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INDUSTRIAL PROCESS PROFILES FOR ENVIRONMENTAL USE: Chapter 17. The Gypsum and Wallboard Industry

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INDUSTRIAL PROCESS PROFILES

FOR ENVIRONMENTAL USE

CHAPTER 17

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GYPSUM AND WALLBOARD INDUSTRY

INDUSTRY DESCRIPTION

The industry comprises operations which mine gypsum deposits and process the mined gypsum rock into crushed or pulverized uncalcined gypsum, pulverized calcined gypsum (various types of wall plasters and specialty plasters), and a diversity of prefabricated gypsum-core board products (wallboard, rock-lath, sheathing, and formboard). The latter end-product category accounts for approximately three-quarters of the total product tonnage and an even greater fraction of total product value.

The relative simplicity of gypsum processing is evident from the single flow diagram of Figure 2 (page 7). All operations except for differences in product mix are similar, employing basically the same processes in fundamentally the same sequence. Mining is by open-pit (quarrying) methods in three-quarters of the operations. Calcining is conducted in either pot-kilns (usual) or in continuous rotary kilns. The balance of the operations chiefly involve size reduction and size separations. Most of the equipment, including that in pre-fabricating plants, is standardized throughout the industry.

The industry includes a total of 108 facilities (1973) in-volving either mining plus mechanically processing crude gypsum rock, or calcining and producing prefabricated products. Of this total, 36 facilities were integrated mining-plus-fabricating operations.

The size of a single installation, gaged by the number of employees, ranges from four persons in a small open-pit mining operation to between 100 and 120 persons in a large facility combining an underground mine and a calcining-fabrication plant. Total employment during 1973 for the entire industry was 3,200 persons. In the same year about 19 million metric tons of gypsum products were produced from 12 million metric tons of domestically mined gypsum plus 7 million metric tons of imported gypsum rock.

Gypsum rock is mined in 22 states and is calcined and fabri-cated in 32. The relatively low unit value of crude gypsum (approximately $4.50 per metric ton) economically limits its rail transportation to relatively short, single-line hauls and accounts for the importation of approximately 37% of the crude rock consumed. Imported rock was used to supply 32 calcining plants located near population centers in 15 states on all three seaboards. In only five situations is

domestic gypsum rock transported by rail freight from the mine to a calcining plant.

The industry has experienced a compounded, annual 4 1/2 percent growth rate during the decade ending with the close of 1973. A compounded, annual 4 percent growth rate is predicted to 1980.

It is believed that none of the operations in the industry generate on-site power and that steam is generated on-site in package steam boilers. Statistical information is entirely lacking.

Raw Materials

Bedded gypsum "rock" deposits form the usual and most desirable type of raw material for the industry and are usually the only type capable of economic exploitation. These may be either near-surface deposits or lie at typical depths of 50 to 400 meters. This type of deposit usually contains between 85 and 95 percent pure gypsum. Some bedded gypsum rock in Michigan contains about 99 percent gypsum.

Near-surface deposits of gypsite (gypsum intermingled with clay) and selenite, containing as little as 70 percent gypsum, are of commercial value.

About three-quarters of the existing gypsum mines are open-pit operations.

Usually, it is not economically possible to beneficiate mined gypsum ore except by screening. Exceptions are the gypsite deposits of Southern California and the gypsum mined in Ottawa County, Ohio, where heavy-media separation is used.

Adverse environmental impact situations arise from the "craters" and mounds of overburden resulting from strip-mining methods and from the dust (non-toxic) created during drying and crushing the mined rock. Quantifying information is unavailable for both types of problems.

The raw materials used in this industry are listed in Appendix A.

Products

The 19 million metric tons of crude gypsum consumed by the industry during 1973 were processed into the end-product categories listed as follows:

Uncalcined products -

Sold crushed for Portland cement retarder	20%
Sold pulverized for agricultural use (land plaster)	7%

Calcined products -

Prefabricated board products	67%
Wall plasters	4%
Plaster of paris, "soluble anhydrite," dead-burned gypsum for specialty cements, paper fillers, paint pigment, and others	2%
Total	100%

Prefabricated wallboard products are steadily replacing wall plasters for interior wall construction.

A more complete list of products appears in Appendix B.

Companies

The 40 companies populating the industry are of two distinct types:

(1) Companies operating calcining-fabricating installations
(2) Companies conducting only mining and grinding operations

The 13 companies comprising the first group, with two exceptions (Kaiser Gypsum Company and California Gypsum Company), also mine a major fraction of their crude gypsum supply. Collectively, they operate 77 calcining-fabricating plants and 41 mines. Of these, 36 are integrated mine-plus-plant facilities. Nine of the companies are multi-industry organizations with operations in at least one other industry producing end-products for use by the construction industries.

The second group includes 29 companies who sell sized, ground, or crushed gypsum rock to the companies of the first group, to the open market for agricultural use, and to the cement industry. With exceptions, notably Universal Atlas Portland Cement Company and Southwestern Portland Cement Company, these companies are all smaller than those of the first type. Their combined operations produce less than one-quarter of the total gypsum mined.

Five companies produced about 85 percent of the total calcined gypsum in 1972:

United States Gypsum Company
National Gypsum Company
Georgia-Pacific Corporation
The Flintkote Company
Kaiser Gypsum Company, Inc.

Slightly more than three-quarters of the crude gypsum produced was mined by five companies in 1972:

United States Gypsum Company
National Gypsum Company
Georgia-Pacific Corporation
The Flintkote Company
The Celotex Company

Appendix C contains a complete list of producing companies.

Environmental Impact

Fugitive emissions of particulate gypsum or calcium sulfate from crushing and grinding equipment, calciners, and dryers are inherent in the industry. No serious problems have resulted when dust control equipment is adequate. No quantifying information is available. Gypsum dust is non-toxic.

In addition to the temporary overburden piles generated in strip mining, mentioned above, calcining plants may have occasional, inadvertent solid wastes of "overburned" material resulting from faulty operation. Disposal of this material, anhydrite, is by landfill methods or by beneficial use in grading low-lying plant areas. The material is entirely nontoxic.

Because process heat is supplied by fuel combustion, sulfur oxides, nitrogen oxides, particulates, and hydrocarbons may be present in combustion gases, depending on the fuel burned and on the combustion efficiency.

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INDUSTRY ANALYSIS

Mining of domestic sources of gypsum dates to 1792; the use of gypsum-derived plasters, to 1835; and commercial production of gypsum wallboard, to the first decades of the present century. The present-day technology relating to all three of these phases is in general use, with minor variations, by all companies operating within this highly competitive industry. Data derived from the sources listed in the Bibliographies of the Process Descriptions are generally valid for all installations.

Availability of quantitative information on emissions has in most cases been inadequate to completely define the physical characteristics and quantities of process wastes, or even the factual existence of an emission. In these cases the possible occurrence of an emission and its probable magnitude have been estimated from what is commonly known about similar or identical types of equipment operating on material having closely related properties.

The chemical tree of Figure 1 attempts to give diagrammatically a qualitative overview of the entire industry from a raw material-product standpoint. A fairly wide diversity of end uses requires a disproportionately small fraction (2 percent) of total product tonnage represented by dead-burned gypsum.

The process flowsheet of Figure 2 shows process blocks representing the two most frequently used, alternative calcining methods in batchwise operated pot kilns and continuous rotary kilns. The infrequently used method of calcining the gypsum in hammermills is not shown.

The single raw material shown on the flow diagram and labeled "gypsum deposit," includes deposits of gypsite and selenite as well as bedded gypsum, the most important and desirable source.

A number has been assigned to each of the process blocks, uniquely identifying the process with an appropriate title and with a process description. Flag symbols at the upper right-hand corner of the process block are used to indicate the nature of the waste streams, if any, discharged from the process - a circle 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.

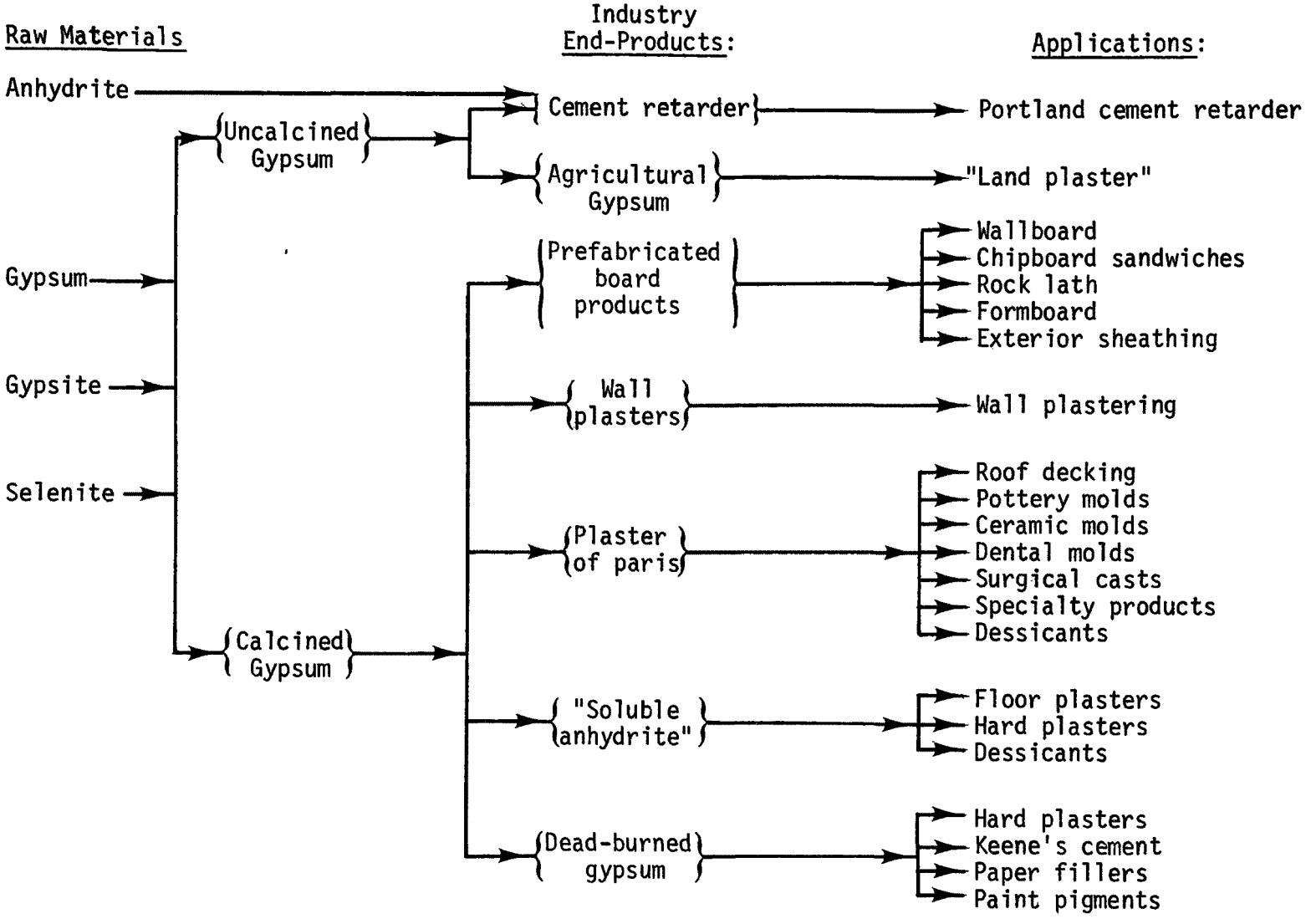

FIGURE 1. GYPSUM AND WALLBOARD PRODUCT TREE

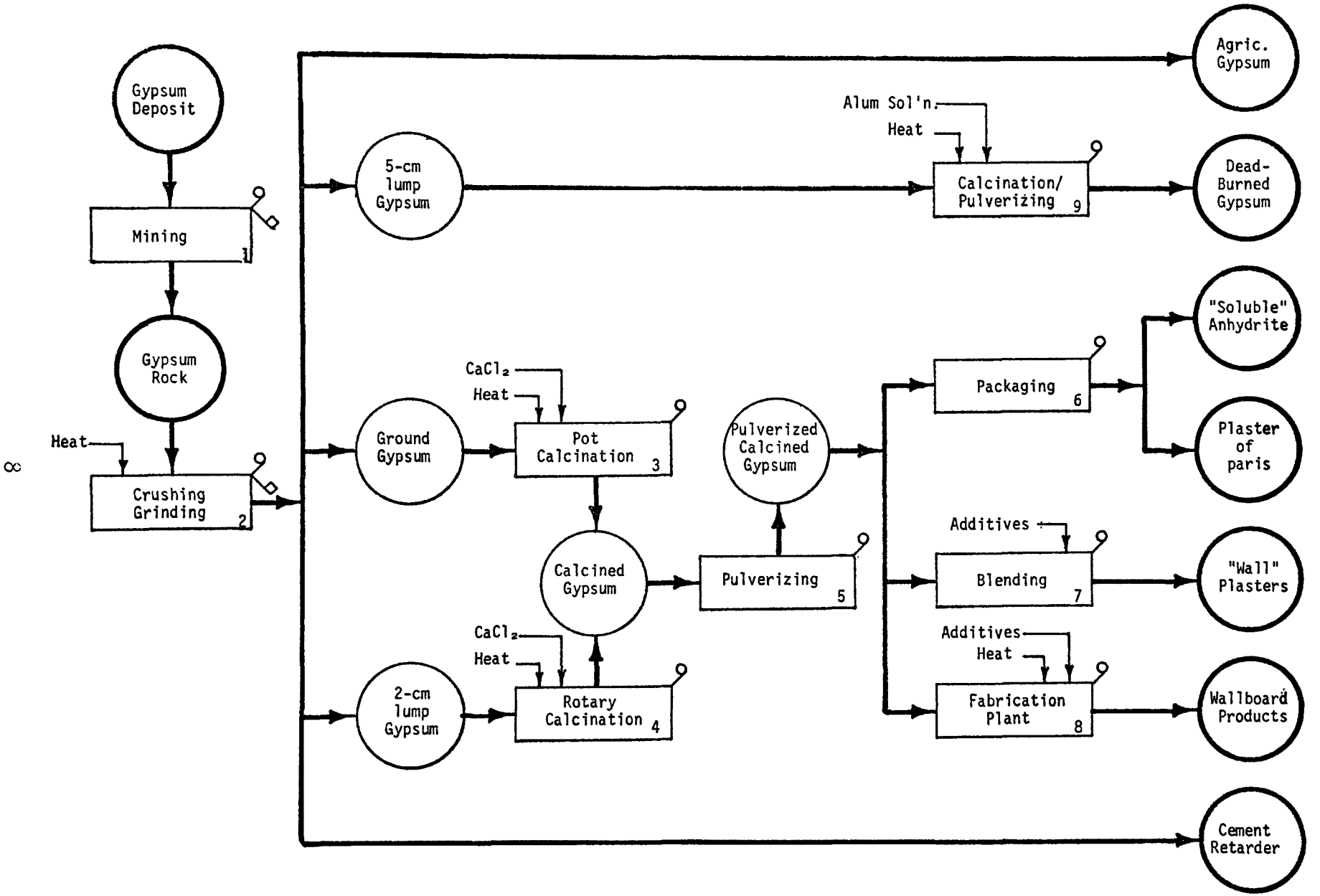

FIGURE 2. GYPSUM PRODUCTS FROM GYPSUM ROCK

MINING

1. Function

The process recovers gypsum rock ($CaSO_4 \cdot 2H_2O$) in a transportable size of up to 15-cm diameter lumps from bedded gypsum deposits. Both open-pit and underground mining methods are used, depending upon the depth and thickness of the deposit and character of the overburden. Open-pit mines predominate.

The process may include the steps of coarse crushing and size separation.

In open-pit operations, scrapers, draglines, front-end loaders, trucks, conveyor belts, and other types of earth-moving equipment are used to strip the overburden, with the addition of blasting equipment to recover the gypsum. With underground operations, equipment types are similar to those used in underground bituminous coal mines. Gyratory crushers are usual for size reduction.

2. Input Materials

Massive gypsum rock of the deposit constitutes the input material. It usually contains particles of sand, clay, shale, or limestone. These inclusions are limited to a low percentage in commercially valuable deposits, since any extensive beneficiation is economically unfeasible.

In a small number of instances, the deposit is gypsite (gypsum or selenite crystals intermingled with clay). These deposits, when of commercial value, are usually worked by open-pit methods.

The estimated quantity of massive rock mined per metric ton of gypsum present in wallboard product is between 1.1 and 1.2 metric tons.

Some "gypsum" deposits are, in fact, anhydrite ($CaSO_4$). In these cases the material may still be crushed to small lumps (approximately 2 cm diameter) in Process 2 and sold to the cement industry for use as Portland cement retarder or may be forwarded to Process 9 eventually to become "Keene's cement"-type end products. In these cases the quantity mined is slightly greater than 1 metric ton per metric ton of respective end product.

3. Operating Parameters

- Approximately three-quarters of active mines are open-pit.
- Seams 1 m thick are considered valuable if horizontal extent is sufficient (~300 hectares) and if depth is reasonable (~50 m with rock overburden, or <5 m for unconsolidated overburden). Most deposits are much thicker (5 to 30 meters).
- Operations employing beneficiation (heavy-media) are rare.
- Fines from primary crushing are usually sold to the Portland cement industry.

4. Utilities

Energy is usually supplied from fuel oil or gasoline for open-pit operations and may be either electrical or oil-supplied for shaft mines. The energy consumption per metric ton of gypsum present in wallboard is grossly estimated to be:

- Between 2 and 10 kWh, or,
- Between 1 and 5 kg fuel oil.

5. Waste Streams

Atmospheric emissions of particulate gypsum and clay are surmised. No quantitative information is available. The quantity of particulates is estimated to be less than 5 kg per metric ton of gypsum present in wallboard.

Excluding stripped overburden, solid wastes of clay, shale, limestone fragments, and low-grade gypsum are estimated to amount to between 0.05 and 0.15 metric ton per metric ton of gypsum present in wallboard. Disposal is by local landfill.

In open-pit operations, up to approximately 2 metric tons of overburden (about 1 metric ton is usual) may be stripped per metric ton of gypsum present in wallboard. Disposal of these solids is also by local landfill.

6. EPA Source Classification Code

None established

7. References

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CRUSHING/GRINDING

1. Function

The process reduces the size of mined gypsum ($CaSO_4 \cdot 2H_2O$) rock from approximately 15 cm maximum diameter lumps to a range required by the type of calcining equipment used.

The steps of screening and drying are usually included in the process.

Equipment may consist of:

- Grizzlies for rough sizing.
- Primary crushing equipment. This may be a gyratory crusher, single-roll crusher, or hammer mill.
- Vibrating screens for size classification.
- Secondary crusher, usually of the roll type.
- Grinding equipment. This may be roller mills or Raymond mills. Either type may be equipped to air-dry the product.
- Rotary dryers may be used to dry the crushed product.

Fine-grinding equipment is omitted if the operation uses rotary kilns for calcining in Process 3.

The product of the process may be forwarded in any of five directions:

- Directly to sales as an end product (agricultural gypsum, or "land plaster").
- Directly to sales to the cement industry for use as a retarder in Portland cement.
- To Process 3, for calcination in pot kilns.
- To Process 4, for calcination in rotary kilns.
- To Process 9, for calcination in vertical, stack kilns. (The quantity for this use is considerably less than for the first-named four.)

2. Input Materials

Mined gypsum rock, ranging in size from fines to lumps approximately 15 cm maximum diameter, is the input material. Its estimated requirement is 1.03 to 1.07 metric tons per metric ton of gypsum in wallboard.

3. Operating Parameters

- Product fineness is 95% minus 100 mesh for both feed to pot kilns and for direct sale as agricultural gypsum.
- Particle size of product varies between 0.3 and 1.5 cm for feed to rotary kilns.
- Particle size varies between 0.6 and 1.5 cm for direct sale as retarder in Portland cement.
- Lump size for feed to vertical kilns (Process 9) is typically 4 to 5 cm diameter.
- A typical integrated crushing, grinding, and screening operation has a daily throughput of 500 to 800 metric tons of gypsum.

4. Utilities

Consumption of electrical energy per metric ton of gypsum in wallboard:

- Between 0.8 and 1.5 kWh for crushing to 1-cm lumps.
- Between 10 and 15 kWh for crushing and grinding to 95% minus 100 mesh.
- In operations where a rotary dryer is used for removing free water, the electrical energy consumption will be increased by 3 to 5 kWh.

Fuel consumption for removing free water (estimated at 5% of gypsum weight) is estimated between 50×10^3 and 100×10^3 kcal per metric ton of gypsum in wallboard.

5. Waste Streams

Fugitive emissions of gypsum dust to the atmosphere result from all types of crushing and grinding equipment, as well as from the rotary dryer. No quantitative information is available. The total amount of particulates is estimated to be less than 5 kg of minus 100-mesh gypsum per metric ton of gypsum in wallboard, with dust collection equipment operative.

Solid wastes are discharged from grizzlies and vibrating screens. These consist of sand, clay, limestone, and gypsum particles. Their total weight is estimated between 30 and 50 kg per metric ton of gypsum in wallboard.

Fuel combustion may result in emissions of sulfur oxides, nitrogen oxides, particulates and hydrocarbons, depending on fuel burned and combustion efficiency.

6. EPA Source Classification Code

3-05-015-01 Raw Material Dryer
3-05-015-02 Primary Grinder

7. References

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POT CALCINATION

1. Function

The process removes combined water from ground gypsum rock ($CaSO_4 \cdot 2H_2O$) by calcination in a kiln of specialized design (gypsum pot-kiln).

The kiln feed is received from Process 2. Almost all of the product tonnage is calcium sulfate hemihydrate ($CaSO_4 \cdot \frac{1}{2}H_2O$). It is forwarded to Process 5 for pulverization. In a small fraction of the cases, the product is "second-settle" stucco, or anhydrite ($CaSO_4$) and may have end uses similar to those of the Keene's cement end product of Process 9.

The step of mixing calcium chloride liquor ($CaCl_2$) is included in the process. The mixing is conducted in the batch kiln-feed stream. A subsequent step of cooling, or "soaking," is also included.

Essential equipment consists of an externally fired, upright, cylindrical pot or kettle of steel or cast iron, provided internally with rotating horizontal stirrer arms. Cooling pits are rectangular steel boxes.

2. Input Materials

The process is fed ground gypsum rock from Process 2, having a particle size of approximately 95% minus 100 mesh. Between 1 and 1.03 metric tons are required per metric ton of gypsum present in the wallboard product.

Approximately 1 to 2 kg $CaCl_2$ per metric ton of gypsum present in wallboard product is added to the charge. This is probably added as a 35% solution. Its function is to hasten rehydration to the hemihydrate of any anhydrite formed. The addition of $CaCl_2$ is omitted when "soluble" anhydrite is the intentional product.

3. Operating Parameters

Both $CaSO_4 \cdot \frac{1}{2}H_2O$ (plaster of paris or "first-settle" stucco) and anhydrous $CaSO_4$ (anhydrite or "second-settle" stucco) are produced in the identical pot-kilns (in different batches) of the following description:

- Kiln sizes range from 3 m diameter by 3 m deep to 5 m diameter by 6 m deep.
- Weight of charge ranges from 10 to 30 metric tons of ground gypsum rock.
- Kilns are operated batchwise at substantially atmospheric pressure.
- Stirrer revolves at approximately 20 rpm.

In producing $CaSO_4 \cdot \frac{1}{2}H_2O$, the controlled parameters are temperature and residence time:

- Empty kiln preheated to about 100°C.
- Batch charge remains at 120° to 130°C for period of 1 3/4 to 2 hours.
- Kiln is discharged at temperature of approximately 160°C.

In the small number of cases where anhydrous $CaSO_4$ is produced, the charge is allowed to undergo the same sequence as described above and then allowed to remain in the kiln during a constant-temperature period at about 190°C. This requires an additional 30 to 60 minutes. The kiln is discharged at a temperature of approximately 220°C.

Exact temperatures and residence times required are a function of the particular kiln.

4. Utilities

Quantities are expressed per metric ton of gypsum present in wallboard product.

- Heat, as either coal, natural gas, or fuel oil - between 2.5×10^5 and 3.5×10^5 kcal.
- Electrical energy - between 2 and 5 kWh.

5. Waste Streams

During charging and discharging operations of the kiln, fugitive emissions of particulate $CaSO_4 \cdot 2H_2O$, $CaSO_4 \cdot \frac{1}{2}H_2O$, or $CaSO_4$ to the atmosphere are surmised. No information is available on either absolute quantity or particle size. Estimated quantity is less than 3 kg per metric ton of gypsum present in wallboard product, with dust control equipment operating, and approximately 20 kg per metric ton of gypsum in wallboard product without dust control equipment.

Fuel combustion may result in emissions of sulfur oxides, nitrogen oxides, particulates and hydrocarbons, depending on fuel burned and combustion efficiency.

6. EPA Source Classification Code

3-05-015-03 Calciner

7. References

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ROTARY CALCINATION*

1. Function

The process removes combined water from lump gypsum ($CaSO_4 \cdot 2H_2O$) rock received from Process 2. The product is forwarded to Process 6 for size reduction. In addition to calcination, two steps are included:

- Addition of $CaCl_2$ to the kiln feed and mixing.
- Cooling, or "soaking," the calcined product in silos.

Essential equipment consists of a continuously operating rotary kiln and at least several "aging" silos, provided with means of ventilation.

2. Input Materials

Crushed gypsum rock, between 0.3 and 1.5 cm in diameter, is fed continuously to the kiln. Between 1.0 and 1.03 metric tons (estimated) of kiln feed are required per metric ton of gypsum present in wallboard product.

Approximately 1 to 2 kg of $CaCl_2$ are added to the kiln feed for "pre-aging" the product.

3. Operating Parameters

Kilns are direct fired. The charge attains a temperature of between 175° and 200°C. "Aging" the product in the "aging" silos is a necessary step to allow the dehydration to complete itself in the "underburned" portions of the charge and to allow rehydration of any anhydrous calcium sulfate to occur.

Kilns are in the same size range as cement kilns--approximately 3.5 m diameter by 100 to 125 m in length.

4. Utilities

Quantities are expressed per metric ton of gypsum present in wallboard product:

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*This process is an alternate to Process 3, Pot Calcination. The latter is used in the majority of the operations processing gypsum. The use of rotary kilns for calcining is declining.

- Heat, supplied by coal, natural gas, or fuel oil - between 3×10^5 and 3.5×10^5 kcal (estimated).
- Electrical energy - 3 to 6 kWh (estimated).

5. Waste Streams

Calcination in rotary kilns results in a greater amount of fugitive particulate emissions to the atmosphere than does pot calcination.

With dust control equipment operative on the kiln exhaust, estimated total weight of particulates emitted to the atmosphere is estimated to be less than 5 kg of anhydrite per metric ton of gypsum in wallboard product.

Fuel combustion may result in emissions of sulfur oxides, nitrogen oxides, particulates and hydrocarbons, depending on fuel burned and combustion efficiency.

6. EPA Source Classification Code

3-05-015-03 Calciner

7. References

Cement, Lime and Plaster. In: Rogers' Industrial Chemistry, Furnas, C. C. (ed.). New York, Van Nostrand & Co., 1942. p. 872-877.

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Taggart, A. F. Gypsum. In: Handbook of Mineral Dressing. New York, John Wiley & Sons, Inc., 1945. p. 3-40 to 3-42.

PULVERIZING

1. Function

The process further reduces the particle size of the calcined gypsum received from either Process 3 or Process 4. The product, if "first-settle" stucco or calcium sulfate hemihydrate ($CaSO_4 \cdot \frac{1}{2}H_2O$), is forwarded as follows in order of increasing tonnage:

Directly to sales, as plaster of paris.
To Process 7 for blending to wall plasters.
To Process 8 for fabrication into wallboard products.

In a small fraction of instances, the calcined gypsum is "second-settle" stucco or soluble anhydrite ($CaSO_4$) and is sold as the end product.

Air separation and screening are usually steps in the process.

If the feed material is received from Process 4, equipment may consist of Raymond mills or rod mills in combination with ball mills, plus shaking screens and cyclone separators. If fed from Process 3, equipment usually consists of ball mills and cyclone separators.

2. Input Materials

The calcined gypsum (both $CaSO_4 \cdot \frac{1}{2}H_2O$ and $CaSO_4$) fed to the process has a particle size approximating 90 to 95% minus 100 mesh, if received from Process 3, or 1- to 2-cm diameter lumps plus fines, if received from Process 4. Approximately 0.85 metric ton of "first-settle" stucco is required per metric ton of gypsum present in wallboard. Approximately 1 metric ton of "second-settle" stucco is needed per metric ton of soluble anhydrite end product.

3. Operating Parameters

The process is conducted at above-ambient temperatures (40°-60°C) and at essentially atmospheric pressure.

The product discharged by the process is 100% minus 100 mesh and may be as fine as 60% minus 200 mesh.

4. Utilities

Electrical energy consumption is estimated to be between 10 and 20 kWh per metric ton of gypsum in wallboard product.

5. Waste Streams

Fugitive atmospheric emissions of particulates, consisting of calcined gypsum dust, are surmised during periods of equipment malfunctioning and from imperfect duct-to-equipment seals. The total quantity of material escaping is estimated to be less than 0.5 kg per metric ton of gypsum contained in wallboard product.

Normally, atmospheric emissions are not a problem, since grinding and size-separation equipment are closed-circuited and sealed from the atmosphere, except for the bleed stream which is passed through a bag filter prior to venting.

6. EPA Source Classification Code

None established

7. References

Cement, Lime and Plaster. In: Rogers' Industrial Chemistry, Furnas, C. C. (ed.). New York, Van Nostrand & Co., 1942. p. 872-877.

Hammond, W. A. Calcium Compounds. In: Kirk-Othmer Encyclopedia of Chemical Technology, 2nd Edition, Standen, A. (ed.). New York, Interscience Publishers, 1964. 4:20-23.

Havighorst, C. R. A Quick Look at Gypsum Manufacture. Chem. Eng. 72:52-54, January 4, 1965.

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Taggart, A. F. Gypsum. In: Handbook of Mineral Dressing. New York, John Wiley & Sons, Inc., 1945. p. 3-40 to 3-42.

PACKAGING

1. Function

Pulverized calcined gypsum (plaster of paris in almost all instances), received from Process 5 in bulk, is packaged in bags or in bulk in rail cars. The bagged product is one of the six major end products of the industry.

Automatic weighing-bagging machines, retractable belt- or roller-conveyors, and fork trucks are used.

2. Input Material

An estimated 98 to 99% of the tonnage of input material is plaster of paris ($CaSO_4 \cdot \frac{1}{2}H_2O$). The remainder of the tonnage is "soluble anhydrite," a form of anhydrous $CaSO_4$.

The particle size of both materials is 100% minus 100 mesh and 60% minus 200 mesh.

One metric ton of input material is required per metric ton of end product.

3. Operating Parameters

The material is usually warm (40° to 50°C) during the packaging process.

The usual bag used is paper or multi-walled paper with plastic interliner and contains 45.3 kg of product, either plaster of paris or "soluble anhydrite."

Bulk shipments in rail cars are also made.

Unadulterated plaster of paris is usually produced in operations also producing wall plasters and wallboard. The tonnage produced is usually considerably less than that of mixed wall plaster. A typical operation producing all three products produces 50 metric tons per day of plaster of paris.

4. Utilities

Electrical energy consumption is 0.5 to 2.0 kWh per metric ton of product.

5. Waste Streams

Fugitive atmospheric emissions (surmised) of fine particulate $CaSO_4 \cdot \frac{1}{2}H_2O$ result from "puffing" at the filling valve of the bag. Atmospheric emissions are estimated to be less than 0.2 kg per metric ton of product.

6. EPA Source Classification Code

3-05-015-04 Conveying

7. References

Cement, Lime and Plaster. In: Rogers' Industrial Chemistry, Furnas, C. C. (ed.). New York, Van Nostrand & Co., 1942. p. 872-877.

Hammond, W. A. Calcium Compounds. In: Kirk-Othmer Encyclopedia of Chemical Technology, 2nd Edition, Standen, A. (ed.). New York, Interscience Publishers, 1964. 4:20-23.

BLENDING

1. Function

The process blends relatively small quantities of additives into plaster of paris ("first-settle" stucco or $CaSO_4 \cdot \frac{1}{2}H_2O$) received from Process 6. The product is wall plaster and is sold as one of the major end products of the industry.

The step of packaging is included in the process.

Equipment consists of several continuous-flow mixing devices, such as the Broughton mixer, airveyor systems, continuous-flow weighing devices, bagging equipment, and bag conveyors.

2. Input Materials

The major input material is "first-settle" stucco or plaster of paris. Between 0.9 and 0.99 metric ton is required per metric ton of bagged plaster, depending on the particular formulation.

Additives to the plaster of paris, to impart specific properties, include the substances listed below. Quantities are expressed as kilograms per metric ton of bagged wall plaster.

Retarder (glue, tankage, starch, etc.)	2 - 8
Accelerator (usually alum; sometimes omitted)	1 - 3
Animal hair, chopped glass fiber, or wood fiber	1 - 5
Sand or perlite (for "ready-mix" plasters)	10 - 100

3. Operating Parameters

The operation is conducted at atmospheric pressure and, usually, the plaster of paris is still warm (40° to 50°C) from the calcining process.

Wall plaster is usually one of the products of an integrated operation also producing wallboard and unadulterated plaster of paris. One typical integrated plant produces about 100 metric tons per day of wall plasters.

4. Utilities

Electrical power consumption, including that for the packaging step, is estimated between 5 and 10 kWh per metric ton of product.

5. Waste Streams

Fugitive atmospheric emissions (surmised) of fine particulate $CaSO_4 \cdot \frac{1}{2}H_2O$, originate at the bagging machine filling spout and at loading hatches of railroad cars during bulk-loading periods. The total quantity is estimated to be less than 1 kg per metric ton of product. No factual information is available.

6. EPA Source Classification Code

3-05-015-04 Conveying

7. References

Cement, Lime and Plaster. In: Rogers' Industrial Chemistry, Furnas, C. C. (ed.). New York, Van Nostrand & Co., 1942. p. 872-877.

Hammond, W. A. Calcium Compounds. In: Kirk-Othmer Encyclopedia of Chemical Technology, 2nd Edition, Standen, A. (ed.). New York, Interscience Publishers, 1964. 4:20-23.

Havard, J. F. Gypsum. In: Industrial Minerals and Rocks, 3rd Edition, Gillson, J. L. (ed.). New York, Am. Soc. of Min. Met. & Petr. Eng., 1960. p. 471-476.

Reed, A. H. Gypsum. In: Minerals Yearbook, 1971, Schreck, A. E. (ed.). Washington, U. S. Dept. of the Interior, 1973. I:569-576.

Riegel, E. R. Portland Cement, Lime and Gypsum Plaster. In: Industrial Chemistry, 5th Edition. New York, Reinhold Publishing Corp., p. 173-175.

FABRICATION PLANT

1. Function

The process fabricates wallboard-type products from pulverized, calcined gypsum ("first-settle" stucco, $CaSO_4 \cdot \frac{1}{2}H_2O$) received from Process 6, with additions of various other materials. The products, chiefly gypsum board, rock lath, and laminated panels, constitute the major end products of the industry.

The principal process steps are:

- Blending
- Board fabrication
- Drying
- Packaging

Major equipment usually consists of:

- Pulping tanks
- Wet mixers and proportioning equipment
- Forming rolls
- "Setting-up" conveyor belt
- Tunnel dryer

2. Input Materials

The principal input material, "first-settle" stucco, is required in the ratio of approximately 0.85 metric ton per metric ton of gypsum in the fabricated product. This corresponds to a ratio of between 0.5 and 0.8 (estimated) metric ton of "first-settle" stucco per metric ton of finished fabricated product, depending on the specific type of the latter.

Materials mixed with the stucco are listed below. The approximate quantity of each is given per metric ton of finished product.

Process water, to slurry the stucco	0.6 m^3
Lignin	1 kg
Raw gypsum (accelerator)	5 kg (est.)
Starch	5 kg
Fiber glass	2 kg
Paper pulp	4-8 kg
Soap (to produce foam)	1 kg
Sawdust (may replace paper pulp)	4-8 kg
Potassium sulfate	0.5 kg
Perlite	4-6 kg

Other materials used in board fabrication may be paper, chip-board, wood veneer or aluminum foil, depending on the specific type of board produced.

3. Operating Parameters

The process is conducted at essentially atmospheric pressure. Temperatures at selected points in the process are:

- Slurry in mixer: 40-50°C (estimated)
- Air at feed end of dryer: 150-160°C
- Air at discharge end of dryer: 120°C

Residence times:

- Slurry in mixer: 2-40 seconds
- "Green" board on conveyor: 4-7 minutes

The daily capacity of a typical three-product operation is:

- 45 metric tons of plaster-of-paris
- 90 metric tons of wall plaster
- 56,000 square meters of 1.27-centimeter thick wallboard, equivalent to approximately 550 metric tons of wallboard.

The plant mentioned has a wallboard production line (setting conveyor plus dryer) approximately 420 meters long.

4. Utilities

Estimated total electrical energy consumption is between 10 and 20 kWh per metric ton of average product.

Heat, supplied as steam at 18 kilograms per square centimeter gage pressure, is required at an approximate ratio of 300×10^3 kcal per metric ton of average product.

5. Waste Streams

Fugitive atmospheric emissions of particulate $CaSO_4 \cdot \frac{1}{2}H_2O$ are surmised to originate at feed ports of mixers. No factual information is available. Their quantity is estimated to be less than 0.5 kilogram per metric ton of average product.

6. EPA Source Classification Code

3-05-015-04 Conveying

7. References

Cement, Lime and Plaster. In: Rogers' Industrial Chemistry, Furnas, C. C. (ed.). New York, Van Nostrand & Co., 1942. p. 872-877.

Hammond, W. A. Calcium Compounds. In: Kirk-Othmer Encyclopedia of Chemical Technology, 2nd Edition. Standen, A. (ed.). New York, Interscience Publishers, 1964. 4:20-23.

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Havighorst, C. R. A Quick Look at Gypsum Manufacture. Chem. Eng. (N.Y.). 72:52-54, January 4, 1965.

Niles, B. W. Gypsum Board. In: Kirk-Othmer Encyclopedia of Technology, 2nd Edition. Standen, A. (ed.). New York, Interscience Publishers, 1970. 21:621-625.

Reed, A. H. Gypsum. In: Minerals Yearbook, 1971, Shreck, A. E. (ed.). Washington, U.S. Dept. of the Interior, 1973. I:569-576.

Riegel, E. R. Portland Cement, Lime and Gypsum Plaster. In: Industrial Chemistry, 5th Edition. New York, Reinhold Publishing Corp., p. 173-175.

CALCINATION/PULVERIZING

1. Function

The process produces finely ground (<100 mesh) dead-burned gypsum, or anhydrite ($CaSO_4$) from 5-cm diameter lumps of gypsum received from Process 2. The pulverized product of the process is an end product of the industry.

The principal process steps, in sequence, are, in general:

- Calcination
- Cooling
- Pulverizing

In special cases, where the product is Keene's cement, the sequential process steps are:

- Calcination
- Cooling
- Soaking in alum solution
- Recalcination
- Cooling
- Pulverizing

Major equipment consists of:

- Stack kilns or beehive ovens
- Soaking tanks (used only if product is Keene's cement)
- Raymond mill, or rod-ball mill

2. Input Materials

Lumps of gypsum rock, inferred to be about 5 cm diameter, are fed to the process. The quantity is estimated to be approximately 1.3 metric ton per metric ton of dead-burned gypsum produced.

3. Operating Parameters

The process is conducted at atmospheric pressure and at temperatures in the range of 600° to 700°C. Calcination time is about four hours.

No information is available pertaining to the physical size of kilns, or on the parameters relating to the soaking in alum solution in the case of production of Keene's cement.

This process is used in the production of products which account for less than 2% of the total consumption of all crude gypsum. The principal products in this category are:

- Specialty plasters (including Keene's cement)
- Paint pigments
- Paper filler

4. Utilities

Heat, usually supplied by coal, is required in the calcination step. The quantity is estimated between 3×10^5 and 5×10^5 kcal per metric ton of dead-burned gypsum.

Total electric energy consumption is estimated between 1 and 3 kWh per metric ton of dead-burned gypsum.

5. Waste Streams

Fugitive atmospheric emissions of particulate anhydrite are surmised to originate at the stack-kiln exhaust. No quantitative information is available. The total quantity of solids emitted is estimated to be less than 5 kg of anhydrite per metric ton of dead-burned gypsum produced, with dust abatement equipment operative.

Fuel combustion may result in emissions of sulfur oxides, nitrogen oxides, particulates and hydrocarbons, depending on fuel burned and combustion efficiency.

6. EPA Source Classification Code

3-05-015-03 Calciner

7. References

Cement, Lime and Plaster. In: Rogers' Industrial Chemistry, Furnas, C. C. (ed.). New York, Van Nostrand & Co., 1942. p. 872-877.

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Table A-1. LIST OF RAW MATERIALS

1. Gypsum ($CaSO_4 \cdot 2H_2O$)

   •Bedded gypsum rock (most important source)

   •General composition range:

$CaSO_4 \cdot 2H_2O$	85 to 95% occasionally to 99%
Impurities are:	clay shale limestone anhydrite silica

2. Gypsite (gypsum intermingled with clay)

   •Usually secondary, surface deposits (less important source)

   •General composition range:

$CaSO_4 \cdot 2H_2O$	70 to 85%
Clay	10 to 20%

   Other impurities are as for gypsum

3. Selenite (large gypsum crystals in clay gangue)

   •Usually secondary, surface deposits (minor source)

   •General composition similar to that of gypsite.

4. Anhydrite ($CaSO_4$)

   •Usually mined only for use as cement retarder.

   •General composition range:

$CaSO_4$	85 to 95%

   Identity of impurities same as for bedded gypsum.

APPENDIX B

PRODUCTS

Table B-1. LIST OF PRODUCTS

Prefabricated gypsum-core board products:
Paper-covered wallboard
Chipboard-covered wallpanels
Paper-covered "rock"-lath
Exterior sheathing
Formboard (for poured industrial roofs)
Wall plasters
Plaster of paris
"Soluble anhydrite"
Dead-burned gypsum
Agricultural gypsum (land plaster)
Portland cement retarder

APPENDIX C

COMPANIES AND PRODUCTS

Table C-1. GYPSUM MINES AND CALCINING PLANTS IN THE UNITED STATES IN 1973[1]

Company	Location of Operation County & State	Type of Operation
Agro Minerals, Inc. Box 279 Droville, WA 98855	Okanogan, Washington	Mine Only
American Gypsum Company Box 6345 Albuquerque, NM 87107	Bernalillo, New Mexico	Plant Only
California Gypsum Company 37851 Cherry St. Newark, CA 95460	Almeda, California	Plant Only
Duke City Gravel Products 2421 Iris Road, NW Albuquerque, NM 87104	Sandoval, New Mexico	Mine Only
The Celotex Corporation 1500 N. Dale Mabry Tampa, FL 33607	Webster, Iowa Bergen, New Jersey Ottawa, Ohio Fisher, Texas Park, Wyoming	Mine & Plant Plant Only Mine[2] & Plant Mine & Plant Mine & Plant
Consumers Co-op Association 502 Pioneer Rd. Weiser, ID 83672	Washington, Wyoming	Mine Only
Cox Enterprises, Inc. 50 E. Main N. Manti, UT 84642	Sanpete, Utah	Mine Only
Dulin Bauxite Company, Inc. 835 Valley Hot Springs, AR 71901	Pike, Arkansas	Mine Only
Fannin-Superior Gypsum Company Route 1, Box 7, Hwy. 46 Wasco, CA 93280	Kern, California	Mine Only

Table C-1 (Continued) GYPSUM MINES AND CALCINING PLANTS IN THE UNITED STATES IN 1973[1]

Company	Location of Operation County & State	Type of Operation
The Flintkote Company 480 Central Avenue E. Rutherford, NJ 07073	Alameda, California	Plant Only
	Fremont, Colorado	Mine & Plant
	Chatham, Georgia	Plant Only
	Clark, Nevada	Mine & Plant
	Camden, New Jersey	Plant Only
	Nolan, Texas	Mine & Plant
Fredericksburg Gypsum Company Mason Route Fredericksburg, TX 78624	Gillespie, Texas	Mine Only
Georgia-Pacific Corporation 900 S.W. Fifth Avenue Portland, OR 97204	New Castle, Delaware	Plant Only
	Glynn, Georgia	Plant Only
	Webster, Iowa	Mine & Plant
	Marshall, Kansas	Mine & Plant
	Kent, Michigan	Mine[2] & Plant
	Erie, New York	Mine[2] & Plant
	Westchester, New York	Plant Only
	Hardeman, Texas	Mine & Plant
	Sevier, Utah	Mine & Plant
	Big Horn, Wyoming	Mine & Plant
Grand Rapids Gypsum Company 201 Monroe Avenue, NW Grand Rapids, MI 49502	Kent, Michigan	Mine[2] & Plant
Harrison Gypsum Company, Inc. Box 176 Lindsay, OK 73052	Caddo, Oklahoma	Mine Only
H. M. Holloway, Inc. 714 Sixth Street Wasco, CA 93280	Kern, California	Mine Only

Table C-1 (Continued). GYPSUM MINES AND CALCINING PLANTS IN THE UNITED STATES IN 1973[1]

Company	Location of Operation County & State	Type of Operation
Johns-Manville Corporation	Clark, Nevada	Mine & Plant
Kaiser Gypsum Company, Inc. 300 Lakeside Drive Oakland, CA 94604	Contra Costa, California	Plant Only
	Los Angeles, California	Plant Only
	Duval, Florida	Plant Only
	Burlington, New Jersey	Plant Only
	King, Washington	Plant Only
Michigan Gypsum Company 2840 Bay Road Saginaw, MI 48601	Iosco, Michigan	Mine Only
E. W. Munroe 101 E. Vine Drive Fort Collins, CO 80521	Larimer, Colorado	Mine Only
National Gypsum Company 325 Delaware Avenue Buffalo, NY 14202	Maricopa, Arizona	Plant Only
	Pinal, Arizona	Mine Only
	Contra Costa, California	Plant Only
	Los Angeles, California	Plant Only
	New Haven, Connecticut	Plant Only
	Hillsborough, Florida	Plant Only
	Chatham, Georgia	Plant Only
	Lake, Illinois	Plant Only
	Martin, Indiana	Mine[2] & Plant
	Webster, Iowa	Mine & Plant
	Barber, Kansas	Mine & Plant
	Jefferson, Louisiana	Plant Only
	Baltimore, Maryland	Plant Only
	Iosco, Michigan	Mine & Plant
	Rockingham, New Hampshire	Plant Only
	Burlington, New Jersey	Plant Only
	Bronx, New York	Plant Only
	Erie, New York	Mine[2] & Plant
	Lorain, Ohio	Plant Only
	Fisher, Texas	Mine & Plant

Table C-1 (Continued). GYPSUM MINES AND CALCINING PLANTS IN THE UNITED STATES IN 1973[1]

Company	Location of Operation County & State	Type of Operation
Pinal Mammoth Gypsum Company 2020 S. 9th Street Coolidge, AZ 85228	Pinal, Arizona	Mine Only
Quad-Honstein Joint Venture 5770 McIntyre St. Golden, CO 80401	Larimer, Colorado	Mine Only
Raymond Schweitzer Gypsum Route 2 Okarche, OK 73762	Canadian, Oklahoma	Mine Only
Republic Gypsum Company 1100 Mercantile Bank Bldg. Dallas, TX 75201	Santa Fe, New Mexico Jackson, Oklahoma	Mine & Plant Mine & Plant
South Dakota Cement Commission Drawer 351 Rapid City, SC 57701	Meade, South Dakota	Mine Only
Southwestern Portland Cement Company Box 392 El Paso, TX 79943	Hudspeth, Texas	Mine Only
Superior Companies Box 6497 Phoenix, AZ 85005	Pinal, Arizona Yavapai, Arizona	Mine Only Mine Only
Temblor Gypsum Company Carrisa Plains Star Rt. Box 80 St. Margarita, CA 93453	Kern, California	Mine Only

Table C-1 (Continued). GYPSUM MINES AND CALCINING PLANTS IN THE UNITED STATES IN 1973[1]

Company	Location of Operation County & State	Type of Operation
Temple Industries, Inc. Box 368 Diboll, TX		
Temple Gypsum Company, Subsidiary West Memphis, AK	Critenden, Arkansas	Plant Only
Texas Gypsum Company, Inc., Subsidiary Box 768 Irving, TX 75060	Comanche, Ohlahoma Dallas, Texas	Mine Only Plant Only
United States Gypsum Company 101 South Wacker Drive Chicago, IL 60606	Imperial, California Duval, Florida Lake, Indiana Martin, Indiana Des Moines, Iowa Webster, Iowa Orleans, Louisiana Baltimore, Maryland Suffolk, Massachusetts Iosco, Michigan Wayne, Michigan Fergus, Montana Pershing, Nevada Washoe, Nevada Genesee, New York Richmond, New York Rockland, New York Ottawa, Ohio Blaine, Oklahoma Philadelphia, Pennsylvania Harris, Texas Nolan, Texas Sevier, Utah Chesapeake, Virginia Washington, Virginia	Mine & Plant Plant Only Plant Only Mine[2] & Plant Mine & Plant Mine & Plant Plant Only Plant Only Plant Only Mine Only Plant Only Mine[2] & Plant Mine Only Plant Only Mine[2] & Plant Plant Only Plant Only Mine[2] & Plant Mine & Plant Plant Only Plant Only Mine & Plant Mine & Plant Plant Only Mine[2] & Plant

Table C-1 (Continued). GYPSUM MINES AND CALCINING PLANTS IN THE UNITED STATES IN 1973[1]

Company	Location of Operation County & State	Type of Operation
United States Steel Corporation Universal Atlas Portland Cement Division 600 Grant Street Pittsburgh, PA 15230	Blaine, Oklahoma	Mine Only
U.S. Soil Conditioning Company Box 346 Salida, CO 81201	Fremont, Colorado	Mine Only
Victor Material Company Box 1024 Victorville, CA 92392	San Bernardino, California	Mine Only
Walton Gypsum Company Route 1 Homestead, OK 73745	Blaine, Oklahoma	Mine Only
Weyerhaeuser Company Route 4, Box 78 Nashville, AR 71852	Howard, Arkansas	Mine & Plant
White Mesa Gypsum Company 124 Jackson NE Albuquerque, NM 78108	Sandoval, New Mexico	Mine Only
Art Wilson Company Box 1160 Carson City, NV 89701	Lyon, Nevada	Mine Only
E. J. Wilson & Sons Dubois, ID 83423	Lemhi, Idaho	Mine Only

Table C-1 (Continued). GYPSUM MINES AND CALCINING PLANTS IN THE UNITED STATES IN 1973[1]

Company	Location of Operation County & State	Type of Operation
Winn Rock, Inc. Box 790 Winnfield, LA 71483	Winn, Louisiana	Plant Only
Wyoming Construction Company Box 907 Laramie, WY 82070	Albany, Wyoming	Mine Only

[1] Companies Producing Gypsum or Gypsum Products During 1973

Company operations listed below comprising a mine only, may produce one or more of the following forms of uncalcined gypsum:

- Lump gypsum rock (intermediate product) for use by other operations within the industry.
- Gravel-size gypsum rock for use as Portland cement retarder.
- Pulverized gypsum for agricultural use (land plaster).

Operations comprising only a plant produce:

- Fabricated products (wallboard, rock lath, or formboard),
- Wall plaster,
- Plaster of paris, and in addition, may produce small quantities of "soluble anhydrite", or dead-burned gypsum.

Operations comprising both a mine and a plant always produce lump gypsum rock (intermediate product) and fabricated products, almost always produce wall plaster and plaster of paris, and may produce any of the other products mentioned above.

[2] Indicates underground mine; otherwise open-pit operation.

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15. SUPPLEMENTARY NOTES

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 gypsum and wallboard industry comprises operations which mine gypsum deposits and process the mined gypsum rock into crushed or pulverized uncalcined gypsum, pulverized calcined gypsum and a diversity of prefabricated gypsum-core board products. One chemical tree, one process flow sheet and nine 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

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