotary-dryer-discharge gas prior to treatment can normally be expected.[10] In one example, data for two tests of an older dryer showed 13,000 cubic feet per minute of exit gas at 200° F, carrying 6.0 grains per cubic foot.[11] In another case, a number of rotary dryers discharged exit gases through individual multicyclones followed by a common electrostatic precipitator. Tests indicated 150,000 cubic feet per minute at 150° F discharged from the precipitator with inlet and outlet loadings of 3.50 and 0.20 particulate grains per cubic foot, respectively. This is equivalent to 94.2 percent collection efficiency of the electrostatic precipitator. At an estimated collection efficiency of 70 percent for the multicyclones, the 3.5 grains per cubic foot loading discharged by them is equivalent to 11.8 grains per cubic foot loading in the dryer discharge gases.[12] The type of dust control equipment used at this plant would be considered adequate in that the gases from the drying - grinding operation were processed through a multicyclone followed by an electrostatic precipitator. In this particular case, however, the combined collection efficiency of the multicyclone and precipitator was not sufficient to preclude a dust nuisance problem in a residential area 1 mile downwind from the cement plant. A design for greater dust collection efficiencies could have precluded this problem.

The rotary dryer, like the rotary kiln, is a major source of dust generation in a cement plant and requires collecting systems designed for higher temperatures. Systems in common use generally include multicyclones or other type mechanical collectors, electrostatic precipitator or combinations thereof. Where cloth filters are applied to drying operations, they must be the glass-fiber type suitable for temperatures above 250° F.

The most common dry grinding circuits, whether they use ball mills, compartment mills, or vertical units, are vented from mill discharge points to provide some air sweep through the mills to prevent mill dusting during grinding. In the normal closed circuits, vents may also be connected to mill discharge elevators, conveyors, and air separators to maintain the entire system under negative pressure. The heavily dust-laden air from these vents is conducted to dust-collecting apparatus, generally low temperature cloth filters.

Dusts collected from mill systems, raw or finish transfer points, and conveyors present only minor air pollution problems as these are essentially closed systems and the dust collected is returned into the unit from which it was collected, or to the mass of material in transit at the appropriate stage of the process.

Data on dust loading from mill vent circuits are not readily available, but the loading may be considered extremely high. One test on a vertical ring roller mill showed an exit dust loading of 50 grains per cubic foot at 139° F in a gas flow of 1,460 cubic feet per minute. These data are of only academic significance, however, because the low temperature cloth collectors used for this service, when properly maintained, will essentially collect 99.9 percent of the dust--which is returned to the circuit. For extremely heavy dust concentrations, pre-cleaning cyclonic collectors are normally used ahead of and in series with the cloth filters.

In the case of "dry-in-the-mill" combination drying and grinding circuits, the final vent from the drying or closed-circuit separator or cyclone would be treated similarly with cloth filters or with electrostatic precipitators in cases where moisture content of gases is too great to assure operation of the filters above the dew point. Dust-collector gas volumes for ginding circuits depend on the productive capacity and type of circuit; they range from 2,500 to 50,000 cubic feet per minute per unit.

RAW GRINDING WET PROCESS

Inasmuch as the raw materials are not dried, but are ground in the presence of water as a slurry, no dust is generated.

KILN OPERATION

The largest source of emissions within cement plants is the kiln operation, which may be considered to have three units: the feed system, a fuel-firing system, and a clinker-cooling and handling system. The kiln itself (fuel-firing system) has three functions: drying, calcining, and clinkering.

While the same general objective prevails with a closed system for return of collected dust to the kiln, the complications of kiln burning and the larger volumes of material to be handled have led to many systems of dust collection and return.

Attention has been given to containing within the kiln some portion of the dust generated. This may range from simple dust curtain chain systems (a dense curtain of light-weight chain hung close to the kiln exit) to still highly experimental closed systems of fluidized bed calcination sintering of clinker. Enlargement of the kiln diameter at the feed end, which reduces gas velocities, improves the situation slightly by entraining less dust in the emitting gases. Most modern kilns are so constructed.

Modifications of a rotary kiln system or the addition of a suspension preheater that uses cyclones or moveable grate preheaters are partially effective in controlling dust generated in the kiln. Additional control equipment such as cyclone collectors and electrostatic precipitators, fabric filters, or scrubbers are normally used for satisfactory collection of kiln dust.

The most desirable method for disposing of the collected dust is to return it to the kiln. The alkali content of the cement product, however, must often be less than 0.6 percent by weight (calculated as sodium). Where the alkali content of the raw material going into the kiln is high, e. g. greater than 1 percent sodium and potassium feldspar, then leaching of the collected dust may be required to reduce the alkali content in order to return the dust to the kiln. Methods of returning dust to the kiln are:

1. Direct dust return to kiln feed prior to kiln entry by mixing dry dust and kiln feed either wet or dry.
2. Direct dust return to the kiln parallel to the kiln feed either wet or dry.
3. In multiple kiln installations, collection of all dust from the group of kilns for use as dry kiln feed for a single kiln.
4. Dust return by scoop feeders located in front of the chain system as dry dust usually on a wet process kiln.
5. Leaching systems where the collected dust is mixed with large volumes of water and then dewatered by thickener or mechanical filters or centrifuges to remove water soluble alkalies. The resultant slurry of reduced alkali dust may subsequently be remixed with kiln feed, introduced parallel to kiln feed, spray impinged onto the chain system, or in some cases used as slurry for wet process raw milling. The leaching process has been applied to collected dust from both wet and dry process kilns when low alkali requirements are mandatory, when raw materials are alkali bearing, and when high-efficiency dust collection systems entrap the alkalies in the emission gases.
6. Insufflation, which is the return of dry dust into the burning zone either through the fuel pipe, as is frequently the case in coal fired kilns on unit coal pulverizers, or by a separate pipe parallel to the burner pipe. Here the dust entering the burning zone sinters into small grains of clinker and is discharged with the clinker to the cooler. In this process the collected dry dust is usually pumped from the collecting unit at the feed end to the burner floor and into the burning zone through the kiln hood.

There is no one satisfactory method of returning the collected dust to the kiln; as a result, to control alkalies or improve kiln operation, part of the dust is disposed of in other ways.

Disposal of dust, unless it can be sold as a substitute for agricultural limestone, fertilizer, or as a mineral filler, presents problems. Since the collected dust may range from a few hundred pounds per hour to many tons, disposal requires a waste area and a means of moving dust from the collector to the waste area. The collected dust may be mixed with water and pumped to waste ponds in a manner similar to fly ash disposal commonly practiced in power generating stations. It may be dry pumped or truck hauled to worked-out quarry areas where rain and weather concrete the disposal pile into a monolithic mass. Where open truck haul to waste is practiced, usually the dust is dampened in a pug screw as it is discharged into the truck.

If multistage dust collectors are installed on a kiln, it is common to return the first stage or stages to the kiln and discard the final stages. Because the alkalies tend to concentrate in the final stage (the finest-size particle of dust), low alkali cement can be produced with minimum dust disposal.

Gaseous Emissions

Gaseous emissions from the combustion of fuel in the kiln are usually not sufficient to create significant air pollution problems. Most of the sulfur dioxide formed from the sulfur in the fuel is recovered as it combines with the alkalies and also with the lime when the alkali fume is low.[13,14] Tests of the kiln exit gases from one portland cement plant burning 2.8 percent sulfur coal showed a concentration of sulfur dioxide ranging from 6 to 39 parts per million.[15] Nitrogen oxides can form at kiln temperatures of 2,600° to 3,000° F, and may be of some concern in areas that experience photochemical-type air pollution. Odoriferous hydrogen sulfide and polysulfides may also be produced in the drying of the slurry or in the drying of the dry-process raw material when the latter is composed of marl, sea shells, shale, or clay. No data on the amount of nitrogen oxides or polysulfides produced are available at this time.

Particulate Concentrations Before Dust Collectors

To determine an average particulate emission rate for kiln operations is often impractical because of the diversity of kiln sizes, firing rates, types of preheaters and clinker coolers, and feed characteristics (wet or dry). Different types of feed composition also affect emission rates. In fact, one of the most important causes of dust emissions is the way in which gases are liberated and expelled from the raw feed during the calcination of limestone. Some raw materials remain relatively calm while the liberated gases escape; others appear to expand and explode, throwing the material into the gas stream. This may explain why some wet-process plants have a higher dust loss than some dry-process plants.[14]

Ranges of particulate emission rates for kiln operations are presented here along with generalized emission rates for certain specific kiln operations. The two basic processes, wet and dry, and the grate preheater or semi-dry process are discussed.

Dry Process

Data are presented in Table 4 for the following three basic types of dry-process kilns: 1) the short rotary kiln with or without a waste heat boiler, 2) the suspension preheater system, and 3) the long rotary kiln without a built-in preheater.

The concentration of dust leaving the kiln and entering the dust collection systems for all of the dry-process kilns ranged from 1.1 to 12.4 grains per cubic foot. The arithmetic average concentration for all tests was 6.4 grains per cubic foot. No appreciable difference in the range of dust loadings was apparent for the different types of dry-process kilns.

The amount of dust in the exit gases from dry-process kilns ranged from 1 to 25 percent expressed in terms of the finished cement, or from 4 to 94 pounds per barrel. The arithmetic average for dust loading in the kiln exit gases is 11.3 percent of the equivalent finished cement based on available data for nine dry-process kilns. Note that several kilns are considerably below and above this figure. The average weight of dust collected from the kiln exit gases per barrel of clinker has been reported by Kannewarf and Clausen[16] to be 48.1 pounds. This value would be equivalent to 46 pounds of dust per barrel of finished cement if 5 percent of the finished cement was gypsum.

Wet Process

Emission and operating data for the wet rotary process kilns are shown in Table 5. The concentrations of dust leaving the kilns and entering the dust collection systems ranged from 0.995 to 13.51 grains per cubic foot for all of the wet-process kilns. The arithmetic average for all tests was 5.7 grains per cubic foot. Again, no appreciable difference in the range of dust leadings is apparent for kilns of different lengths.

The amount of dust in the exit gases from wet process kilns ranged from 1 to 33 percent of the finished cement. This is equivalent to 4 to 124 pounds per barrel. The arithmetic average for dust loadings in the exit gases from the 13 wet-process kilns is 10.1 percent of the equivalent finished cement. This is slightly lower than the average for dry-process kilns despite the abnormally high values for plant 21. According to Kannewarf and Clausen[16] the average weight of dust collected per barrel of clinker is 39.8 pounds. This is equivalent to about 38 pounds of dust per barrel of finished cement.

Table 4. EMISSION AND OPERATING DATA FOR DRY-PROCESS ROTARY CEMENT KILNS AND DUST COLLECTORS

Test number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Feed preheat method[a]	None	S-P	None	None	None	None	DP	Cross	None	None	None	None	None	None
Kiln length, feet	140	150	323	314	380	150 200	118	400	365	125	400	125	-	-
Number of kilns per test	2	1	1	3	-	2	1	1	1	10	1	1	-	-
Number of tests averaged	5	1	3	3	-	1	3	1	2	1	3	2	-	-
Total production rate, bbl/day	-	4,000	1,880	5,260	9,580	4,800	2,150	3,800	1,668	6,100	3,300	504	2,900	2,750
Stack gas volume, 1,000 cfm	33.9	48.7	40.4	202.0	300.0	196.6	-	233.7	104.9	421.0	129.0	40.3	122	125
Stack gas temperature, °F	353	375	500	500	510	150	200	467	497	565	550	845	600	560
Method of dust collection,[b] primary	WHB	MC	MC	MC	Mech	MC	None	MC	EP	EP	MC	None	MC	MC
secondary	MC	EP			Bag	EP		EP			EP		EP	EP
Inlet dust loading, grains/ft^3 (stack conditions)	6.91	7.01	8.61	5.51	9.69	12.43	-	-	1.116	1.6	8.5	2.41	-	-
Outlet dust loading, grains/ft^3 (stack conditions)	1.25	0.23	0.84	1.66	0.02	0.47	-	0.041	0.084	0.022	0.684	2.41	0.013	0.136
Outlet dust loading, grains/ft^3 (60°F)	1.95	0.37	1.55	3.06	0.039	0.55	-	0.073	0.154	0.043	1.3	6.05	0.0265	0.267
Outlet dust quantity, lbs/day	8,730	2,280	9,390	67,900	1,264	19,000	2,830	1,970	1,790	1,910	18,216	20,280	326	3,500
Dust collector catch, lbs/day primary	14,200	68,000	62,200	161,000	430,000	300,000	-	-	24,083	13,450	63,600	-	-	-
secondary	25,300				167,000	183,000	-	-			144,000	-	-	-
Dust collector efficiency, percent primary	30	-	-	-	71	60	-	-	-	-	77.7	-	-	-
secondary	74.5	-	86.9	70.2	99.3	90.6	-	-	-	-	63.5	-	-	-
overall	81.9	96.8	86.9	70.2	99.8	96.2	-	-	93.0	98.6	91.9	-	-	-
Dust loss before collection, percent clinker	-	4.9	10.7	12.2	17.5	29.3	-	-	4.35	0.705	27.6	11.3	-	-
Dust emission, percent product	-	0.151	1.31	3.43	0.0351	1.04	0.35	0.138	0.286	0.083	1.47	10.7	0.03	0.34
Reference	17	17	17	17	18	12	19	28	28	28	28	28	28	28

[a] S-P = Suspension-preheater; DP = Double pass.

[b] WHB = Waste heat boiler; MC = Multicyclones; EP = Electrostatic precipitator; Mech. = Mechanical collector; Bag = Glass fabric baghouse.

Table 5. EMISSION AND OPERATING DATA FOR WET-PROCESS ROTARY CEMENT KILNS AND DUST COLLECTORS

Test number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Feed preheat method[a]	None	-	CB, C	-	-	-	-	-	-	None	None	C	C	C	C, CB	-	-	-	-	-	-	-
Kiln length, feet	160	350	460	-	-	-	-	310	-	2@380 2@220	-	-	-	-	475	425	300-425	300-425	425	425	175	600
Number of kilns per test	3	4	1	1	1	4	1	1	1	4	4	-	-	-	1	2	3	3	2	1	3	1
Number of tests averaged	2	1	1	2	2	2	2	4	3	8	-	-	-	-	3	4	2	4	4	4	1	1
Total production rate, bbl/day	3,980	5,000	4,500	-	-	-	-	2,200	-	7,500	5,600	2,500	1,900	3,475	3,900	7,067	6,250	7,600	6,861	3,600	2,825	8,269
Stack gas volume, 1,000 cfm	155.0	186.0	146.0	72.2	97.5	72.4	155.9	98.6	155.5	445.0	277.0	141.5	95.0	166.5	84.4	229.9	207.5	448.3	369.8	152.8	209.0	279.0
Stack gas temperature, °F	363	290	320	293	390	450	450	550	550	350	355	385	450	330	285	343	525	460	450	547	352	390
Percent moisture in stack gas (volume percent)	-	-	36.8	37	29	20	32.5	25-30	25-35	-	-	-	-	-	-	40.3	36.7	30.2	23.7	35.0	22.9	35.6
Method of dust collection[b] primary	EP	-	Bag	MC	EP	EP	EP	EP	EP	EP	EP	MC	EP	EP	EP	EP	EP	EP	EP	EP	EP	EP
secondary		EP#1&2		EP								EP										
Inlet dust loading, grains/ft³ (stack conditions)	6.50	1.97	11.75	8.47	3.21	3.77	4.99	3.63	11.44	3.14, 3.31; 7.21, 8.28	-	-	-	-	4.6	0.995	5.28	1.49	3.86	13.51	1.80	4.03
Outlet dust loading, grains/ft³ (stack conditions)	0.22	0.15	0.0098	0.0220	0.0520	0.0194	0.0434	0.0648	0.104	0.469	0.091	0.390	0.250	0.069	0.022	0.058	0.030	0.0695	0.034	0.108	0.070	0.028
Outlet dust loading, grains/ft³ (60°F)	0.35	0.22	0.0148	0.0360	0.0850	0.0339	0.0760	0.126	0.211	0.730	0.1425	0.634	0.485	0.105	0.032	0.089	0.057	0.123	0.053	0.208	0.110	0.046
Outlet dust quantity, lbs/day	6,940	5,720	296	327	1,042	289	1,391	1,314	3,383	14,000	5,260	11,400	4,930	2,350	384	2,725	1,296	6,425	2,332	3,395	3,024	1,622
Dust collector catch, lbs/day primary	200,000	69,500	307,000	75,400	70,000	55,800	161,000	72,300	357,000	-	-	-	-	-	-	44,260	224,000	130,570	291,350	421,630	74,280	229,680
secondary				49,900	45,400					-	-	-	-	-								
Dust collector efficiency, percent primary	-	-	-	60	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
secondary	96.5	96-90	99.9	99.35	97.7	99.49	99.13	98.21	98.21	-	-	-	-	-	-	-	-	-	-	-	-	-
overall	96.5	92.4	99.9	99.74	99.1	99.49	99.13	98.21	99.05	97.73	-	-	-	-	99.51	94.2	99.4	95.4	99.2	99.17	96.1	99.3
Dust loss before collection, percent clinker	14.6	4.2	19.1	-	-	-	-	9.4	-	-	-	-	-	-	5.8	1.88	10.0	5.0	11.9	33.0	7.6	7.7
Dust emission, percent product	0.463	0.304	0.0175	-	-	-	-	0.159	-	0.497	0.25	1.21	0.69	0.18	0.0261	0.1025	0.551	0.225	0.09	0.250	0.285	0.052
Reference	17	21	22	23	23	23	23	23	23	28	28	28	28	28	28	28	28	28	28	28	28	28

[a] C = Chain; CB = Cross-baffle.

[b] MC = Multicyclones; EP = Electrostatic precipitators; Bag = Glass fabric baghouse.

EVALUATION OF DUST CONTROL EQUIPMENT AS IT AFFECTS KILN EFFLUENT

The data in Tables 4 and 5 show that dust collection equipment is necessary on all cement kilns in the United States. The method and degree of control vary with the type of plant and its location. Ranges of dust emissions from control systems serving wet- and dry-type cement kilns are shown in Table 6.

Table 6. RANGES OF DUST EMISSIONS FROM CONTROL SYSTEMS SERVING DRY- AND WET-TYPE CEMENT KILNS

Source	Type of dust collector	Range of dust emissions from collector	
		grain /scf[c]	lb/ton of cement
Kiln-dry type[a]	Multicyclones	1.55 - 3.06	26.2 - 68.6
	Electrical precipitators	0.04 - 0.15	1.7 - 5.7
	Multicyclone and electrical precipitators	0.03 - 1.3	0.6 - 29.4
	Multicyclone and cloth filter	0.039	0.7
Kiln-wet type[b]	Electrical precipitators	0.03 - 0.73	0.52 - 9.9
	Multicyclone and electrical precipitators	0.04 - 0.06	4.3 - 24.2
	Cloth filter	0.015	0.35

[a]Based on data from Table 4.

[b]Based on data from Table 5.

[c]Grains/scf Grains per standard cubic foot of gas corrected to 60°F and 1 atmosphere pressure.

It is recommended that the particulate matter be collected by a high-efficiency collector because of the small particle size of the emitted dust (see Table 7). As much as 55 percent of the kiln dust particles may be smaller than 10 microns.

Table 7. EXAMPLE OF SIZE DISTRIBUTION OF DUST EMITTED FROM KILN (Reference 24)

Particle size, micron	Kiln dust finer than respective particle size, %
60	97 to 100
50	95 to 100
40	85 to 95
30	70 to 90
20	50 to 70
10	30 to 55
5	20 to 40
2.5	10 to 35

Although a number of types of dust collectors are used in the cement industry, only the high-efficiency collectors such as the electrostatic precipitator and fabric filter, sometimes used in series with inertial collectors, effectively collect fine dust. The 60 to 87 percent efficiency of the multicyclone collector results in a minimum grain loading of 1.55 grains per standard foot (Table 4). Consequently, the multicyclone alone is not an acceptable means of reducing dust emission from the kiln to the atmosphere.

Electrostatic precipitators or glass-fabric filters, sometimes preceded by mechanical collectors, are necessary to reduce emissions to a satisfactory level. Results (Tables 4 and 5) of tests made on inlet and exit ducts of older electrostatic precipitation units indicate that even though precipitator efficiencies of 96 to 97 percent are obtainable on large volumes of kiln gas the exit grain loading may still range from 0.2 to 0.3 grains per standard cubic foot. Although these emission rates may be acceptable in nonurban areas, they would probably result in dust nuisance problems if located in or near urban areas. New, well designed and maintained precipitators can remove 99 plus percent of the dust loading (Test 15, Table 5), and reduce grain loading to 0.05 grains per standard cubic foot. At least two manufacturers guarantee at least 99.5 percent collection efficiency.[20,25]

Glass-fabric filters can reduce dust loading 99.5 plus percent, or below 0.02 grains per standard cubic foot. Figures 5 and 6 show a fabric filter installation. These collectors can reduce the plume to less than 10 percent equivalent opacity when properly maintained. One test (Test 3, Table 5) with a kiln that utilized a glass-fabric baghouse shows grain loadings as low as 0.01 grains per cubic foot.

Although some plants have experienced problems from moisture condensation in glass-fabric filters, other plants have been successful in precluding this condition. Dewpoint temperatures in glass-fabric collectors are normally avoided by proper application of insulating material on drop-out hoppers, ducting, fan casings, and compartment separators. When it is necessary to shut a kiln down for repairs, the forced draft fan and baghouse should be kept operating to keep air moving through the fabric filters and thus avoid condensation.[26]

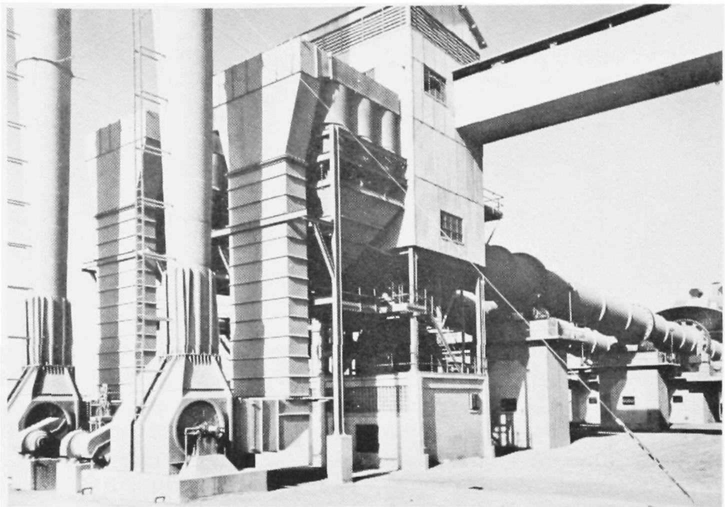

Figure 5. Feed end of rotary kilns showing multicyclone dust collectors, draft fans, and stacks.

The data in Tables 4 and 5 indicate that high-efficiency electrostatic precipitators, glass-fabric baghouses, or mechanical collectors followed by precipitators or baghouses can lower dust grain loadings to below 0.05 grains per standard cubic foot. Data illustrating the dust grain loadings and dust collection efficiencies needed to meet particulate emission limitations based on process weight are presented in Table 8.

TABLE 8. ESTIMATED DUST GRAIN LOADINGS AND COLLECTION EFFICIENCIES NEEDED TO MEET SELECTED EMISSION REGULATIONS

Capacity of kiln, bbl/day	Type of fuel	Process weight, raw material plus solid fuel, lb/hr	Allowable dust emission rate, lb/hr		Approximate dust grain loading to meet ordinance, grains/scf		Approximate dust collection efficiency needed to meet ordinance, %	
			L[a]	B[b]	L[a]	B[b]	L[a]	B[b]
2,000	coal	57,600	38.6	38.6	0.08	0.08	98.3	98.3
2,000	oil or gas	50,000	34.3	35.4	0.08	0.08	98.5	98.4
4,000	coal	115,000	40.0	45.8	0.05	0.06	99.6	99.6
4,000	oil or gas	100,000	40.0	44.6	0.05	0.05	99.6	99.6
6,000	coal	173,000	40.0	44.9	0.03	0.04	99.7	99.6
6,000	oil or gas	150,000	40.0	48.5	0.03	0.04	99.7	99.6
8,000	coal	230,000	40.0	52.6	0.02	0.03	99.8	99.7
8,000	oil or gas	200,000	40.0	51.2	0.02	0.03	99.8	99.7

[a] Los Angeles Air Pollution Control District.

[b] Bay Area Air Pollution Control District (San Francisco).

[c] Grains per standard cubic foot at 60° F and 1 atmosphere pressure.

These data are based on averaged emission and gas-flow information from Tables 4 and 5, applied to particulate emission limitations for Los Angeles and the Bay Area (San Francisco) Air Pollution Control Districts.

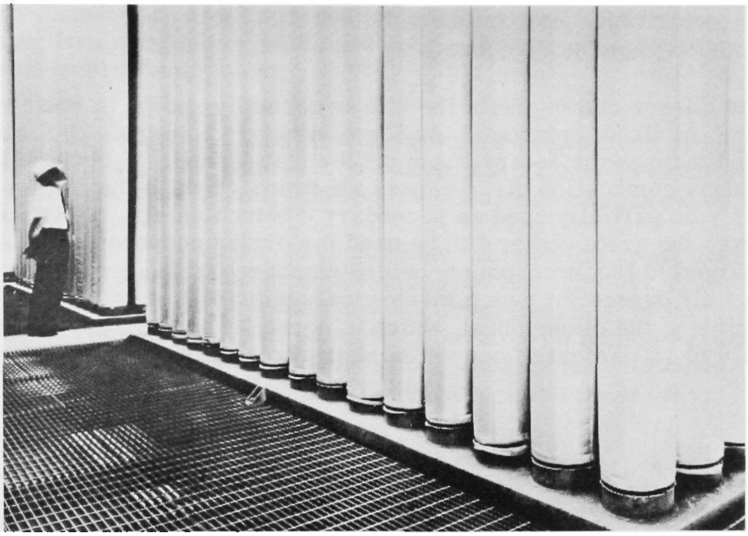

Figure 6. Inside of baghouse dust collector showing siliconized glass-fiber bags in position.

Approximate dust-grain loadings needed to meet these California ordinances vary from 0.08 grain per standard cubic foot for small kilns (i. e., 2,000 barrels per day capacity) to 0.02 grain per standard cubic foot for large units (i. e., 8,000 barrels per day capacity). The approximate corresponding dust collection efficiencies range from 98.3 percent for small kilns to 99.8 for large units. Kilns of up to 4,000 barrels per day capacity could meet the process weight limitations for Los Angeles and for the Bay Area with exit dust loadings of 0.05 grains per standard cubic foot. A dust collection efficiency of approximately 99.6 percent would be required, however. For large kilns (8,000 barrels per day) lower exit dust loadings of 0.02 to 0.03 grain per standard cubic foot would be required to meet the emission regulations of Los Angeles and of the Bay Area, respectively.

GRATE PREHEATER PROCESS

Although the grate preheater is used presently by only two plants in the United States, it is briefly discussed here because of its low emission rates. The advantages of the grate preheater system are twofold: first, the fuel requirement is approximately 30 to 40 percent less than that for the other long-dry-process kilns; and second, expressed in terms of finished cement, the kiln dust losses are equivalent to only 0.05 to 1.0 percent.[27] Test 7 in Table 4 shows data on the grate preheater process that utilized no dust collection equipment. For the three tests, the dust emissions averaged only 0.35 percent of the cement clinker. Application of the grate preheater process is often limited to raw materials with low alkali values.

CLINKER-COOLER EMISSIONS

The clinker coming from the kiln is normally cooled in rotary-drum, shaking, inclined, horizontal, or traveling grate coolers. Cooling air induced through the rotary-drum cooler may be utilized in the kiln as secondary combustion air, whereas air drawn through the grate cooler can only be partially used as secondary combustion air. The excess air from the grate cooler can be used for drying purposes, or it can be discharged to the atmosphere; before discharge to the atmosphere, the excess air passes through a mechanical collector that is very effective in removing the clinker dust, which is normally of large particle size. Only 10 to 15 percent of cement clinker-cooler dust is below 10 microns in size.

FINISHING AND SHIPPING

Clinkers are ground in the same type of mills in which raw materials are ground. The discharge from these mills is elevated to an air separator in closed-circuit grinding. The cement with the proper fineness is sent to storage, and the oversize is sent back to the mill for regrinding. The circuit may be cooled by air passing through the mill and separator and into a fabric-filter dust collector.

Cement-material handling (such as pneumatic conveying of finished material, bagging, and bulk loading) is a potential source of dust emissions. The high salvage value of the escaping material makes dust collection an economic necessity. Almost all dust control equipment is of the fabric-filter type. Normally material transfer points are hooded, which prevents escape of most of the dust.

Although most plants adequately control emissions from their finishing and shipping operations by the methods mentioned, some plants still emit dust. These emissions may create extreme nuisances, not only at cement plants but also at cement distribution centers.

TRENDS

The manufacture of portland cement has changed enormously in the past several decades. The cement industry of the past produced 0.45 ton of clinker per ton of raw material at a fuel-use rate of 1.5 million Btu's per barrel of cement. Today the same capacity plant produces 0.60 to 0.65 ton of clinker per ton of raw material at a fuel-use rate of less than 1 million Btu's per barrel.[29]

Although emissions from many plants have been partially or wholly controlled, a few older plants still discharge as much as 3 percent of their kiln product into the atmosphere. These older plants are gradually being replaced with new, modern plants that utilize larger units; the resulting fewer emission points are equipped with high-efficiency dust-emission-control equipment.

Cloth filter bags adequately clean the gases drawn from crushers, grinders, dryers, and material transfer points. Glass-fiber filter bags or electrostatic precipitators adequately clean the hot kiln gases.

Cement plants are expected to continue this modern trend toward more efficient production through centralized and effective dust control. Although the economic benefits resulting from the reuse of collected dust do not completely offset the cost of the dust-collection equipment, the esthetic value to the community plus a compliance with certain municipal and state air pollution control ordinances make these advances in dust arrestment worthwhile.

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GPO 803—789—5

APPENDIX

PORTLAND CEMENT ESTABLISHMENTS IN THE UNITED STATES

The main purpose of this tabulation of portland cement manufactures is to indicate the wide distribution and the principal areas of concentration of this industry throughout the country. Information was drawn from various sources, particularly Pit and Quarry magazine and in some cases cement companies, and is believed to represent the installations operating as of September 1, 1966. As a result of sale, merger, or lease, company identifications may in some cases differ from those presently in use, but this tabulation should serve the intended purpose of general identification.

PLANTS PRODUCING PORTLAND
CEMENT IN THE UNITED STATES

Capacities Stated in Barrels Per Year (1966).

ALABAMA

Birmingham

Alpha Portland Cement Co.
Wet process; 1,800,000 bbl.

Lehigh Portland Cement Co.
Wet process; 1,840,000 bbl.

Lone Star Cement Corp.
Wet process; 1,900,000 bbl.

Southern Cement Co.
Div. American-Marietta Corp.
Finish grinding plant - no kiln operation

Demopolis

Lone Star Cement Corp.
Dry process; 1,500,000 bbl.

Leeds

Universal Atlas Cement Div.
U. S. Steel Corp.
Wet process; 2,000,000 bbl.

Mobile

Ideal Cement Co.
Wet process; 2,800,000 bbl.

Ragland

National Cement Co.
Dry process; 1,500,000 bbl.

Roberta

Southern Cement Co.
Division American-Marietta Corp.
Dry process; 2,600,000 bbl.

ARIZONA

Clarkdale

Phoenix Cement Co.
Div. of American Cement Corp.
Dry process; 2,600,000 bbl.

Rillito

Arizona Portland Cement Co.
Dry process; 2,700,000 bbl.

ARKANSAS

Foreman

Arkansas Cement Corp.
Wet process; 2,800,000 bbl.
(5,000,000 bbl. in 1966)

Okay

Ideal Cement Co.
Wet process; 1,850,000 bbl.

CALIFORNIA

Colton

California Portland Cement Co.
Dry process; 4,500,000 bbl.

Davenport

Pacific Cement and Aggregates, Inc.
Dry process; 2,800,000 bbl.

Lebec

Pacific Western Industries
Dry process; 3,000,000 bbl.
(To be completed in 1966)

Lucerne Valley

Permanente Cement Co.
Cushenbury Plant
Wet process; 5,400,000 bbl.

Mojave

California Portland Cement Co.
Dry process; 6,000,000 bbl.

Monolith

Monolith Portland Cement Co.
Wet process; 4,000,000 bbl.

Oro Grande

Riverside Cement Corp.
Div. American Cement Corp.
Dry process; 6,500,000 bbl.

Permanente

Permanente Cement Co.
Wet process; 8,500,000 bbl.

Redding

Calaveras Cement Co.
Dry process; 1,500,000 bbl.

Redwood City

Ideal Cement Co.
Wet process; 2,550,000 bbl.

Riverside

Riverside Cement Co.
Div. American Cement Corp.
Dry process; 4,750,000 bbl.
(gray)

Riverside Cement Co.
Div. American Cement Corp.
Dry process; 650,000 bbl.
(white)

San Andreas

Calaveras Cement Co.
Wet process; 4,500,000 bbl.

San Juan Bautista

Ideal Cement Co.
Wet process; 950,000 bbl.

Victorville

Southwestern Portland Cement Co.
Wet process; 6,000,000 bbl.

COLORADO

Florence

Ideal Cement Co.
Wet and dry process;
2,150,000 bbl.

Fort Collins

Ideal Cement Co.
Dry process; 2,800,000 bbl.

FLORIDA

Bunnell

Lehigh Portland Cement Co.
Wet process; 3,350,000 bbl.

Miami

General Portland Cement Co.
Florida Division
Wet process; 2,500,000 bbl.

Lehigh Portland Cement Co.
Wet process; 2,500,000 bbl.

Tampa

General Portland Cement Co.
Florida Division
Wet process; 7,000,000 bbl.

GEORGIA

Atlanta

Southern Cement Corp.
Div. American-Marietta Co.
Dry process; 1,200,000 bbl.

Clinchfield

Penn-Dixie Cement Corp.
Wet process; 2,372,000 bbl.

Rockmart

Marquette Cement Mfg. Co.
Dry process; 1,250,000 bbl.

HAWAII

Waianau, Honolulu

Permanente Cement Co.
Wet process; 1,700,000 bbl.

Waipahu, Oahu

Hawaiian Cement Corp.
Dry process; 1,000,000 bbl.

IDAHO

Inkom

Idaho Portland Cement Co.
Wet process; 800,000 bbl.

ILLINOIS

Clarksville

Dundee Cement Co.
Wet process; 7,000,000 bbl.
(To be completed in 1966)

Dixon

Medusa Portland Cement Co.
Dry process; 3,500,000 bbl.

La Salle

Alpha Portland Cement Co.
Dry process; 1,500,000 bbl.

Oglesby

Marquette Cement Mfg. Co.
Dry process; 4,250,000 bbl.

Joppa

Missouri Portland Cement Co.
Dry process; 3,000,000 bbl.

INDIANA

Buffington

Universal Atlas Cement Div.
U. S. Steel Corp.
Dry process; 9,700,000 bbl.

Greencastle

Lone Star Cement Corp.
Wet process; 2,700,000 bbl.

Logansport

Louisville Cement Co.
Wet process; 1,200,000 bbl.
(2,400,000 bbl. in 1966)

Mitchell

Lehigh Portland Cement Co.
Dry process; 2,500,000 bbl.

Speed

Louisville Cement Co.
Dry process; 5,250,000 bbl.

IOWA

Davenport (Linwood)

Dewey Portland Cement Co.
Div. American-Marietta Corp.
Wet process; 3,200,000 bbl.

Des Moines

Marquette Cement Mfg. Co.
Wet process; 4,500,000 bbl.

Mason City

Lehigh Portland Cement Co.
Dry process; 3,340,000 bbl.

Northwestern States Portland
Cement Co.
Dry process; 4,000,000 bbl.

West Des Moines

Penn-Dixie Cement Corp.
Wet process; 2,340,000 bbl.

KANSAS

Bonner Springs

Lone Star Cement Corp.
Wet process; 2,400,000 bbl.

Chanute

Ash Grove Lime and Portland
Cement Co.
Wet process; 2,800,000 bbl.

Fredonia

General Portland Cement Co.
Victor Division
Wet process; 2,300,000 bbl.

Humbolt

Monarch Cement Co.
Dry process; 2,400,000 bbl.

Independence

Universal Atlas Cement Division
U. S. Steel Corp.
Dry process; 2,200,000 bbl.

Iola

Lehigh Portland Cement Co.
Wet process; 1,340,000 bbl.

KENTUCKY

Kosmosdale

Kosmos Portland Cement Co., Inc.
Dry process; 4,000,000 bbl.

LOUISIANA

Baton Rouge

Ideal Cement Co.
Wet process; 3,000,000 bbl.

Lake Charles

Lone Star Cement Corp.
Wet process; 2,000,000 bbl.

New Orleans

Lone Star Cement Corp.
Wet process; 1,500,000 bbl.

MAINE

Thomaston

Dragon Cement Co.
Div. American-Marietta Corp.
Wet process; 2,000,000 bbl.

MARYLAND

Lime Kiln

Alpha Portland Cement Co.
Wet process; 2,250,000 bbl.

Security

Marquette Cement Manufacturing Co.
Dry process; 2,200,000 bbl.

Union Bridge

Lehigh Portland Cement Co.
Dry process; 3,500,000 bbl.

MICHIGAN

Alpena

Huron Portland Cement Co.
Sub. National Gypsum Co.
Dry process; 13,800,000 bbl.

Bay City

Aetna Portland Cement Co.
Div. American Marietta Corp.
Wet process; 8,800,000 bbl.

Cement City

General Portland Cement Co.
Peninsular Div.
Wet process; 1,200,000 bbl.

GPO 803—789—4

Detroit

Peerless Cement Co.
Div. American Cement Corp.
Wet process; 3,700,000 bbl.

Peerless Cement Co.
Div. American Cement Corp.
Wet process; 1,800,000 bbl.

Dundee

Dundee Cement Co.
Wet process; 6,000,000 bbl.

Petoskey

Penn-Dixie Cement Co.
Wet process; 3,000,000 bbl.

Port Huron

Peerless Cement Co.
Div. American Cement Corp.
Wet process; 1,000,000 bbl.

Wyandotte

Wyandotte Chemicals Corp.
Wet process; 2,000,000 bbl.

MINNESOTA

Duluth

Universal Atlas Cement Div.
U. S. Steel Corp.
Dry process; 2,000,000 bbl.

MISSISSIPPI

Brandon

Marquette Cement Manufacturing Co.
Wet process; 1,300,000 bbl.

Redwood

Mississippi Valley Portland Cement Co.
Wet process; 2,000,000 bbl.

MISSOURI

Cape Girardeau

Marquette Cement Mfg. Co.
Wet process; 1,200,000 bbl.

Marquette Cement Mfg. Co.
Dry process; 1,800,000 bbl.

Festus

River Cement Co.
Div. Missouri River and Fuel
Dry process; 3,000,000 bbl.

Hannibal

Universal Atlas Cement Div.
Wet process; 2,200,000 bbl.
(4,000,000 bbl. in 1966)

Lemay

Alpha Portland Cement Co.
Wet process; 2,600,000 bbl.

St. Louis

Missouri Portland Cement Co.
Wet process; 5,000,000 bbl.

Sugar Creek

Missouri Portland Cement Co.
Dry process; 3,000,000 bbl.

MONTANA

Helena

Permenente Cement Co.
Wet process; 1,400,000 bbl.

Trident

Ideal Cement Co.
Dry process; 1,500,000 bbl.

NEBRASKA

Louisville

Ash Grove Lime and Portland Cement Co.
Wet process; 3,500,000 bbl.

Superior

Ideal Cement Co.
Wet process; 1,300,000 bbl.

NEVADA

New Fanley

Nevada Cement Co.
Dry process; 3,000,000 bbl.

NEW MEXICO

Tijeras

Ideal Cement Co.
dry process; 2,700,000 bbl.

NEW YORK

Alsen

Lehigh Portland Cement Co.
Dry process; 2,650,000 bbl.

Buffalo

Lehigh Portland Cement Co.
Wet process; 2,340,000 bbl.

Catskill

Alpha Cement Co.
Wet process; 3,000,000 bbl.

Marquette Cement Mfg. Co.
Wet process; 2,500,000 bbl.
(3,300,000 bbl. in 1966)

Cementon

Alpha Portland Cement Co.
Dry process; 1,700,000 bbl.

Glens Falls

Glens Falls Portland Cement Co.
Wet process; 1,850,000 bbl.

Howes Cave

Penn-Dixie Cement Corp.
Dry process; 1,650,000 bbl.

Hudson

Lone Star Cement Corp.
Wet process; 3,000,000 bbl.

Universal Atlas Cement Div.
U. S. Steel Corp.
Dry process; 4,300,000 bbl.

Jamesville

Alpha Portland Cement Co.
Wet process; 900,000 bbl.

Kingston

Hudson Cement Corp.
Wet process; 4,000,000 bbl.

Ravena

Atlantic Cement Co., Inc.
Wet process; 10,000,000 bbl.

NORTH CAROLINA

Castle Hayne

Ideal Cement Co.
Wet process; 3,500,000 bbl.

OHIO

Barberton

Pittsburgh Plate Glass Co.
Chemical Division
Wet process; 1,500,000 bbl.

Fairborn

Southwestern Portland Cement Co.
Wet process; 3,300,000 bbl.

Universal Atlas Cement Div.
U. S. Steel Corp.
Wet process; 2,500,000 bbl.

Ironton

Alpha Portland Cement Co.
Dry process; 1,200,000 bbl.

Middle Branch

Diamond Portland Cement Co.
Div. Flintkote Company
Dry process; 3,000,000 bbl.

Paulding

General Portland Cement Co.
Wet process; 2,500,000 bbl.

Silica

Medusa Portland Cement Co.
Dry process; 1,450,000 bbl.

Superior

Marquette Cement Manufacturing Co.
Dry process; 1,250,000 bbl.

Zanesville

Columbia Cement Mfg. Co.
Sub. Pittsburgh Plate Glass Co.
Wet process; 3,000,000 bbl.

OKLAHOMA

Ada

Ideal Cement Co.
Wet process; 4,150,000 bbl.

Pryor

Oklahoma Cement Co.
Dry process; 2,000,000 bbl.

Tulsa

Dewey Portland Cement Co.
Div. American-Marietta Corp.
Dry process; 2,800,000 bbl.

OREGON

Gold Hill

Ideal Cement Co.
Wet process; 700,000 bbl.

Lime

Oregon Portland Cement Co.
Wet process; 1,200,000 bbl.

Lake Oswego

Oregon Portland Cement Co.
Wet process; 2,000,000 bbl.

PENNSYLVANIA

Bath

Keystone Portland Cement Co.
Wet process; 3,300,000 bbl.

Bessemer

Bessemer Limestone and Cement Co.
Wet process; 3,000,000 bbl.

Bethlehem

National Portland Cement Co.
Wet process; 2,000,000 bbl.

Cementon

Whitehall Cement Mfg. Co.
Dry process; 3,000,000 bbl.

Coplay

Coplay Cement Manufacturing Co.
Dry process; 2,250,000 bbl.

Egypt

Giant Portland Cement Co.
Dry process; 1,850,000 bbl.

Evansville

Allentown Portland Cement Co.
Dry process; 2,572,000 bbl.
(5,000,000 bbl. in 1966)

Fogelsville

Lehigh Portland Cement Co.
Dry process; 2,210,000 bbl.

Nazareth

Lone Star Cement Corp.
Dry process; 3,600,000 bbl.

Nazareth Cement Co.
Dry process; 2,400,000 bbl.

Penn-Dixie Cement Corp.
Dry process; 1,836,000 bbl.

Neville Island

Marquette Cement Mfg. Co.
Wet process; 1,750,000 bbl.

Northampton

Dragon Cement Co.
Div. American-Marietta Corp.
Dry process; 2,000,000 bbl.

Universal Atlas Cement Div.
U. S. Steel Corp.
Wet process; 2,900,000 bbl.

Stockertown

Hercules Cement Co.
Div. American Cement Corp.
Dry process; 3,500,000 bbl.

Universal

Universal Atlas Cement Div.
U. S. Steel Corp.
Dry process; 2,600,000 bbl.

Wampum

Medusa Portland Cement Co.
Dry process; 2,500,000 bbl.

West Conshohocken

Allentown Portland Cement Co.
Wet process; 2,100,000 bbl.

West Winfield

Penn-Dixie Cement Corp.
Wet process; 1,908,000 bbl.

SOUTH CAROLINA

Harleyville

Giant Portland Cement Co.
Carolina Giant Division
Wet process; 4,000,000 bbl.

Holly Hill

Santee Portland Cement Corp.
Wet process; 2,000,000 bbl.
(To be completed in 1966)

SOUTH DAKOTA

Rapid City

South Dakota Cement Plant
Wet process; 3,300,000 bbl.

TENNESSEE

Cowan

Marquette Cement Mfg. Co.
Wet process; 1,020,000 bbl.

Kingsport

Penn-Dixie Cement Corp.
Wet process; 1,620,000 bbl.

Knoxville

Volenteer Portland Cement Co.
Div. of Ideal Cement Co.
Wet process; 2,800,000 bbl.

Nashville

Marquette Cement Mfg. Co.
Wet process; 1,200,000 bbl.

North Chattanooga

General Portland Cement Co.
Signal Mountain Div.
Wet process; 1,750,000 bbl.

Richard City

Penn-Dixie Cement Corp.
Wet process; 1,584,000 bbl.

TEXAS

Amarillo

Southwestern Portland Cement Co.
Wet process; 1,200,000 bbl.

Cementville

San Antonio Portland Cement Co.
Wet process; 2,500,000 bbl.

Corpus Christi

Halliburton Portland Cement Co.
Wet process; 1,400,000 bbl.

Eagle Ford (P. O. Dallas)

General Portland Cement Co.
Wet process; 3,650,000 bbl.

Dallas

Lone Star Cement Corp
Wet process; 4,000,000 bbl.

El Paso

Southwestern Portland Cement Co.
Dry process; 1,800,000 bbl.

Forth Worth

General Portland Cement Co.
Trinity Division
Wet process; 4,000,000 bbl.

Gelena Park

Ideal Cement Co.
Wet process; 4,075,000 bbl.

Houston

General Portland Cement Co.
Trinity Division
Wet process; 3,650,000 bbl.

Lone Star Cement Corp.
Wet process; 3,300,000 bbl.

Gulf Coast Portland Cement Co.
Wet process; 1,500,000 bbl.

Maryneal

Lone Star Cement Corp.
Dry process; 2,900,000 bbl.

Midlothian

Texas Industries, Inc.
Wet process; 1,400,000 bbl.

Gifford-Hill and Co., Inc.
Wet Process; 1,500,000 bbl.
(To be completed in 1966)

Odessa

Southwestern Portland Cement Co.
Dry process; 1,200,000 bbl.

Orange

Texas Portland Cement Co.
Wet process; 2,000,000 bbl.

San Antonio

Longhorn Portland Cement Co.
Wet process; 2,700,000 bbl.

Capitol Aggregates, Inc.
Wet process; 1,000,000 bbl.

Waco

University Atlas Cement Div.
U. S. Steel Corp.
Dry process; 2,000,000 bbl.

UTAH

Devil's Slide

Ideal Cement Co.
Wet process; 2,000,000 bbl.

Salt Lake City

Portland Cement Co. of Utah
Wet process; 1,000,000 bbl.

VIRGINIA

Fordwick

Lehigh Portland Cement Co.
Dry process; 1,690,000 bbl.

Lone Star

Lone Star Cement Corp.
Dry process; 3,500,000 bbl.

Norfolk

Lone Star Cement Corp.
Wet process; 2,300,000 bbl.

WASHINGTON

Bellingham

Permanente Cement Co.
Olympic Plant
Wet process; 1,900,000 bbl.

Concrete

Lone Star Cement Corp.
Wet process; 1,700,000 bbl.

Grotto

Ideal Cement Co.
Wet process; 675,000 bbl.

Metaline Falls

Lehigh Portland Cement Co.
Dry process; 1,290,000 bbl.

Seattle

Lone Star Cement Corp.
Wet process; 1,300,000 bbl.

Spokane

Ideal Cement Co.
Dry process; 700,000 bbl.

GPO 803-789-3

WEST VIRGINIA

Martinsburg

Capital Cement Co.
Div. American-Marietta Corp.
Wet process; 4,200,000 bbl.

WISCONSIN

Manitowac

Manitowac Portland Cement Co.
Sub. Medusa Portland Cement Co.
Wet process; 2,000,000 bbl.

Milwaukee

Marquette Cement Mfg. Co.
Dry process; 1,250,000 bbl.

WYOMING

Laramie

Monolith Portland Midwest Co.
Wet process; 1,100,000 bbl.

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