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Calciners and Dryers in Mineral Industries—Background Information for Proposed Standards

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Calciners and Dryers in Mineral Industries— Background Information for Proposed Standards

Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Radiation
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1. SUMMARY

1.1 REGULATORY ALTERNATIVES

Standards of performance for new stationary sources are developed under Section 111 of the Clean Air Act (42 U.S.C. 7411), as amended. Section 111 requires the establishment of standards of performance for any new stationary source which ". . . causes, or contributes significantly to air pollution which may reasonably be anticipated to endanger public health or welfare." The Act requires standards of performance for such sources to ". . . reflect the degree of emission limitation and the percentage reduction achievable through application of the best technological system of continuous emission reduction which (taking into consideration the cost of achieving such emission reduction, any nonair quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated." The standards apply only to stationary sources, the construction, modification, or reconstruction of which starts after regulations are proposed in the Federal Register.

Regulatory alternatives were considered for particulate matter emissions from calciners and dryers in 17 mineral processing industries. In this document, a mineral processing plant is defined as any facility that processes or produces any of the following minerals or their concentrates: alumina, ball clay, bentonite, diatomite, feldspar, fire clay, fuller's earth, gypsum, industrial sand, kaolin, lightweight aggregate, magnesium compounds, perlite, roofing granules, talc, titanium dioxide, and vermiculite.

The affected facility for mineral processing plants in each of the industries listed above would be each calciner and each dryer. The types of dryers included in the regulatory alternative analysis are: rotary (direct), rotary (indirect), fluid bed, vibrating-grate, flash, and spray dryers. The types of calciners considered include: rotary, flash, and kettle calciners, and multiple hearth furnaces. Expansion furnaces in the perlite and vermiculite industries and rotary kilns in the lightweight aggregate industry were also included because their operations and emissions are similar to those of calciners.

Three regulatory alternatives were evaluated for calciners and dryers in mineral industries. Regulatory Alternative I (RA I), baseline, is equivalent to no additional action beyond that required by current, typical State implementation plans (SIP's). This alternative is the baseline condition against which the impacts of the other alternatives are compared. Regulatory Alternative II (RA II) is equivalent to an emission control level for both calciners and dryers of 0.09 grams per dry standard cubic meter of gas (g/dscm) (0.04 grains per dry standard cubic foot [gr/dscf]). Regulatory Alternative III (RA III) is equivalent to an emission control level for calciners of 0.09 g/dscm (0.04 gr/dscf) and an emission control level for dryers of 0.057 gr/dscf (0.025 gr/dscf). These alternatives are discussed further in Chapter 6.

1.2 ENVIRONMENTAL IMPACT

The beneficial and adverse environmental impacts associated with the levels of RA II and RA III are compared with the baseline emission level in Tables 1-1 and 1-2. These impacts are discussed in detail in Chapter 7.

Nationwide emissions of particulate matter would decrease by 7,500 megagrams (Mg) (8,300 tons) and 7,900 Mg (8,800 tons) under RA II and RA III, respectively, compared with projected baseline emissions in the fifth year, if standards of performance based on these three alternatives are implemented. These figures represent a 74 percent emission reduction for RA II and a 78 percent emission reduction for RA III.

Wet scrubbers are the only control devices on calciners and dryers in the mineral industries that generate wastewater streams requiring treatment or disposal. Typically, a particulate-contaminated water stream from a scrubber is pumped to a settling pond on the site and not

TABLE 1-1. ENVIRONMENTAL AND ECONOMIC IMPACTS OF REGULATORY ALTERNATIVES II AND III COMPARED TO REGULATORY ALTERNATIVE I (BASELINE) IN THE FIFTH YEAR (1990)

Reg. Alt.	Emission reduction			Solid waste increase[b]			Energy increase	Cost increase[a]	
	Mg/yr	tons/yr	%	Mg/yr	tons/yr	%	MWh/yr[c]	Capital, $000	Annualized, $000
II	7,500	8,300	74	7,000	7,700	72	16,000	2,100 to 2,900	600 to 1,000
III	7,900	8,800	78	7,500	8,300	77	17,000	2,200 to 3,000	700 to 1,000

[a] The range of costs is due to those process units for which either a BH or WS could be installed; if only WS's are installed, the capital cost would be lower and the annualized cost would be higher than if only BH's are installed.

[b] Solid waste values are reported as dewatered sludge containing 70 percent moisture.

[c] These values represent the highest incremental electric energy requirement between fabric filters and wet scrubbers where an option exists.

TABLE 1-2. MATRIX OF ENVIRONMENTAL AND ECONOMIC IMPACTS FOR REGULATORY ALTERNATIVES

Reg. Alt.	Air impact	Water impact	Solid waste impact	Energy impact[a]	Noise impact	Economic impact
I	0	0	0	0	0	0
II	+3**	0	+3**	0 to +4***	0	+3**
III	+3**	0	+3**	0 to +4***	0	+3**

[a] A range of impacts is indicated based upon the range of possible energy increases shown in Table 1-1.

KEY:
+ = Beneficial impact.
- = Adverse impact.
* = Short-term impact.
** = Long-term impact.
*** = Irreversible impact.

0 = No impact.
1 = Negligible impact.
2 = Small impact.
3 = Moderate impact.
4 = Large impact.

discharged into navigable waters. The solids settle in the pond, and the water is recirculated to the scrubber. When solids fill the pond, the pond can be dredged and the solids can be landfilled, or a new pond can be constructed. Therefore, there would be no adverse water pollution impact due to implementation of any of the regulatory alternatives.

The main source of solid waste from control of particulate matter emissions from calciners and dryers in mineral industries would be the sludge produced by wet scrubbers, which is composed primarily of the processed minerals. The nationwide increase in solid waste (as sludge containing 70 percent moisture) in 1990 compared to the baseline level would be 7,000 Mg (7,700 tons) for RA II and 7,500 Mg (8,300 tons) for RA III. These represent increases over the baseline level of 72 percent and 77 percent, respectively.

The same air pollution control devices used to meet current SIP's could be used to meet standards of performance based on the regulatory alternatives. Therefore, no noise or radiation impacts will be caused by the implementation of RA II or RA III.

The increase in nationwide energy consumption for mineral calciner and dryer control devices would be at most 16,000 megawatt hours (MWh) for RA II and 17,000 MWh for RA III in the fifth year compared to the demand under the SIP's. The incremental energy requirements to operate control equipment are less than 1 percent of the energy demands to operate the calciner and dryer process units.

1.3 ECONOMIC IMPACT

The economic impacts of each regulatory alternative are summarized in Tables 1-1 and 1-2. These impacts are discussed in detail in Chapters 8 and 9. Capital and annualized costs are presented as ranges because in 7 out of the 17 mineral processing industries, process units could utilize more than one type of control device to meet standards of performance based upon these regulatory alternatives.

Five years after implementation of RA II, the total nationwide incremental pollution control equipment capital costs would range from $2.1 to $2.9 million. Under RA III, the total nationwide incremental pollution control equipment capital costs would range from $2.2 to

$3.0 million. The range in costs is due to the process units for which either a fabric filter or a wet scrubber could be installed. If only wet scrubbers were installed, the capital costs would be lower than if only fabric filters were installed. In most cases the capital costs are essentially the same for RA II and RA III because the capital investment in a particular control device does not change for the two alternatives. It is the operation and maintenance of these devices that enables the same control device to achieve a lower emission level under RA II or RA III than under RA I (e.g., same scrubber is operated at a higher pressure drop). The total incremental annualized costs nationwide to the industries would range from $0.6 million to $1.0 million for RA II and would range from $0.7 million to $1.0 million for RA III.

While general market conditions may affect the economic viability of some of the industries discussed, the addition of particulate matter emission controls does not represent an adverse economic impact for most of the industries. The typical size facilities in all 17 industries would have a maximum product price increase of less than 1.75 percent for both RA II and RA III.

Although some of the individual industries are concentrated in a particular region, when the 17 industries are considered as a group, the plants are widely dispersed geographically. If standards of performance based upon these alternatives are implemented, it is not likely that a significant regional or employment economic effect will result. Similarly, if the industries are considered together, a substantial effect on small businesses should not result, as defined by the Regulatory Flexibility Act of 1980.

2. INTRODUCTION

2.1 BACKGROUND AND AUTHORITY FOR STANDARDS

Before standards of performance are proposed as a Federal regulation, air pollution control methods available to the affected industry and the associated costs of installing and maintaining the control equipment are examined in detail. Various levels of control based on different technologies and degrees of efficiency are expressed as regulatory alternatives. Each of these alternatives is studied by EPA as a prospective basis for a standard. The alternatives are investigated in terms of their impacts on the economic well-being of the industry, the impacts on the national economy, and the impacts on the environment. This chapter summarizes the types of information obtained by EPA through these studies in the development of the proposed standards.

Standards of performance for new stationary sources are established under Section 111 of the Clean Air Act (42 U.S.C. 7411) as amended, hereafter referred to as the Act. Section 111 directs the Administrator to establish standards of performance for any category of new stationary source of air pollution which ". . . causes, or contributes significantly to air pollution which may reasonably be anticipated to endanger public health or welfare."

The Act requires that standards of performance for stationary sources reflect ". . . the degree of emission limitation and the percentage reduction achievable through application of the best technological system of continuous emission reduction which (taking into consideration the cost of achieving such emission reduction, any nonair quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated." The standards apply only to stationary sources, the construction or modification of which commences after the standards are proposed in the Federal Register.

The 1977 amendments to the Act altered or added numerous provisions that apply to the process of establishing standards of performance. Examples of the effects of the 1977 amendments are:

1. The EPA is required to review the standards of performance every 4 years and, if appropriate, revise them.

2. The EPA is authorized to promulgate a standard based on design, equipment, work practice, or operational procedures when a standard based on emission levels is not feasible.

3. The term "standards of performance" is redefined, and a new term "technological system of continuous emission reduction" is defined. The new definitions clarify that the control system must be continuous and may include a low- or non-polluting process or operation.

4. The time between the proposal and promulgation of a standard under Section 111 of the Act may be extended to 90 days.

Standards of performance, by themselves, do not guarantee protection of health or welfare because they are not designed to achieve any specific air quality levels. Rather, they are designed to reflect the degree of emission limitation achievable through application of the best adequately demonstrated technological system of continuous emission reduction, taking into consideration the cost of achieving such emission reduction, any nonair quality health and environmental impacts and energy requirements.

Congress had several reasons for including these requirements. First, standards having a degree of uniformity are needed to avoid situations where some States may attract industries by relaxing standards relative to other States. Second, stringent standards enhance the potential for long-term growth. Third, stringent standards may help achieve long-term cost savings by avoiding the need for more expensive retrofitting when pollution ceilings may be reduced in the future. Fourth, certain types of standards for coal-burning sources can adversely affect the coal market by driving up the price of low-sulfur coal or by effectively excluding certain coals from the reserve base. Congress does not intend that new source performance standards contribute to these problems. Fifth, the standard-setting process should create incentives for improving technology.

Promulgation of standards of performance does not prevent State or local agencies from adopting more stringent emission limitations for the same sources. States are free under Section 116 of the Act to establish even more stringent emission limits than those established under Section 111 or than those necessary to attain or maintain the National Ambient Air Quality Standards (NAAQS) under Section 110. Thus, new sources may in some cases be subject to State limitations that are more stringent than standards of performance under Section 111, and prospective owners and operators of new sources should be aware of this possibility in planning for such facilities.

A similar situation may arise when a major emitting facility is to be constructed in a geographic area that falls under the prevention of significant deterioration of air quality provisions of Part C of the Act. These provisions require, among other things, that major emitting facilities to be constructed in such areas are to be subject to best available control technology. The term "best available control technology" (BACT), as defined in the Act, means

> . . . an emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under this Act emitted from or which results from any major emitting facility, which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such facility through application of production, processes and available methods, systems, and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques for control of each such pollutant. In no event shall application of "best available control technology" result in emissions of any pollutants which will exceed the emissions allowed by any applicable standard established pursuant to Section 111 or 112 of this Act. (Section 169(3))

Although standards of performance are normally structured in terms of numerical emission limits where feasible, alternative approaches are sometimes necessary. In some cases, physical measurement of emissions from a new source may be impractical or exorbitantly expensive. Section 111(h) provides that the Administrator may promulgate a design or equipment standard in those cases where it is not feasible to prescribe or enforce a standard of performance. For example, emissions of hydrocarbons from storage vessels for petroleum liquids are greatest during tank filling. The nature of the emissions (i.e., high concentrations for short periods during filling and low concentrations for longer periods during storage) and the configuration of storage tanks make direct emission measurement impractical. Therefore, a more practical approach to standards of performance for storage vessels has been equipment specification.

In addition, under Section 111(j) the Administrator may, with the consent of the Governor of the State in which a source is to be located, grant a waiver of compliance to permit the source to use an innovative technological system or systems of continuous emission reduction. To grant the waiver, the Administrator must find that: (1) the proposed system has not been adequately demonstrated, (2) the proposed system will operate effectively and there is a substantial likelihood that the system will achieve greater emission reductions than the otherwise applicable standards require or at least an equivalent reduction at lower economic, energy, or nonair quality environmental cost, (3) the proposed system will not cause or contribute to an unreasonable risk to public health, welfare, or safety, and (4) the waiver, when combined with other similar waivers, will not exceed the number necessary to achieve conditions (2) and (3) above. A waiver may have conditions attached to ensure the source will not prevent attainment of any NAAQS. Any such condition will be treated as a performance standard. Finally, waivers have definite end dates and may be terminated earlier if the conditions are not met or if the system fails to perform as expected. In such a case, the source may be given up to 3 years to meet the standards and a mandatory compliance schedule will be imposed.

2.2 SELECTION OF CATEGORIES OF STATIONARY SOURCES

Section 111 of the Act directs the Administrator to list categories of stationary sources. The Administrator ". . . shall include a category of sources in such list if in his judgment it causes, or contributes significantly to air pollution which may reasonably be anticipated to endanger public health or welfare." Proposal and promulgation of standards of performance are to follow.

Since passage of the Clean Air Amendments of 1970, considerable attention has been given to the development of an approach for assigning priorities to various source categories. The approach specifies areas of interest by considering the broad strategy of the Agency for implementing the Clean Air Act. Often, the concern is for pollutants that are emitted by stationary sources rather than the stationary sources themselves. Source categories that emit these pollutants were evaluated and ranked considering such factors as: (1) the level of emission control (if any) already required by State regulations, (2) estimated levels of control that might be required from standards of performance for the source category, (3) projections of growth and replacement of existing facilities for the source category, and (4) the estimated incremental amount of air pollution that could be prevented in a preselected future year by standards of performance for the source category. Sources for which new source performance standards were promulgated or which were under development before or during 1977, were selected using these criteria.

The Act amendments of August 1977 establish specific criteria to be used in determining priorities for all source categories not yet listed by EPA. These are: (1) the quantity of air pollutant emissions which each such category will emit, or will be designed to emit, (2) the extent to which each such pollutant may reasonably be anticipated to endanger public health or welfare, and (3) the mobility and competitive nature of each such category of sources and the consequent need for nationally applicable new source performance standards. The Administrator is to promulgate standards for these categories according to the schedule referred to earlier.

In some cases, it may not be immediately feasible to develop standards for a source category with a high priority. This might happen if a program of research is needed to develop control techniques or if techniques for sampling and measuring emissions require refinement. In the development of standards, differences in the time required to complete the necessary investigation for different source categories must also be considered. For example, substantially more time may be necessary if numerous pollutants must be investigated from a single source category. Further, the schedule for completion of a standard may change late in the development process. For example, inability to obtain emission data from well-controlled sources in time to pursue the development process in a systematic fashion may force a change in scheduling. Nevertheless, priority ranking is, and will continue to be, used to establish the order in which projects are initiated and resources are assigned.

After the source category has been chosen, the types of facilities within the source category to which the standard will apply must be determined. A source category may have several facilities that cause air pollution, and emissions from these facilities may vary according to magnitude and control cost. Economic studies of the source category and of applicable control technology may show that air pollution control is better served by applying standards to the more severe pollution sources. For this reason, and because there is no adequately demonstrated system for controlling emissions from certain facilities, standards often do not apply to all facilities at a source. For the same reasons, the standards may not apply to all air pollutants emitted. Thus, although a source category may be selected to be covered by standards of performance, not all pollutants or facilities within that source category may be covered by the standards.

2.3 PROCEDURE FOR DEVELOPMENT OF STANDARDS OF PERFORMANCE

Standards of performance must: (1) realistically reflect best demonstrated control practice, (2) adequately consider the cost, the nonair quality health and environmental impacts, and the energy requirements of such control, (3) be applicable to existing sources that are modified or reconstructed as well as to new installations, and (4) meet these conditions for all variations of operating conditions being considered anywhere in the country.

The objective of a program for development of standards is to identify the best technological system of continuous emission reduction that has been adequately demonstrated. The standard-setting process involves three principal phases of activity: (1) information gathering,

(2) analysis of the information, and (3) development of the standards of performance.

During the information gathering phase, industries are questioned through telephone surveys, letters of inquiry, and plant visits by EPA representatives. Information is also gathered from other sources, including a literature search. Based on the information acquired about the industry, EPA selects certain plants at which emission tests are conducted to provide reliable data that characterize the pollutant emissions from well-controlled existing facilities.

In the second phase of a project, the information about the industry and the pollutants emitted is used in analytical studies. Hypothetical "model plants" are defined to provide a common basis for analysis. The model plant definitions, national pollutant emission data, and existing State regulations governing emissions from the source category are then used in establishing regulatory alternatives. These regulatory alternatives are essentially different levels of emission control.

The EPA conducts studies to determine the cost, economic, environmental and energy impacts of each regulatory alternative. From several alternatives, EPA selects the single most plausible regulatory alternative as the basis for standards of performance for the source category under study.

In the third phase of a project, the selected regulatory alternative is translated into performance standards, which, in turn, are written in the form of a Federal regulation. The Federal regulation, when applied to newly constructed plants and to modified or reconstructed facilities, will limit emissions to the levels indicated in the selected regulatory alternative.

As early as is practical in each standard-setting project, EPA representatives discuss the possibilities of a standard and the form it might take with members of the National Air Pollution Control Techniques Advisory Committee. Industry representatives and other interested parties also participate in these meetings.

The information acquired in the project is summarized in the background information document (BID). The BID, the proposed standards, and a preamble explaining the standards are widely circulated to the industry being considered for control, environmental groups, other government agencies, and offices within EPA. Through this extensive review process, the points of view of expert reviewers are taken into consideration as changes are made to the documentation.

A "proposal package" is assembled and sent through the offices of EPA assistant administrators for concurrence before the proposed standards are officially endorsed by the EPA Administrator. After being approved by the EPA Administrator, the preamble and the proposed regulation are published in the Federal Register.

The public is invited to participate in the standard-setting process as part of the Federal Register announcement of the proposed regulation. The EPA invites written comments on the proposal and also holds a public hearing to discuss the proposed standards with interested parties. All public comments are summarized and incorporated into a second volume of the BID. All information reviewed and generated in studies in support of the standards of performance is available to the public in a "docket" on file in Washington, D.C. Comments from the public are evaluated, and the standards of performance may be altered in response to the comments.

The significant comments and the EPA's position on the issues raised are included in the preamble of a promulgation package, which also contains the draft of the final regulation. The regulation is then subjected to another round of review and refinement until it is approved by the EPA Administrator. After the Administrator signs the regulation, it is published as a final rule in the Federal Register.

2.4 CONSIDERATION OF COSTS

Section 317 of the Act requires an economic impact assessment with respect to any standard of performance established under Section 111 of the Act. The assessment is required to contain an analysis of: (1) the costs of compliance with the regulation, including the extent to which the cost of compliance varies depending on the effective date of the regulation and the development of less expensive or more efficient methods of compliance, (2) the potential inflationary and recessionary effects of the regulation, (3) the effects the regulation might have on small business with respect to competition, (4) the effects of the regulation on consumer costs, and (5) the effects of the regulation on energy use. Section 317 requires that the economic impact assessment be as extensive as practicable.

The economic impact of proposed standards upon an industry is usually addressed both in absolute terms and by comparison with the control costs that would be incurred as a result of compliance with typical, existing State control regulations. An incremental approach is taken because both new and existing plants would be required to comply with State regulations in the absence of Federal standards of performance. This approach requires a detailed analysis of the economic impact of the cost differential that would exist between proposed standards of performance and typical State standards.

Air pollutant emissions may cause water pollution problems, and captured potential air pollutants may pose a solid waste disposal problem. The total environmental impact of an emission source must, therefore, be analyzed and the costs determined whenever possible.

A thorough study of the profitability and price-setting mechanisms of the industry is essential to the analysis so that an accurate estimate of potential adverse economic impacts can be made for proposed standards. It is also essential to know the capital requirements for pollution control systems already placed on plants so that the additional capital requirements necessitated by these Federal standards can be placed in proper perspective. Finally, it is necessary to assess the availability of capital to provide the additional control equipment needed to meet the standards of performance.

2.5 CONSIDERATION OF ENVIRONMENTAL IMPACTS

Section 102(2)(C) of the National Environmental Policy Act (NEPA) of 1969 requires Federal agencies to prepare detailed environmental impact statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The objective of NEPA is to build into the decision-making process of Federal agencies a careful consideration of all environmental aspects of proposed actions.

In a number of legal challenges to standards of performances for various industries, the United States Court of Appeals for the District of Columbia Circuit has held that environmental impact statements need not be prepared by the Agency for proposed actions under Section 111 of the Clean Air Act. Essentially, the Court of Appeals has determined that the best system of emission reduction requires the Administrator to take into account counterproductive environmental effects of proposed standards, as well as economic costs to the industry. On this basis, therefore, the Courts established a narrow exemption from NEPA for EPA determinations under Section 111.

In addition to these judicial determinations, the Energy Supply and Environmental Coordination Act of 1974 (PL-93-319) specifically exempted proposed actions under the Clean Air Act from NEPA requirements. According to Section 7(c)(1), "No action taken under the Clean Air Act shall be deemed a major Federal action significantly affecting the quality of the human environment within the meaning of the National Environmental Policy Act of 1969." (15 U.S.C. 793(c)(1))

Nevertheless, the Agency has concluded that the preparation of environmental impact statements could have beneficial effects on certain regulatory actions. Consequently, although not legally required to do so by Section 102(2)(C) of NEPA, EPA has adopted a policy requiring that environmental impact statements be prepared for various regulatory actions, including standards of performance developed under Section 111 of the Act. This voluntary preparation of environmental impact statements, however, in no way legally subjects the Agency to NEPA requirements.

To implement this policy, a separate section is included in this document that is devoted solely to an analysis of the potential environmental impacts associated with the proposed standards. Both adverse and beneficial impacts in such areas as air and water pollution, increased solid waste disposal, and increased energy consumption are discussed.

2.6 IMPACT ON EXISTING SOURCES

Section 111 of the Act defines a new source as ". . . any stationary source, the construction or modification of which is commenced . . ."

after the proposed standards are published. An existing source is redefined as a new source if "modified" or "reconstructed" as defined in amendments to the General Provisions (40 CFR Part 60, Subpart A), which were promulgated in the Federal Register on December 16, 1975 (40 FR 58416).

Promulgation of standards of performance requires States to establish standards of performance for existing sources in the same industry under Section 111(d) of the Act if the standards for new sources limit emissions of a designated pollutant (i.e., a pollutant for which air quality criteria have not been issued under Section 108 or which has not been listed as a hazardous pollutant under Section 112). If a State does not act, EPA must establish such standards. General procedures for control of existing sources under Section 111(d) were promulgated on November 17, 1975, as Subpart B of 40 CFR Part 60 (40 FR 53340).

2.7 REVISION OF EXISTING STANDARDS OF PERFORMANCE

Congress was aware that the level of air pollution control achievable by any industry may improve with technological advances. Accordingly, Section 111 of the Act provides that the Administrator ". . . shall, at least every four years, review and, if appropriate, revise . . ." the standards. Revisions are made to ensure that the standards continue to reflect the best systems of emission reduction that become available in the future. Such revisions will not be retroactive but will apply to stationary sources constructed or modified after the proposal of the revised standards.

3. THE MINERAL PROCESSING INDUSTRIES

The source category mineral dryers and calciners includes process equipment used to dry and calcine metallic and nonmetallic minerals in 17 selected mineral processing industries. Drying is defined as the removal of uncombined (free) water from the mineral material through direct or indirect heating. Calcining is the removal of combined (chemically bound) water and/or gases from the mineral material through direct or indirect heating. Calcining also refers to the heating, at high temperatures, of certain clay materials to create a ceramic change in the raw material.

In addition to the typical dryer and calciner process units, other process equipment is included for evaluation whose primary purpose is not to remove water, although water is removed as a secondary consideration. These special cases include expansion furnaces in the perlite and vermiculite industries and rotary kilns in the lightweight aggregate industry. Grinding or milling equipment such as roller or hammer mills, that also dry mineral materials, are not included in this study. These grinding and milling operations are regulated as process sources under the nonmetallic minerals new source performance standards.

The 17 industries under consideration are found in 43 States and the U.S. Virgin Islands. Several of the industries or segments of industries are composed of a large number of individual facilities located in a large number of States. Others are limited to a relatively few plants located near natural deposits of the minerals being processed.

Pollutant emissions from these sources that are considered in this study are primarily particulate matter emissions, including products of combustion, from the dryers and calciners. Some information on NO_x and SO_x was gathered to define these emissions. Additionally, fugitive particulate matter emissions from raw material feed systems into the dryer/calciner and product outlet points from the dryer/calciner were observed, and opacities were recorded.

Section 3.1 provides a general description of each dryer and calciner type. In Section 3.2, a background discussion and general process description for each of the 17 industries is provided, along with descriptions of the dryers and/or calciners used in each industry. Section 3.3 presents the variables that affect emissions from dryers and calciners. The uncontrolled particulate and particle size distribution data collected for each industry are also presented and discussed in Section 3.3. The baseline level of emissions for each industry is given in Section 3.4.

3.1 GENERAL DESCRIPTION OF PROCESSING EQUIPMENT

The industries being considered in this source category utilize a wide variety of processing equipment for the drying, calcining, and expansion of raw materials. The types of equipment used in each industry are listed in Tables 3-1 and 3-2. Of the six dryer types presented in Table 3-1, direct-fired rotary and fluid bed are the most common; all of the industries that use dryers utilize one or both of these two types. Similarly, as shown in Table 3-2, rotary units are the most common type of calciner used by industries that calcine. Expansion furnaces are used in two industries. A further discussion of dryer and calciner types follows.

3.1.1 Dryers

A variety of dryer designs have been developed to remove unbound moisture from raw materials. The dryer types used in the mineral industries include direct rotary, indirect rotary, fluid bed, flash, spray, and vibrating-grate. Dryers use either a convection (direct) or a conduction (indirect) method of drying. In the convection method, a heating medium, usually air or the products of combustion, is in direct contact with the wet material. In the conduction method, heat is transmitted indirectly by contact of the wet material with a heated surface.[1] The thermal efficiency of direct-fired dryers is higher than the thermal efficiency of indirect dryers.[2] The process material flow in direct rotary dryers may be cocurrent or countercurrent to the gas flow.

TABLE 3-1. TYPES OF DRYERS USED BY EACH INDUSTRY[a]

Industry	Rotary (direct)	Rotary (indirect)	Fluid bed	Vibrating grate	Flash	Spray
Ball clay		x		x[b]		
Bentonite	x		x			
Diatomite	x				x	
Feldspar	x		x			
Fire clay	x			x		
Fuller's earth	x		x			
Gypsum	x					
Industrial sand	x		x			
Kaolin	x					x
Perlite	x					
Roofing granules	x		x			
Talc	x				x	
Titanium dioxide	x	x	x		x	x
Vermiculite	x		x			

[a] Dryers are not used in the alumina, lightweight aggregate, and magnesium compounds industries.

[b] Indirect.

TABLE 3-2. TYPES OF CALCINERS USED BY EACH INDUSTRY[a]

Industry	Rotary	Flash	Multiple hearth furnace	Kettle	Expansion furnace
Alumina	x	x			
Diatomite	x				
Fire clay	x				
Fuller's earth	x				
Gypsum		x		x	
Kaolin	x	x	x		
Lightweight aggregate	x				
Magnesium compounds	x		x		
Perlite					x
Talc	x				
Titanium dioxide	x				
Vermiculite					x

[a] Calciners are not used in the ball clay, bentonite, feldspar, industrial sand, and roofing granules industries.

Dryers may be operated in a batch mode or in a continuous mode. In several of the clay industries, batch operations are used to process several different materials through a given unit. Most dryers used in the mineral industries are operated in the continuous mode.

The most important parameters to consider in the selection of a dryer are: (1) physical properties of the material to be dried (particle size, geometric shape, moisture content, abrasiveness), (2) drying characteristics of the material, (3) production rate, and (4) product quality desired.[3]

3.1.1.1 Rotary Dryers. A rotary dryer consists of a cylindrical shell, ranging in length from 4 to 10 times its diameter, into which wet charge is fed at one end and from which dried product is discharged at the other end. The movement of the material through the dryer is due to the combined effects of the inclination of the shell to the horizontal and the action of lifting flights within the shell. As the shell rotates, the lifting flights pick up the material and shower it as a curtain in the path of hot gases. Flights may be installed as continuous strips down the length of the dryer or may be staggered to improve showering and distribution of the material being dried. Rotary dryers are the most frequently used dryer type. They require minimal labor to operate, and if properly maintained, they can be operated continuously over long periods of time using automatic controls.

3.1.1.1.1 Direct rotary dryers. Direct rotary dryers are used in the mineral industries when the materials to be dried can be safely brought into contact with heated air or combustion gases and when volatile, flammable, or noxious components are absent or are present in only small amounts. The drying medium, heated air or combustion gases, is fed into the dryer at one end and is drawn out the other end, coming into contact with the mineral as it flows through the dryer. The movement of the gases may be either cocurrent or countercurrent with the movement of the process material.[1] Cocurrent dryers are used for heat-sensitive material because air and product leave at about the same temperature. In countercurrent dryers, the exit gas temperature is usually lower than the product temperature.[3] Figure 3-1 is a schematic of a direct rotary dryer. Typical arrangements of cocurrent and countercurrent direct dryers are shown in Figure 3-2.

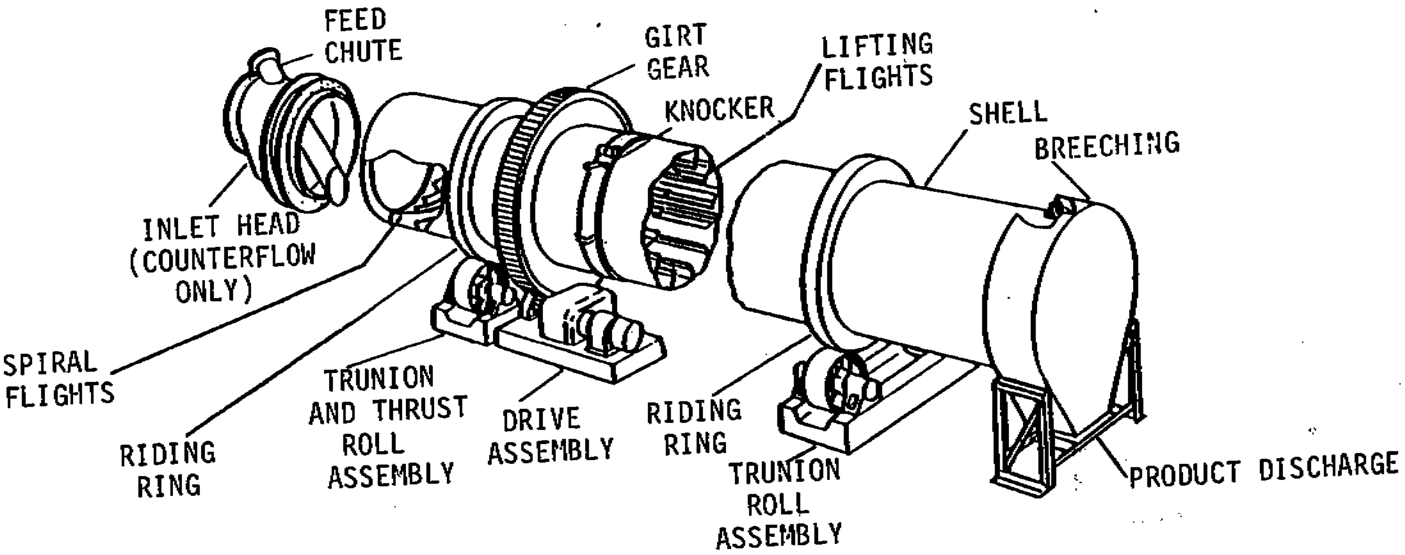
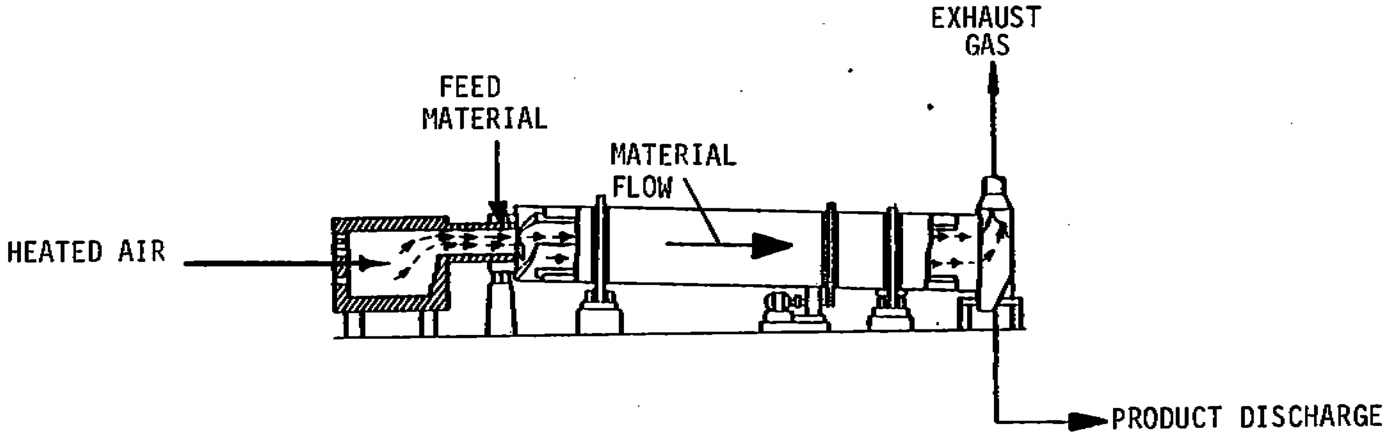
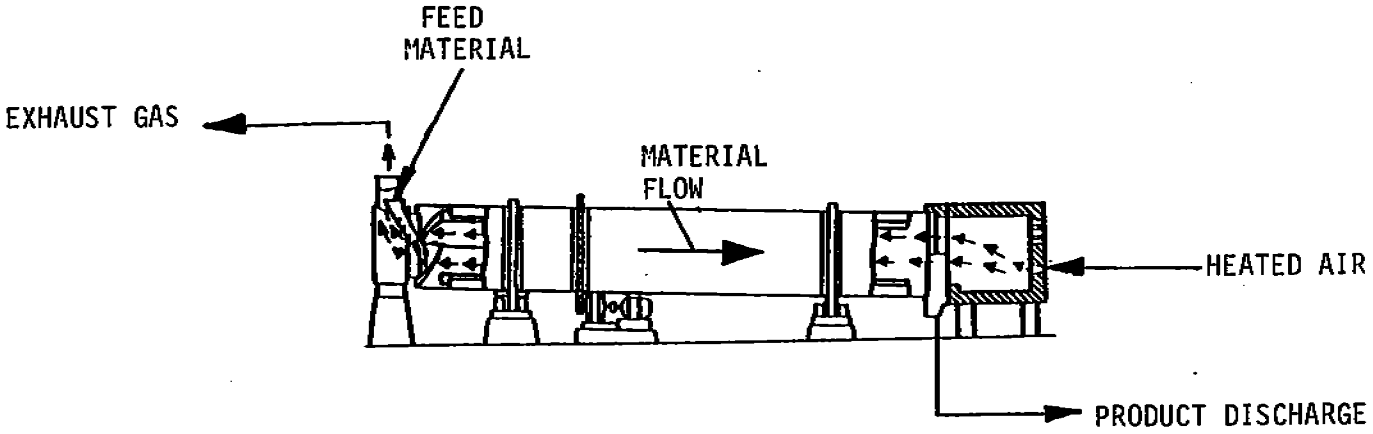


Figure 3-1. Direct rotary dryer.[4]



A. DIRECT COCURRENT ROTARY DRYER



B. DIRECT COUNTER-CURRENT ROTARY DRYER

Figure 3-2. Typical arrangements of direct rotary dryers.[5]

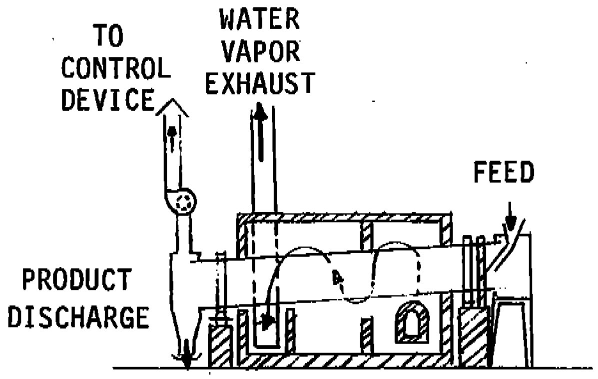
Direct rotary dryers in the mineral industries range in diameter from 1.2 to 3.1 meters (m) (4 to 10 feet [ft]). Dryer lengths vary from 6.1 to 19.8 m (20 to 65 ft). The production rates for mineral rotary dryers vary within each industry and range from 4.5 to 200 Mg/h (5 to 220 tons/h). The retention times in these dryers are 2 to 45 minutes. Natural gas, fuel oil, and coal are the predominant fuels used for direct rotary dryers.

3.1.1.1.2 Indirect rotary dryers. Direct rotary dryers are not suitable for certain applications in the mineral industries. Indirect-heat dryers are used if (1) the process material cannot be exposed to combustion gases, (2) excessive dust carry-over may occur through entrainment, (3) low cost steam is available, or (4) volatile components desirable for recovery are present.[6] Indirect dryers are required for ball clay processing and for some phases of titanium dioxide processing.

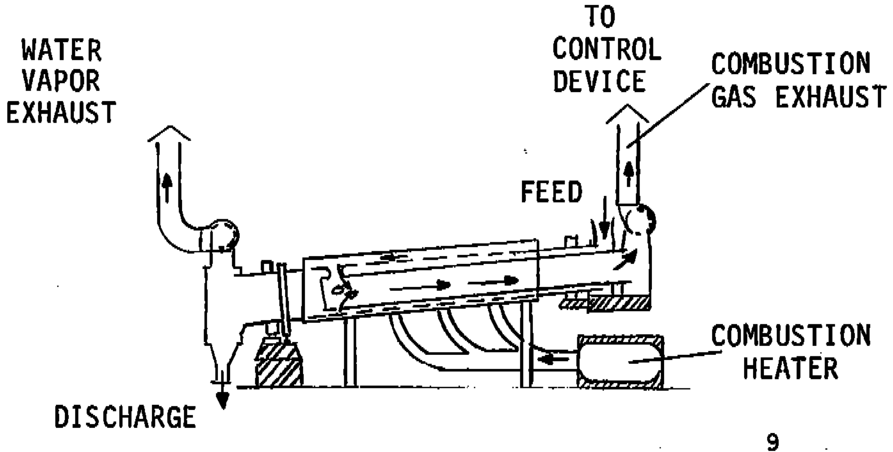
In indirect dryers, the heat required for drying the feedstock is supplied by conduction through the dryer shell or from internal heating tubes usually supplied with steam. Figure 3-3 presents various designs of indirect dryers.

The steam-tube dryer shown in Figure 3-3(c) is the most common type of indirect dryer used in the mineral industries. Feed material enters the dryer through a chute or screw feeder, and the product is discharged through peripheral openings in the shell at the discharge end. These openings also admit air to remove moisture and gases from the shell. Gas flow is countercurrent to material flow. Steam is admitted to the tubes through a revolving steam joint at the discharge end of the shell. Condensation is removed continuously through a steam joint to a condensate receiver. Indirect dryers use a 25 to 40 percent lower gas flow rate than the flow rate required by direct dryers, thus reducing the size of the dust collection system.[7]

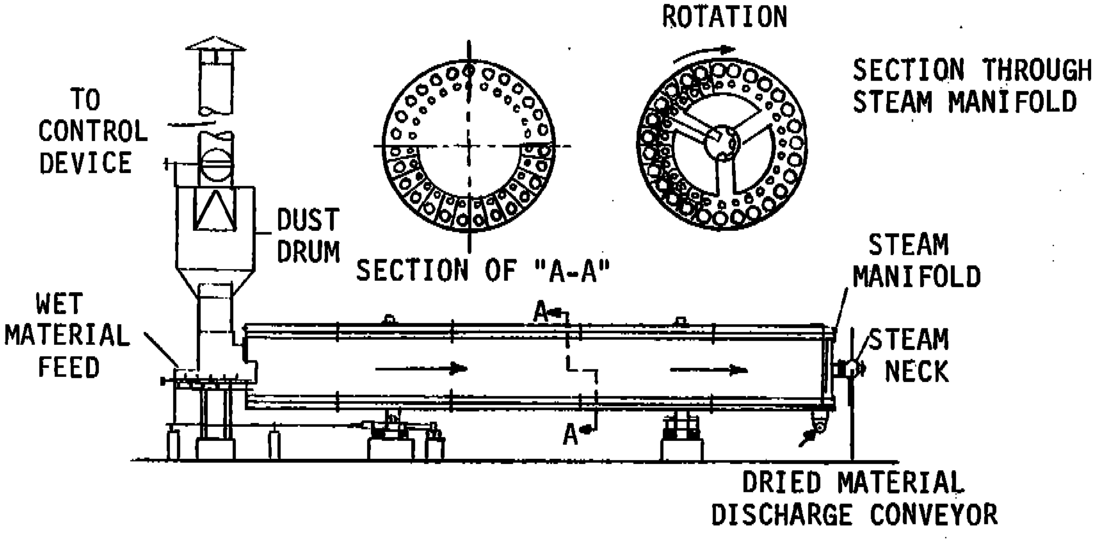
3.1.1.2 Fluid Bed Dryers. As shown in Table 3-1, fluid bed dryers are used in seven of the industries that dry raw materials. A schematic of a fluidized bed system is shown in Figure 3-4. The major parts of a fluidized bed system include:[8]



A. INDIRECT-HEATED ROTARY DRYER[9]



B. DOUBLE-SHELL INDIRECT-HEATED ROTARY DRYER[9]



C. INDIRECT STEAM TUBE ROTARY DRYER[10]

Figure 3-3. Types of indirect-heated rotary dryers.

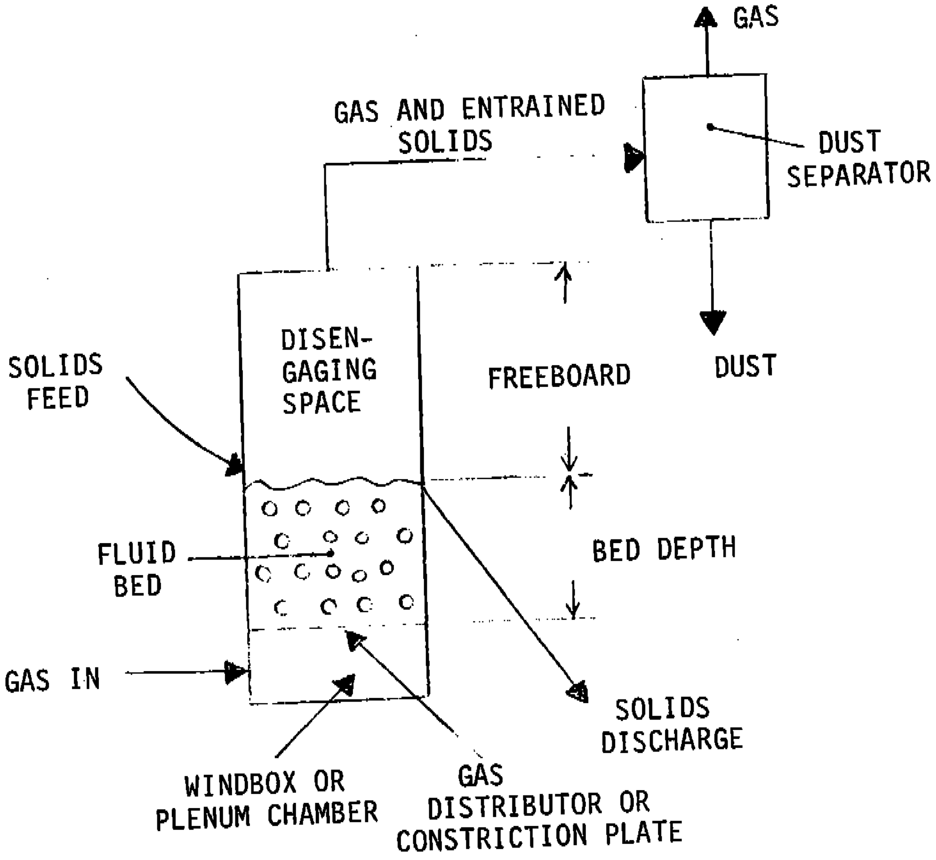


Figure 3-4. Schematic of a fluidized bed system.[11]

1. Reaction vessel,
    (a) gas distributor;
    (b) fluidized bed portion,
    (c) disengaging space or freeboard, and
2. Solids feeder or flow control;
3. Solids discharge mechanism;
4. Dust separator for the exit gases;
5. Instrumentation; and
6. Gas supply.

In a fluid bed dryer, a vertically rising, hot stream of gas is introduced through a dispersion plate (gas distributor) at the base of a bed or column of particulate solids. The velocity of this air stream is such that the wet feed bed expands to allow the particles to move within the bed, i.e., the bed becomes fluidized.[11] The process of fluidization converts a bed of solid particles into an expanded, suspended mass that resembles a boiling liquid. The upward velocity of the gas through the bed is usually between 0.15 and 3.1 meters per second (m/s) (0.5 and 10 feet per second [ft/s]). This velocity is based upon the flow through the empty vessel and is referred to as the superficial velocity.[8]

The size of solid particles that can be fluidized varies from less than 1 micrometer (μm) (4×10^{-5} inch [in.]) to 6.4 centimeter (cm) (2.5 in.). It is generally believed that particles between 10 and 210 μm (4×10^{-4} and 8.4×10^{-3} in.) are the best size for optimum fluidization.[12]

The shapes of fluid bed units can vary from a vertical cylinder to oblong and rectangular units. The volumetric flow of gas is determined by the cross-sectional area and the minimum allowable (fluidizing) velocity of the gas at operating conditions. The velocity required to maintain a completely homogeneous bed of solids, in which coarse or heavy particles will not segregate from the fluidized portion, is higher than the minimum fluidizing velocity. The maximum allowable flow is generally determined by the degree of carry-over or entrainment of solids, and this is related to the dimensions of the disengaging space.[8]

Feed rate, product discharge rate, and the volumetric gas flow and gas temperature are monitored on a fluid bed dryer to maintain steady-state conditions and obtain the desired product moisture content.[13]

Figure 3-5 presents a schematic of a typical fluidized bed dryer system used in the mineral industries. Wet feed material charged to the dryer above the bed is removed as dried product near the base of the vessel. Gas passing up through the bed is exhausted through the top of the dryer to a control device. A high pressure air blower is generally used to dilute high-temperature combustion gases from the furnace and fluidize the bed.

In a fluid bed dryer, efficient mixing of the solid particles occurs, resulting in uniform drying. The technique of fluidization can be applied to a batch of material or to a continuous flow of material. In either case, however, the gas stream velocity must be controlled to yield optimum conditions for drying with regard to particle size and density. This velocity will lie at some point below the point of substantial entrainment.[15]

3.1.1.3 Flash Dryers. A flash (pneumatic) dryer is designed to dry material and convey it by a stream of hot gases from the feed point to some other point of delivery.[16] The feed material must be reasonably free-flowing and capable of being entrained in the gas stream. Separation of the dried product from the conveying air usually takes place in a cyclone followed by further separation in cyclones or baghouses. Figure 3-6 is a schematic of a flash dryer.

A flash drying system consists of the following equipment:[16]

1. A source of hot gases--either hot air or combustion gases produced by an indirect, fuel-fired heat exchanger or a direct, fuel-fired combustion chamber;
2. A material feeding device;
3. A main drying column or duct usually provided with a venturi section at the material feed point;
4. A cyclone for material-air separation; and
5. An air exhaust fan.

The source of hot gases and the material feeding device are similar to those used for direct rotary dryers. The venturi section of the drying column helps to induce entrainment of the wet material and produces a point of suction to assist raw material feeding. No mechanical feeder is required. The majority of the drying takes place in the main drying

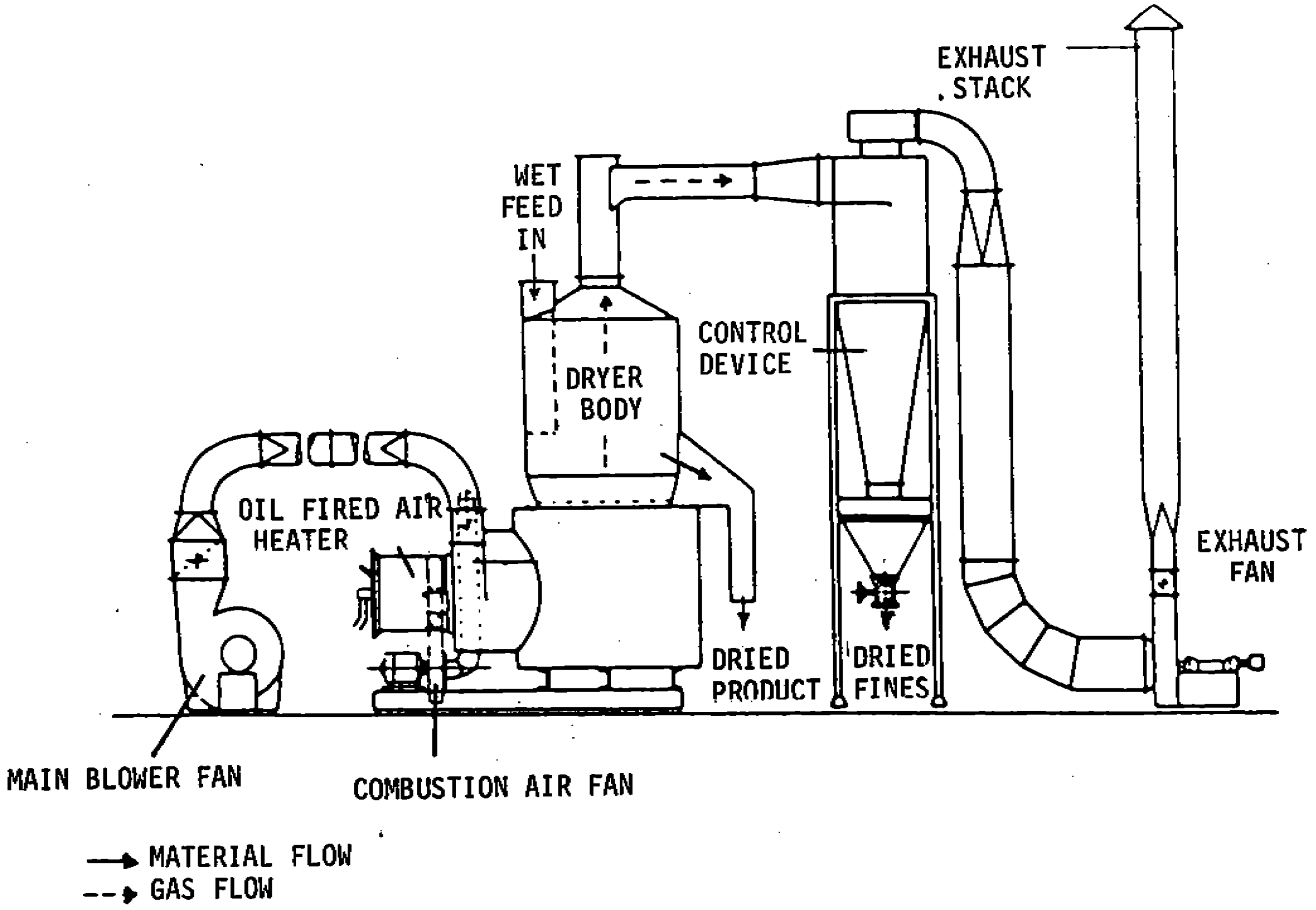


Figure 3-5. Typical fluidized bed dryer system.[14]

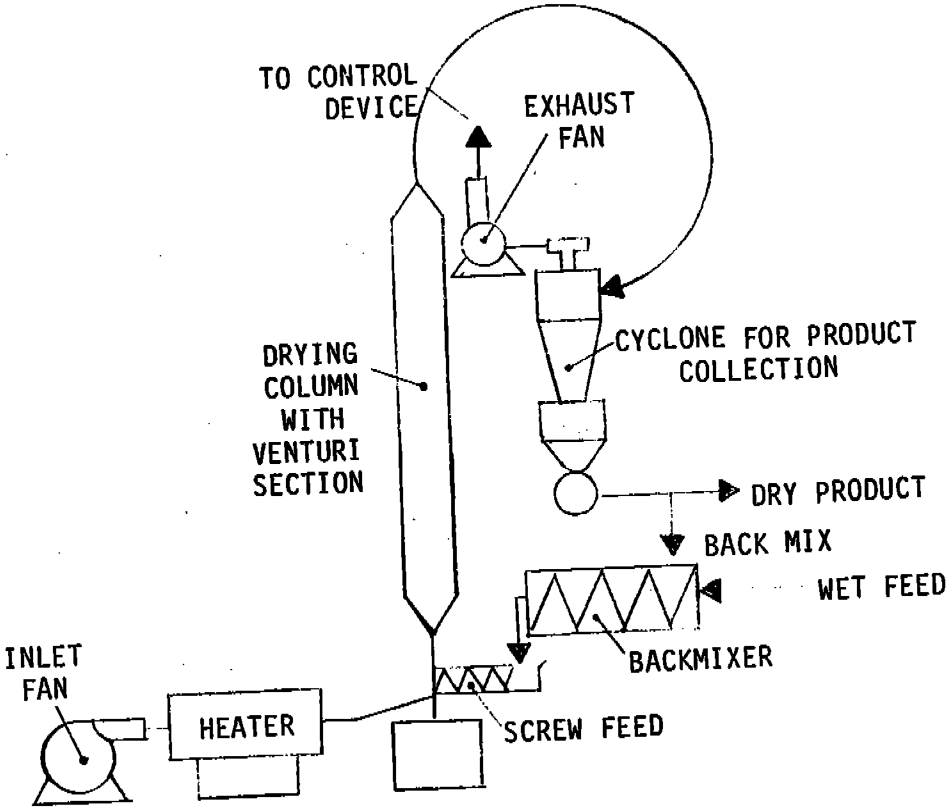


Figure 3-6. Schematic of a flash dryer system.[17]

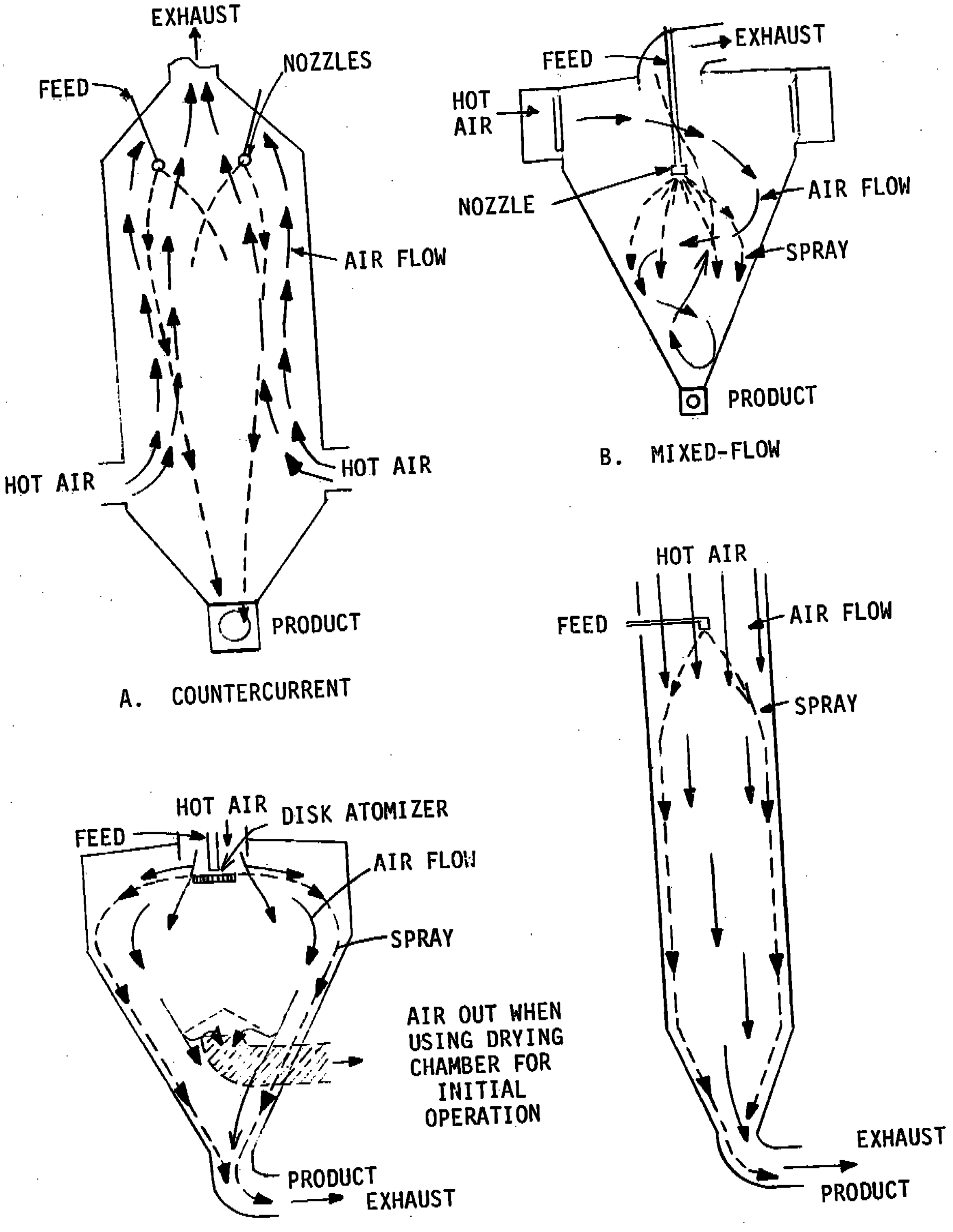
column although further drying is accomplished during transport to the collection device. The main conveying and drying duct may be circular or rectangular and should have a smooth inner surface that will not interfere with air flow or cause a build-up of material. Air and/or material may be recirculated to improve thermal efficiency and uniformity of drying. Because of the short retention time (2 to 3 seconds) of material in a flash dryer, only materials with good drying characteristics are suitable for processing in these units. Feed materials typically contain 6 to 60 percent moisture on a weight basis. The ratio of solids to gas should not be less than 1:2 by weight.[18]

3.1.1.4 Spray Dryers. Spray dryers are used to dry liquids, slurries, and pastes. A spray dryer consists of a source of hot gases, a drying chamber, a means of atomizing the feedstock, some provision for withdrawing the dried product and exhaust gases from the drying chamber, and equipment for the separation of the dried product from the exhaust gases.[19]

The small droplets formed by the feedstock atomizer have a large surface area-to-mass ratio so the drying operation in spray dryers is almost instantaneous. The high rate of evaporation cools the gases and dries the particles. Because of the short process time, the inlet air temperature is typically controlled automatically. The exhaust air temperature and moisture are used to determine the proper dryer feed rate.[20]

For most operations, direct-fired combustion chamber air heaters are used, with natural gas and oil being the most common fuels. Inlet gas temperatures range from 93° to 760°C (200° to 1400°F) depending upon the heating method. The spray dryer may have cocurrent, countercurrent, or mixed air and material flow.[21] Countercurrent dryers yield high bulk density products and are the most common type used in the kaolin and titanium dioxide industries. Figure 3-7 shows four spray dryer flow alternatives.

The design and operation of the atomizing equipment is of major importance in obtaining uniform feedstock particles. Three methods of atomization are normally employed: pressure, pneumatic, and centrifugal. The use of both pressure and pneumatic atomizers is restricted to small



A. COUNTERCURRENT

B. MIXED-FLOW

C. COCURRENT-DISK ATOMIZATION

D. COCURRENT-NOZZLE ATOMIZATION

Figure 3-7. Types of spray dryers.[24]

operations, and both types require frequent cleaning of nozzles for proper atomization. In contrast, centrifugal atomizers use the energy of centrifugal force set up by a spinning disc or paddle. The liquid feed forced to the periphery of the disc is accelerated and ejected, causing the liquid film to break down to droplets. Production capacities as high as 27 Mg/h (30 tons/h) can be reached with a single, large centrifugal atomizer. The range of particle sizes produced by spray dryers is 10 to 1,000 µm (<400 mesh to 18 mesh).[22]

Product collection may be carried out in various ways. If a considerable amount of product separates out within the dryer chamber in the conical base, it may be removed continuously under its own weight through a rotary valve or screw conveyor. If most of the product remains entrained in the gas stream, separation of the dry material is carried out first in high-efficiency cyclones followed by baghouses.

3.1.1.5 Vibrating-grate Dryers. Figure 3-8 is a schematic of a vibrating-grate dryer. Fluidization is maintained by a combination of pneumatic and mechanical forces. The heated gas is introduced into a plenum and passes up through a perforated or slotted conveying deck, through the fluidized bed of solids, and into an exhaust hood.[23] To ensure a uniform velocity distribution through the bed of solids, a combination pressure blower-exhaust fan system is used.

Vibrating-grate dryers are suitable for free-flowing solids containing mostly surface moisture. They are not effective on fibrous materials that form a mat, or on sticky solids that agglomerate or adhere to the deck. The motion imparted to the material particles may vary, but the objective is to move the material upward and forward so that it will travel along the conveyor path in a series of short hops.[26] This mechanical action, combined with the upward velocity of the air flow through the grate, conveys and dries the raw material. Vibrating-grate dryers in the mineral industries are 0.3 to 1.5 m (1 to 5 ft) wide and 3.1 to [illegible].7 m (10 to 150 ft) long. They dry material at a rate of 14 to 23 Mg/h [illegible] to 25 tons/h) and have retention times of 2 to 30 minutes. Natural [illegible] and No. 2 fuel oil are the predominant fuels.

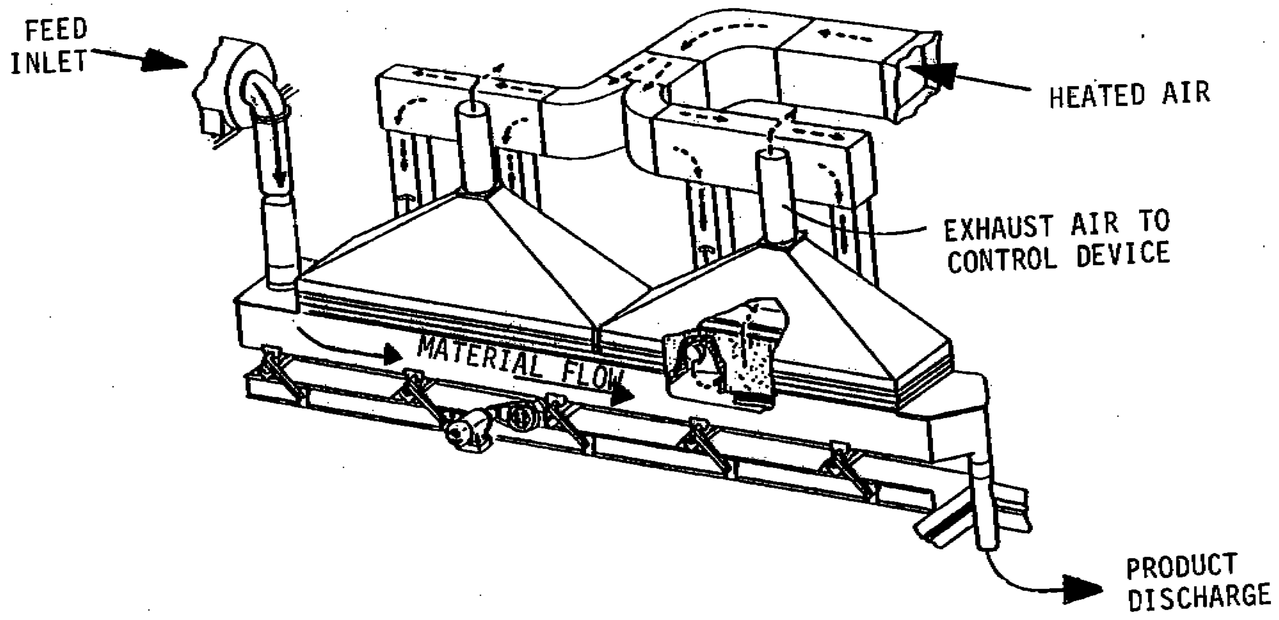


Figure 3-8. Vibrating-grate dryer.[25]

3.1.2 Calciners.

The types of calciners used in mineral industries are rotary, flash, and kettle calciners, and multiple hearth (Herreshoff) and expansion furnaces. Rotary calciners, which are the most common type, are operated in a continuous, direct-heat mode in most cases. Flash calciners are used in the alumina, gypsum, and kaolin industries. Kettle calciners are only used in the gypsum industry. Multiple hearth furnaces are used in the kaolin and magnesium compounds industries, and expansion furnaces are used in the perlite and vermiculite industries. Calciners are designed to remove the majority of combined moisture in the process material and are operated at higher temperatures than the dryers discussed in Section 3.1.1.

3.1.2.1 Rotary Calciners. Rotary calciners are used instead of rotary dryers when the process requires removal of both combined and uncombined moisture from the material. A rotary calciner consists of a cylindrical shell, ranging in length from 10 to 20 times its diameter, into which wet charge (wet-feed) or predried (dry-feed) material is fed at one end and calcined product is discharged at the other end. Rotary calciner shells are lined with refractory brick that insulates the steel shell and permits operation at high temperatures. Figure 3-9 depicts typical rotary calciner designs. Rotary calciners used in the mineral industries are 2.4 to 3.7 m (8 to 12 ft) in diameter and 30.5 to 61.0 m (100 to 200 ft) in length. The production rate is 0.9 to 66.4 Mg/h (1 to 73 tons/h) of material and the retention time ranges from 18 minutes to 14 hours.

Rotary calciners can be used to calcine a variety of materials including fine to lump-size material and "sticky" materials such as clays. The feed is introduced into the elevated end of the calciner by various methods including chutes, overhung screw conveyors, and slurry pipes. Occasionally, ring dams or chokes made from refractory material are installed within the calciner to build a deeper bed of material at one or more points. In rotary calciners, the material is not showered through the air stream but is retained in the bottom of the cylinder.[28] Approximately 3 to 12 percent of the cylinder's volume is filled with material.

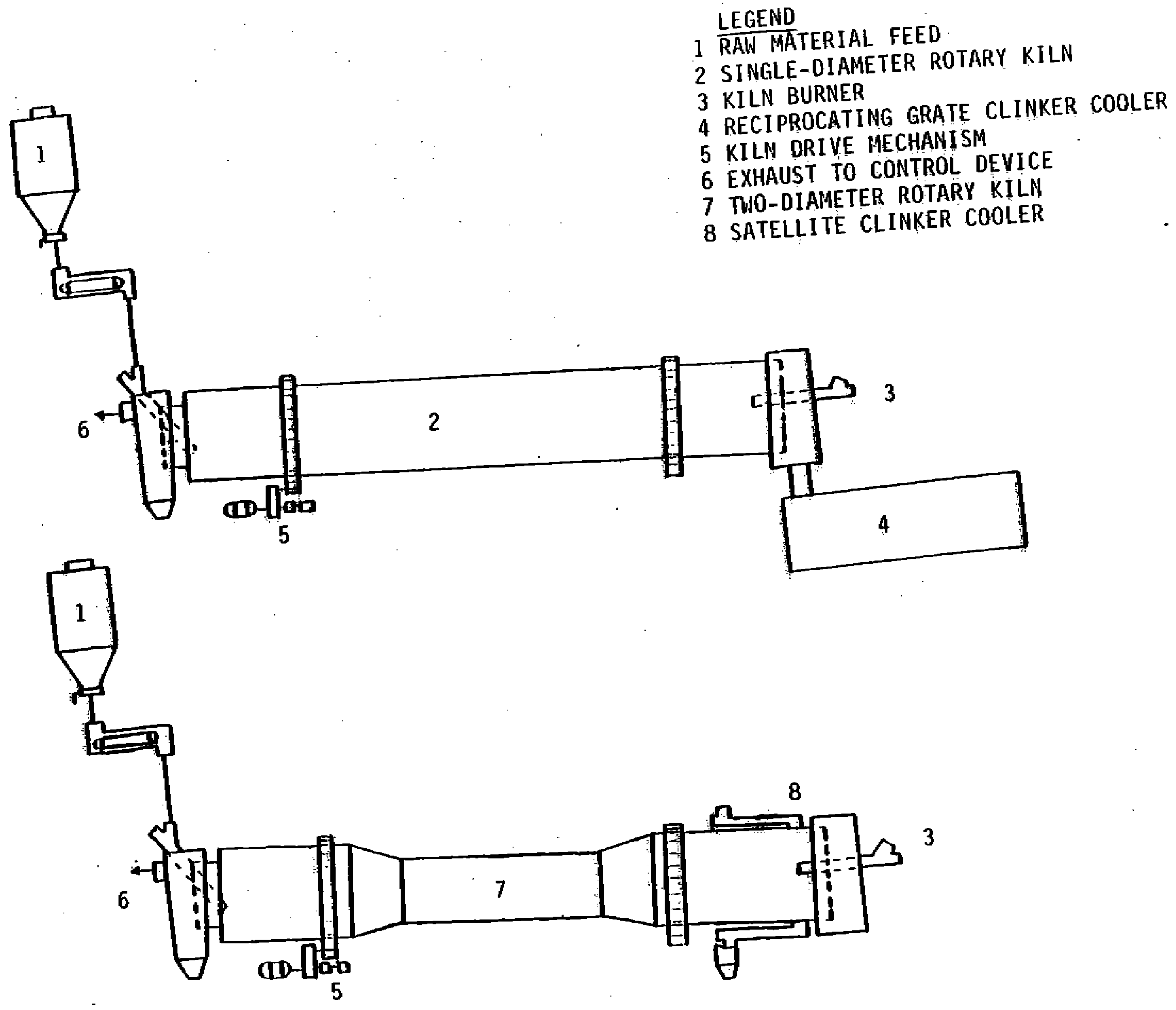


Figure 3- 9. Rotary kiln configurations.[27]

In contrast to rotary dryers, the primary source of heat transfer in rotary calciners is radiation from the refractory to the material bed. Secondary heat transfer occurs by convection from the hot gas to the exposed material bed surface.[29]

A dry-feed calciner has three zones of heating, and a wet-feed calciner has four zones. Each zone has a different heat transfer rate. These zones are:

1. Drying zone--at feed end, where free moisture is removed;
2. Heating zone--where charge is heated to the reaction temperature;
3. Reaction zone--where process material is burned, decomposed, reduced or oxidized, and bound moisture is removed; and
4. Soaking zone--wet-feed calciner only; where reacted charge is superheated or "soaked" at the desired temperature or cooled before discharge.[30]

The calcined product is discharged from the lower end of the drum into quench tanks, conveyors, or cooling devices that may or may not recover the heat content of the product.

Material movement through the kiln results from the combined effects of the kiln inclination and the rotation of the cylinder. Kiln inclination varies from 2 to 6 percent slope and the peripheral speed of rotation varies from 0.5 to 5 rpm.[27]

Most rotary calciners have countercurrent air and material flow to achieve the most energy efficient reduction in moisture content. Natural gas, oil, or pulverized coal are the predominant fuels, with natural gas being used in the greatest number of rotary calcining units.

3.1.2.2 Flash Calciners. Flash calciners are similar to flash dryers in principle and operation except that they operate at higher temperatures than flash dryers operate. A flash calciner is a refractory-lined cylindrical vessel with a conical bottom. Two types of flash alciner systems are used in the mineral industries: multi-stage and irect contact.

A flash calcining system used in the alumina industry is depicted Figure 3-10. This flash calcining unit consists of a two-stage lone, a preheater, a venturi-type flash dryer, the calciner, a

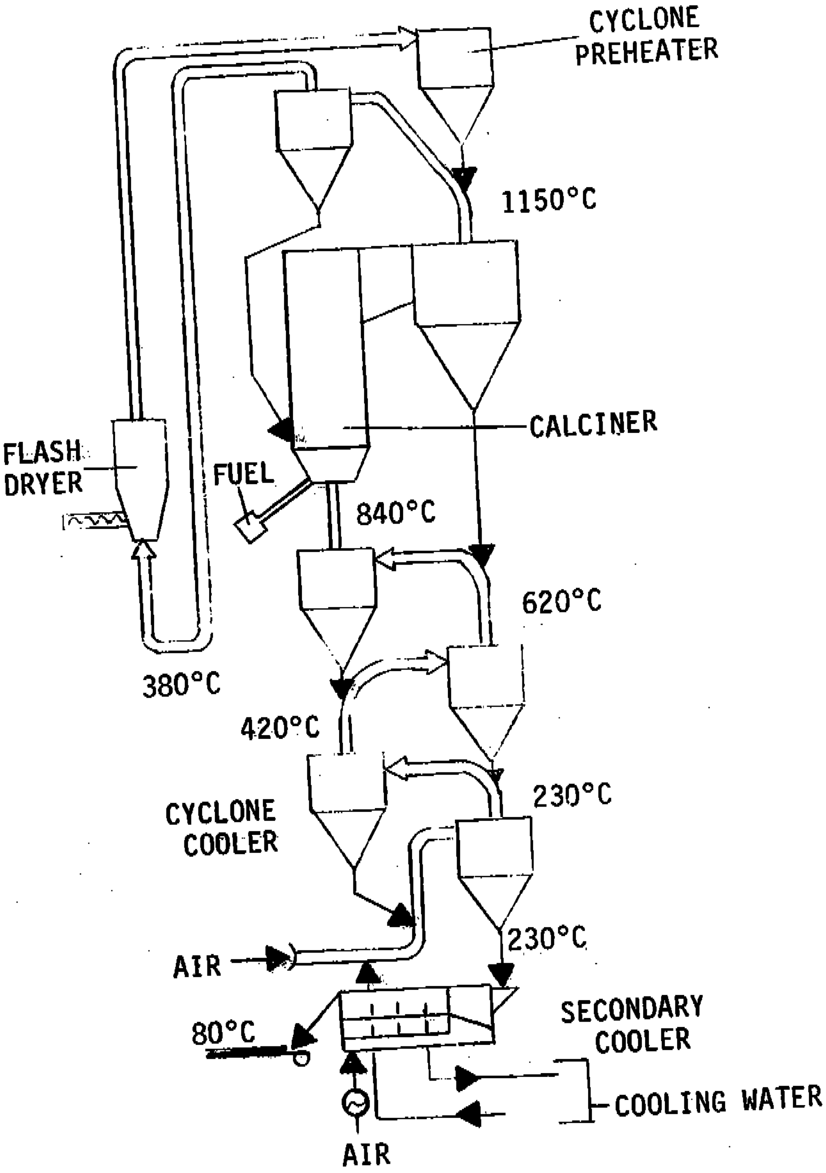


Figure 3-10. Flash calcining--aluminum.[31]

multi-stage cyclone cooler, and a secondary fluid bed cooler. The material enters the calciner from the cyclone preheater at a temperature of 300° to 400°C (570° to 750°F). The combustion air from the cooler enters the calciner at 815°C (1500°F), and a gas temperature of 1100° to 1450°C (2000° to 2640°F) is achieved in the calciner.[31] Preheated, partly calcined material is discharged into the reactor parallel to the bottom, just above the fuel inlet. The calcined material is retained for a few seconds and is then separated from hot gases in the separation cyclone, prior to being discharged into the primary cooler.

Figure 3-11 is a diagram of a direct contact flash calciner used in the gypsum and kaolin industries. Raw material is fed into the flash calciner by a fixed-speed screw feeder. The calcined product is formed in the cylindrical heating zone of the calciner and leaves from the lower end of the cylinder through a rotary valve.

Natural gas and distillate fuel oil are expected to continue to be the primary fuels used in the future at flash calciner installations. Coal is not expected as a future fuel source because of fly ash contamination of the product.

3.1.2.3 Multiple Hearth (Herreshoff) Furnaces. A multiple hearth furnace consists of a number of annular-shaped hearths mounted one above the other. Rabble arms on each hearth are driven from a common center shaft. Multiple hearth furnaces handle granular material and provide a long countercurrent path between flue gases and process material. These furnaces are used in the magnesium compounds and kaolin industries. Figure 3-12 shows a typical multiple hearth furnace design.

Material is fed by a screw conveyor into the furnace at the center of the upper hearth. Rabble arms connected to a center drive shaft move the charge to the periphery of the hearth where it falls to the next lower hearth. The material is then moved to the center of this second hearth from which it falls to the next hearth, and the cycle continues down the furnace. The hollow center shaft is cooled internally by forced air circulation.[33] Burners may be mounted at any of the hearths, and the circulated air is used for combustion.

3.1.2.4 Kettle Calciners. Kettle calciners have cylindrical metal shells, which are set in masonry brick and surrounded by a steel jacket.

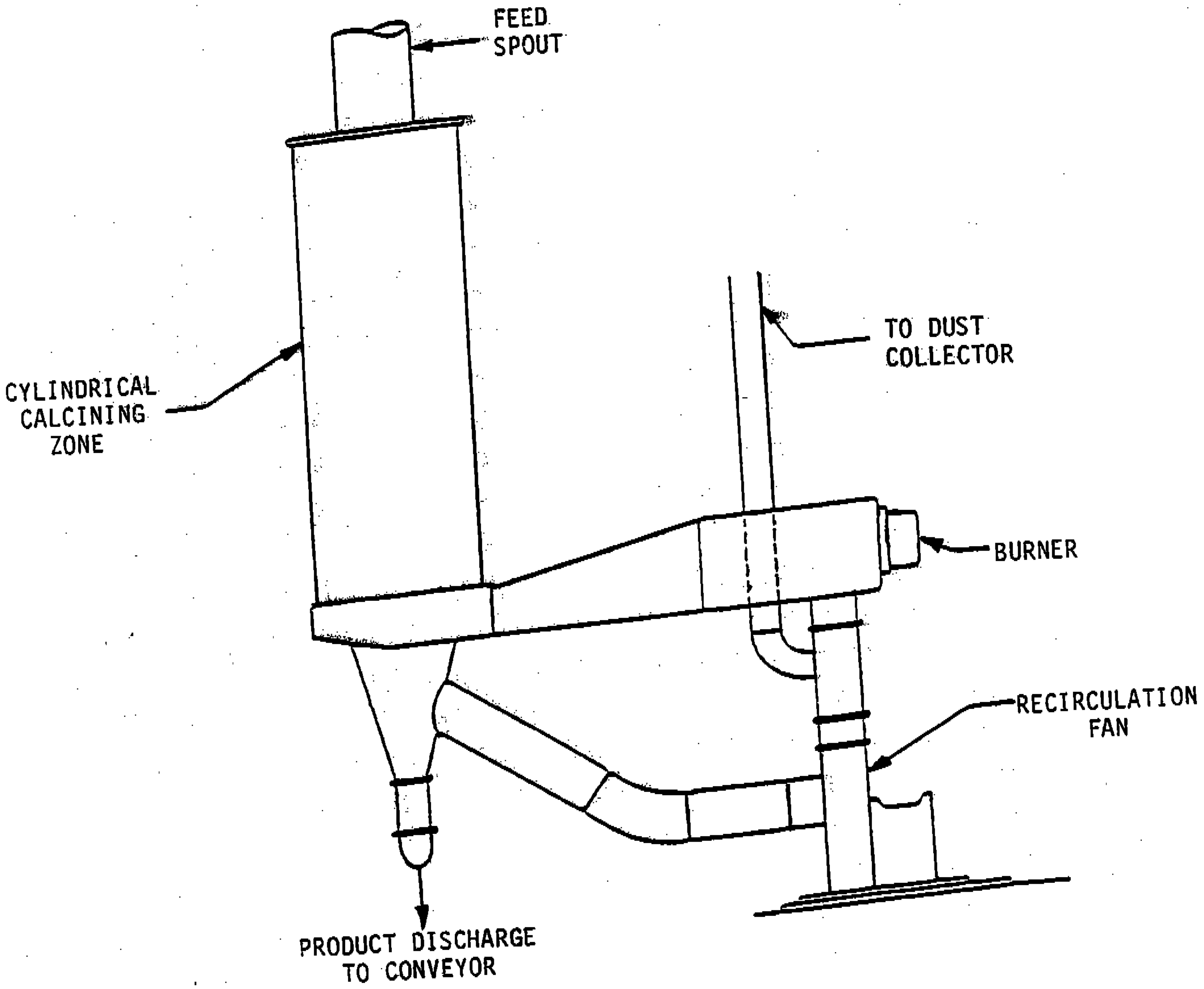


Figure 3-11. Direct contact flash calciner.[32]

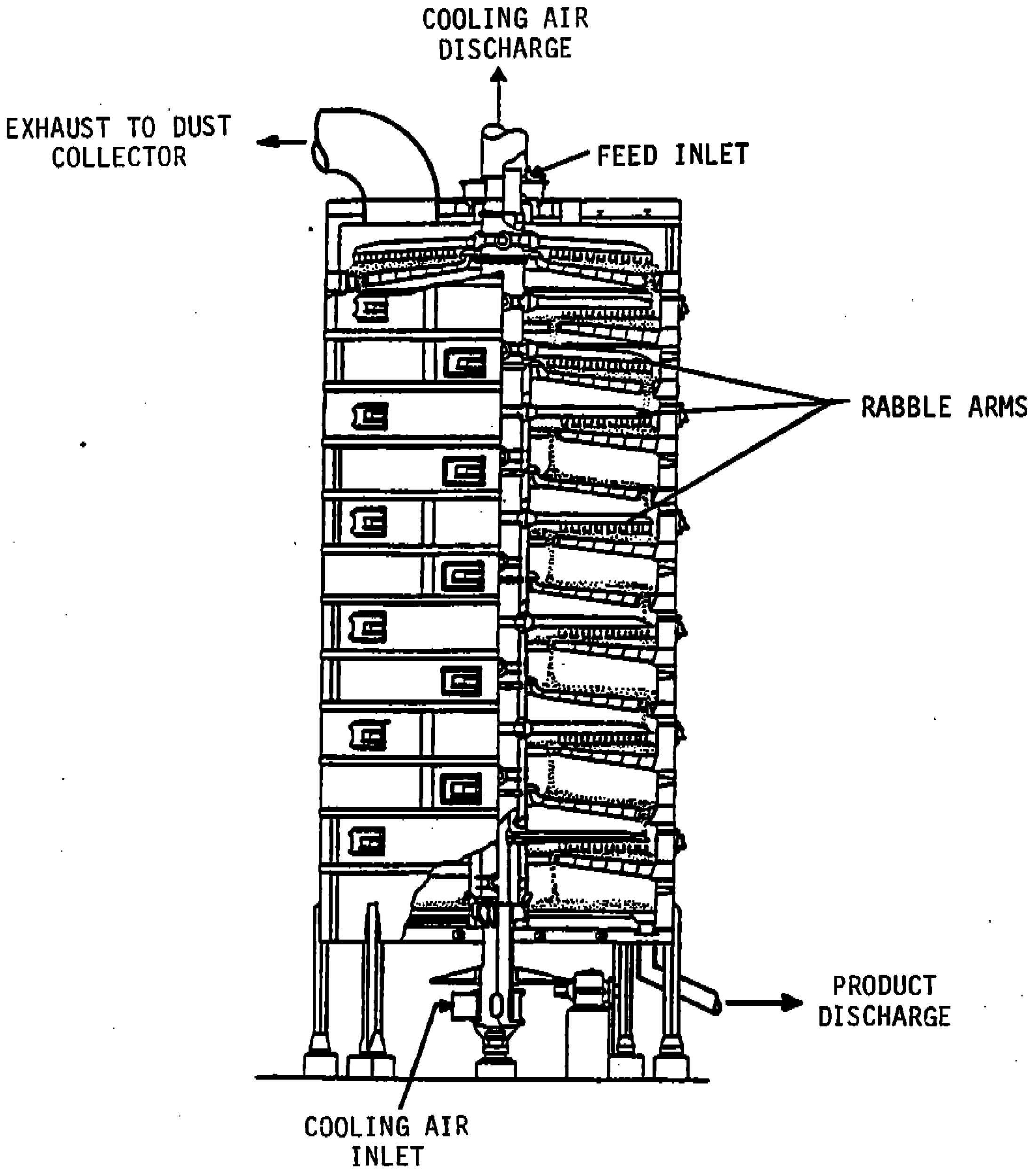


Figure 3-12. Multiple hearth furnace.[33]

The inner wall of the masonry is lined with a refractory. Kettle calciners are equipped with a baffled annular space between the kettle and the refractory lining. Hot combustion gases from a firebox beneath or adjacent to the kettle pass through the annular space and through flues inside the kettle to provide indirect heating. Horizontal arms attached to a vertical shaft in the center of the kettle agitate the raw material to provide mixing and thus prevent over-heating of the material. Ambient air is passed through the kettle to remove the water liberated by calcination. The calcined material is discharged into "hot pits" located below the kettle.[34] Figure 3-13 depicts a continuous kettle calciner.

Kettle calciners can be operated in a continuous or a batch mode. For continuous processes, the material is fed into the calciner using a variable-speed screw feeder. The temperature of the product is maintained between 90° and 120°C (200° and 250°F) by varying the feed rate while the fuel firing rate is held constant. The calcined material is removed continuously either by fluidizing the particles into an overflow channel that discharges directly into a hot pit or by emptying the material directly into a discharge spout.[34]

In batch processes, the dried material is fed to the kettle calciner by screw type feeders and is heated to between 150° and 180°C (300° and 350°F). The kettle is emptied by means of a discharge spout. The time required for batch processing varies from 1 to 3 hours depending on the quality of the feed, the kettle size, and the firing rate.[34]

Kettle calciners used in the gypsum industry are 3.0 m (10 ft) in diameter and 4.3 m (14 ft) in height. They have production rates of 4.5 to 12 Mg/h (5 to 13 tons/h) and a retention time of 60 to 180 minutes. Natural gas and distillate oil are the predominant fuel types used in most units.

3.1.2.5 Expansion Furnaces. Expansion furnaces are used to process ores that "expand" up to 20 times their original volume when exposed to high temperatures. Factors that affect the properties of the final product include the amount of entrapped water, the degree to which the crude ore particles approximate a cubic shape, size gradations, rate of heat application during expansion, and the method of injecting the crude

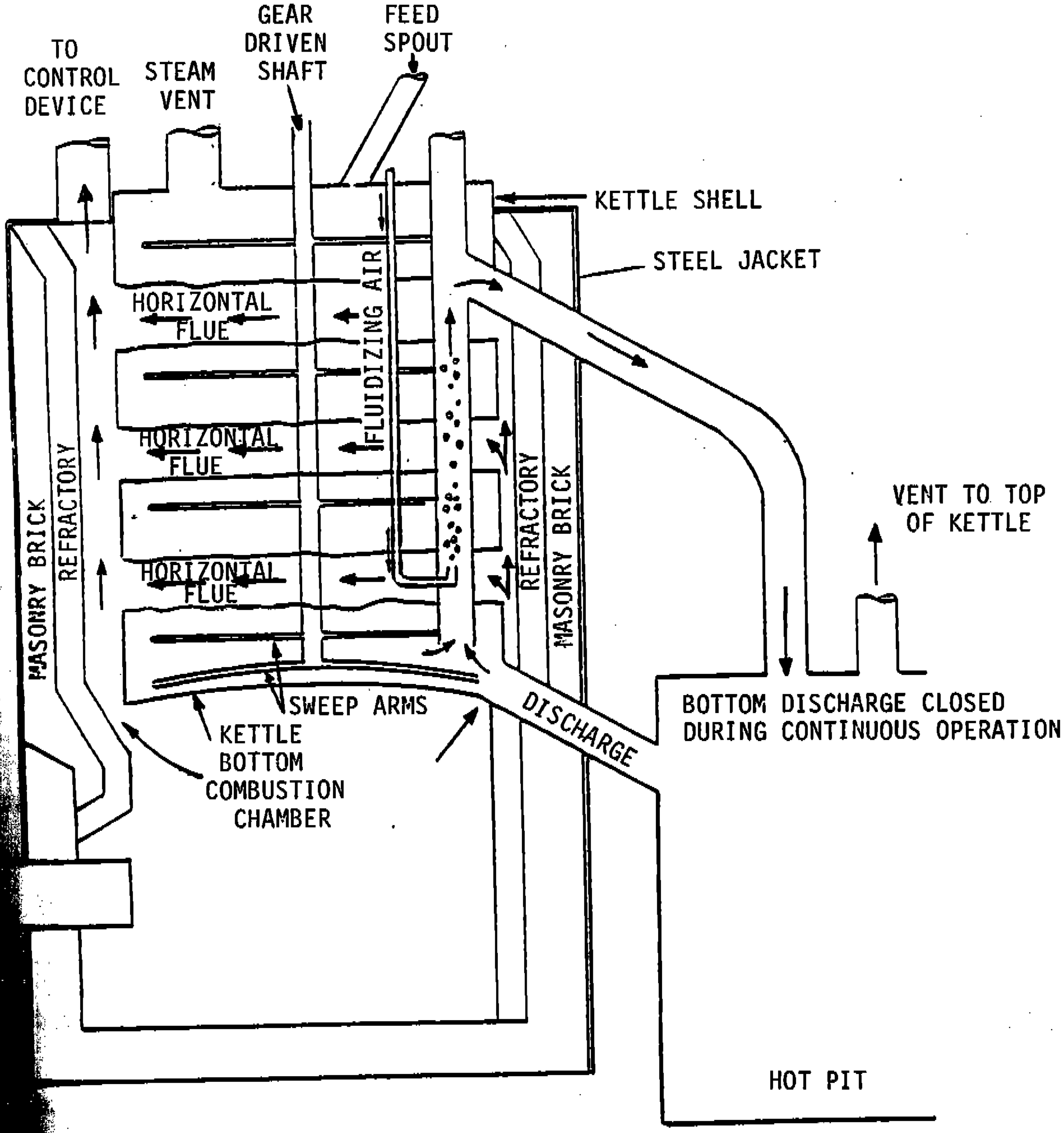


Figure 3-13. Diagram of a continuous kettle calciner.[35]

ore into the expansion zone of the furnace. Expansion furnaces are used in the perlite and vermiculite industries.

3.1.2.5.1 Perlite. Two types of expansion furnaces are used in the perlite industry. The stationary vertical furnace is the most common. Horizontal rotary furnaces are also used to a limited extent. Figures 3-14 and 3-15 present the general layouts of the two furnace types.

The stationary vertical expansion furnace consists of a steel tube insulated with refractory or by means of a shell that provides an air space around the furnace. Ore is introduced into the furnace just above the flame located at the base of the furnace cylinder. Expansion of the material occurs instantaneously as the ore is blown up the furnace by the combustion gases. The temperature at the point of expansion ranges from 700° to 1090°C (1300° to 2000°F), depending on the size of the crude ore to be expanded and its initial moisture content. Most furnaces process 0.9 to 1.8 Mg/h (1 to 2 tons/h) of material, and natural gas and fuel oil are used to fire most perlite expansion furnaces.[38]

The horizontal rotary expansion furnace has a preheating shell around the direct-fired expansion cylinder. After preheating, the feed is introduced into the rotating inner shell where it is exposed to the direct heat of the burner flame. An induced draft fan draws the particles out of the furnace and up to the product collection equipment.

The product from both furnace types is pneumatically conveyed to a product collection cyclone system. The primary cyclone removes the majority of the expanded particles, while the secondary cyclone collects smaller material. Material from the primary cyclone may then fall through a cooler/classifier unit that reduces product temperature before bagging.

At the present time, both horizontal and vertical perlite expansion furnaces are in use. There are advantages and disadvantages to each type, however the vertical furnace is expected to be the predominant design in the future.[39] The advantages a horizontal expansion furnace has over a vertical furnace are: (a) the horizontal furnace can expand wet ore, (b) it generally has a higher yield of expanded product per unit of raw ore because of a longer retention time and/or more uniform

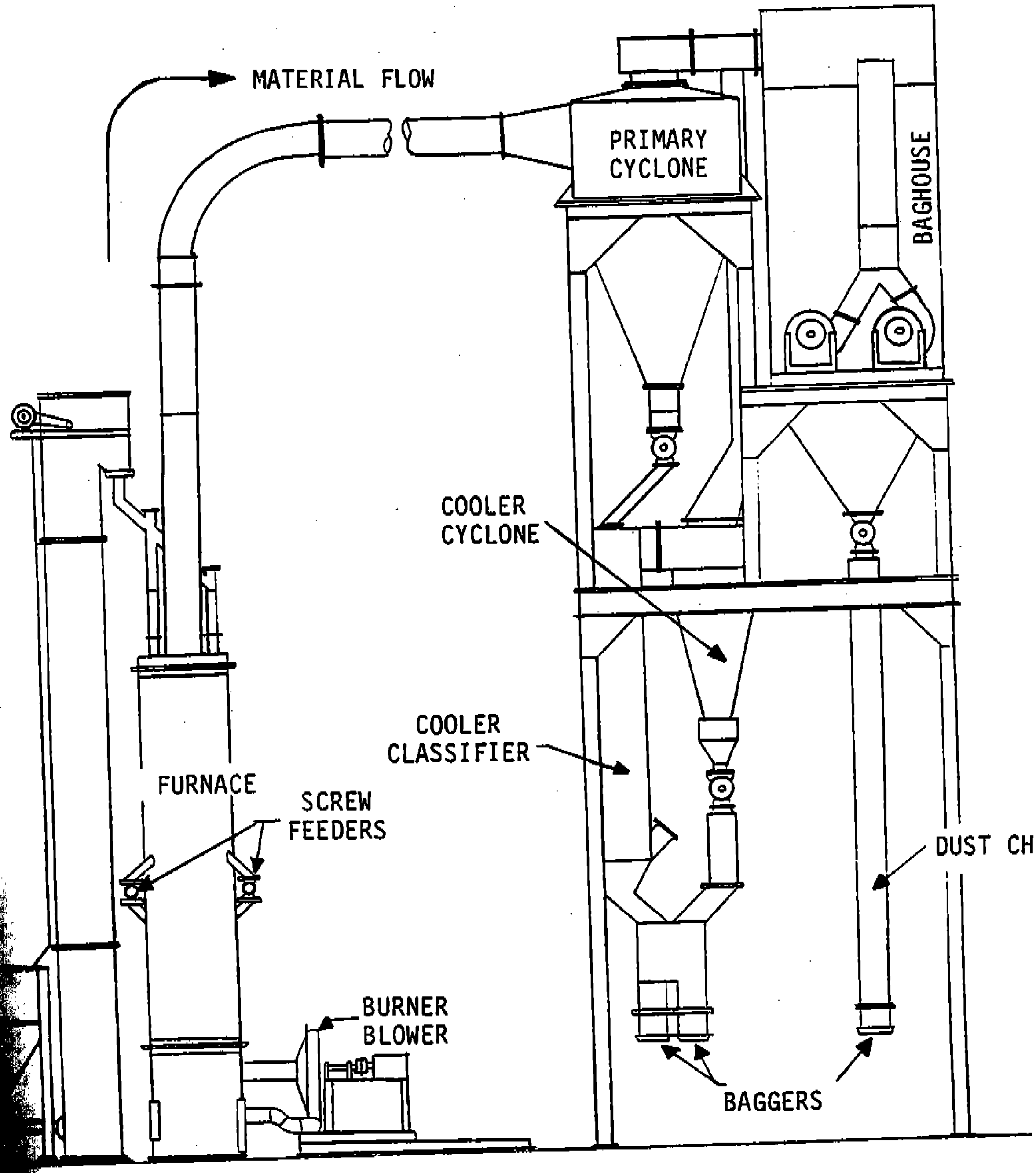


Figure 3-14. Vertical perlite expansion furnace.[36]

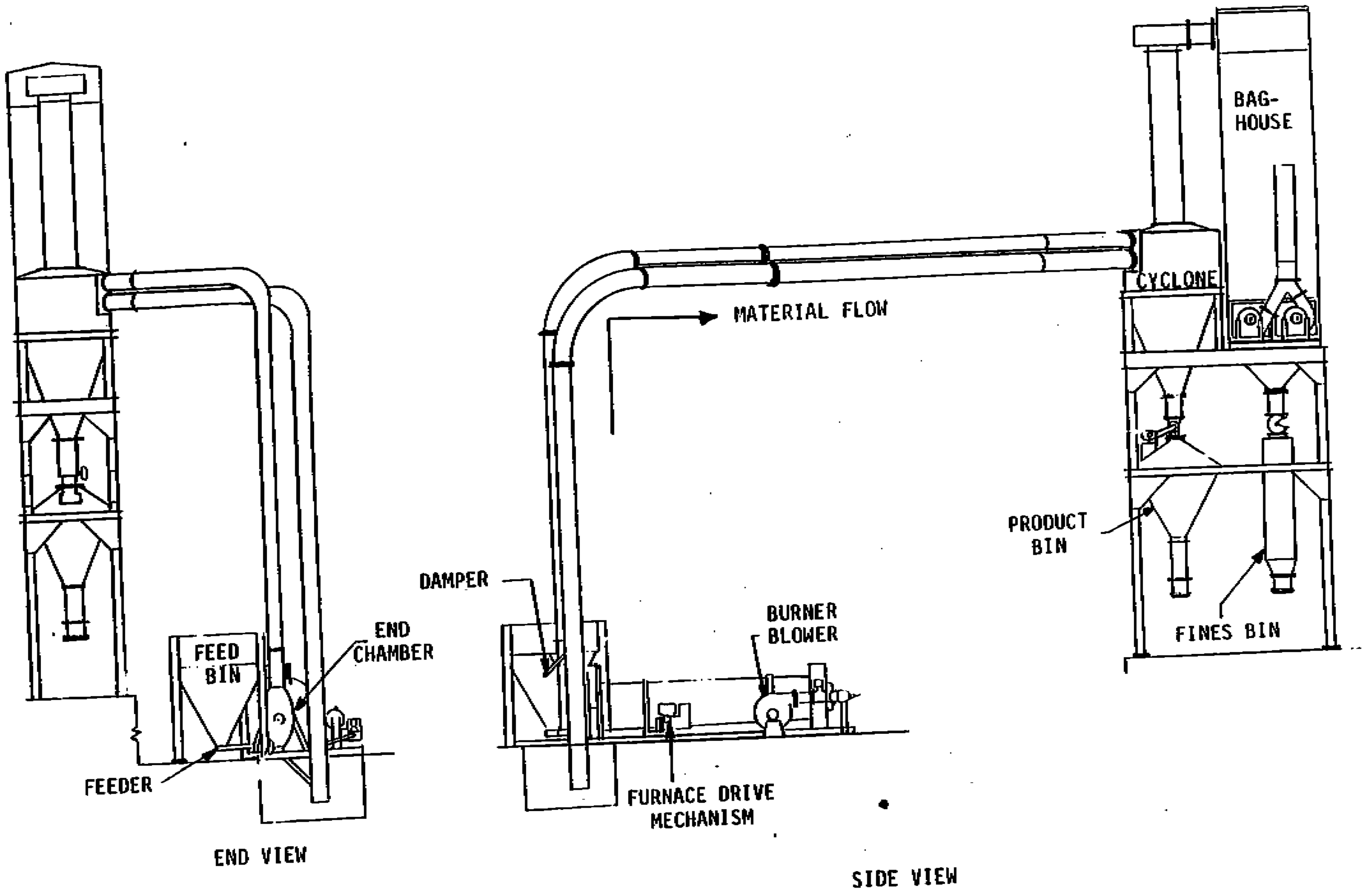


Figure 3-15. Horizontal rotary perlite expansion furnace.[37]

expansion, and (c) the horizontal furnace is more fuel efficient than the vertical furnace. Disadvantages of the horizontal furnace versus the vertical furnace are: (a) it cannot expand coarse grades of raw ore, (b) there is wear on mechanical parts due to the rotation of the shell, and (c) the potential for fugitive emissions is greater due to the methods of ore feed and product discharge.[39]

3.1.2.5.2 Vermiculite. Vermiculite expansion furnaces are similar in size to perlite expansion furnaces. Most vermiculite expansion furnaces are of the vertical type. The vermiculite concentrate is gravity-fed from the top to the bottom of the furnace instead of being blown from the bottom to the top as in vertical perlite furnaces. The combustion burner may be located at the top of the furnace or two horizontally opposed burners may be mounted mid-way in the refractory expansion chamber. The vermiculite expands 8 to 10 times its initial size, and its density decreases from approximately 880 kilograms per cubic meter (kg/m^3) (55 pounds per cubic foot [lb/ft^3]) to 100 to 130 kg/m^3 (6 to 8 lb/ft^3). It falls through the furnace and is then carried through a discharge chute into a finished product elevator. In some furnace types, the expanded vermiculite passes over a vibrating screen (stoner) to separate the unexpandable rock. In others, the expanded vermiculite is air conveyed and unexpandables are dropped out of the air lift rather than in a mechanical separator. The final product is bagged for shipment. The air stream passes through air pollution control equipment (usually a cyclone and a baghouse) prior to being exhausted to the atmosphere.[38]

3.2 DESCRIPTION OF INDUSTRIES

3.2.1 Alumina

3.2.1.1 Background. Alumina (Al_2O_3) is a white powdery material that is chemically extracted from bauxite. Deposits of bauxite are widespread globally, although the major deposits are confined to a belt extending 20° north and south of the equator.[40] Over two-thirds of the world's bauxite reserves are in four areas: Guinea (27 percent), ustralia (21 percent), Brazil (11 percent), and Jamaica (9 percent). .S. bauxite reserves are less than 0.2 percent of the world total.

Imports supplied about 90 percent of the U.S. bauxite requirements and 36 percent of the alumina requirements in 1981.[41]

The main use of alumina is in the production of primary aluminum. Alumina is also used in refractories and chemicals. The alumina products used by the refractories industry are tabular alumina, calcined alumina, and calcium aluminate cement.[42] In addition to these products, other chemical products made from alumina include activated alumina and hydrated alumina.

The Bayer process has been the standard commercial method for refining bauxite to alumina for the past 90 years. Although it has been improved and modified to treat different types of bauxites, the basic elements of the process remain unchanged. Bauxite is the only ore used in the commercial production of alumina. Almost 2 Mg (2.2 tons) of bauxite are required to produce 1 Mg (1.1 ton) of alumina, and almost 2 Mg (2.2 tons) of alumina are required to produce 1 Mg (1.1 ton) of aluminum.[43] Bauxite is comprised of gibbsite ($Al_2O_3 \cdot 3H_2O$) or, in some cases, boehmite ($Al_2O_3 \cdot H_2O$) and various mineral impurities of silicon, iron, titanium, and other elements.[44] Bauxite ores have an average alumina content of 40 to 60 percent.

3.2.1.2 Process Description.

3.2.1.2.1 General. A typical flow diagram for the production of alumina is shown in Figure 3-16. The bauxite ore is crushed in a primary crusher, screened, and is then further reduced in size by wet milling to increase the surface area of the ore. In the wet milling process, a caustic soda solution (a chemical reagent for the Bayer process) is added to the ore. The bauxite is then sent to slurry mixers.

In the slurry mixers, additional caustic soda solution is mixed with the bauxite. The resultant slurry is sent to huge digesters where, under high pressure and heat, the caustic soda dissolves the alumina in the bauxite, forming sodium aluminate. The reactive silica in the ore then reacts with the alumina and caustic soda and precipitates as a sodium aluminum silicate complex. Other impurities such as iron oxide are also insoluble and are removed by sedimentation or clarification.

In the clarification step, sodium aluminate remains in solution while the insoluble materials drop to the bottom of the settling tanks

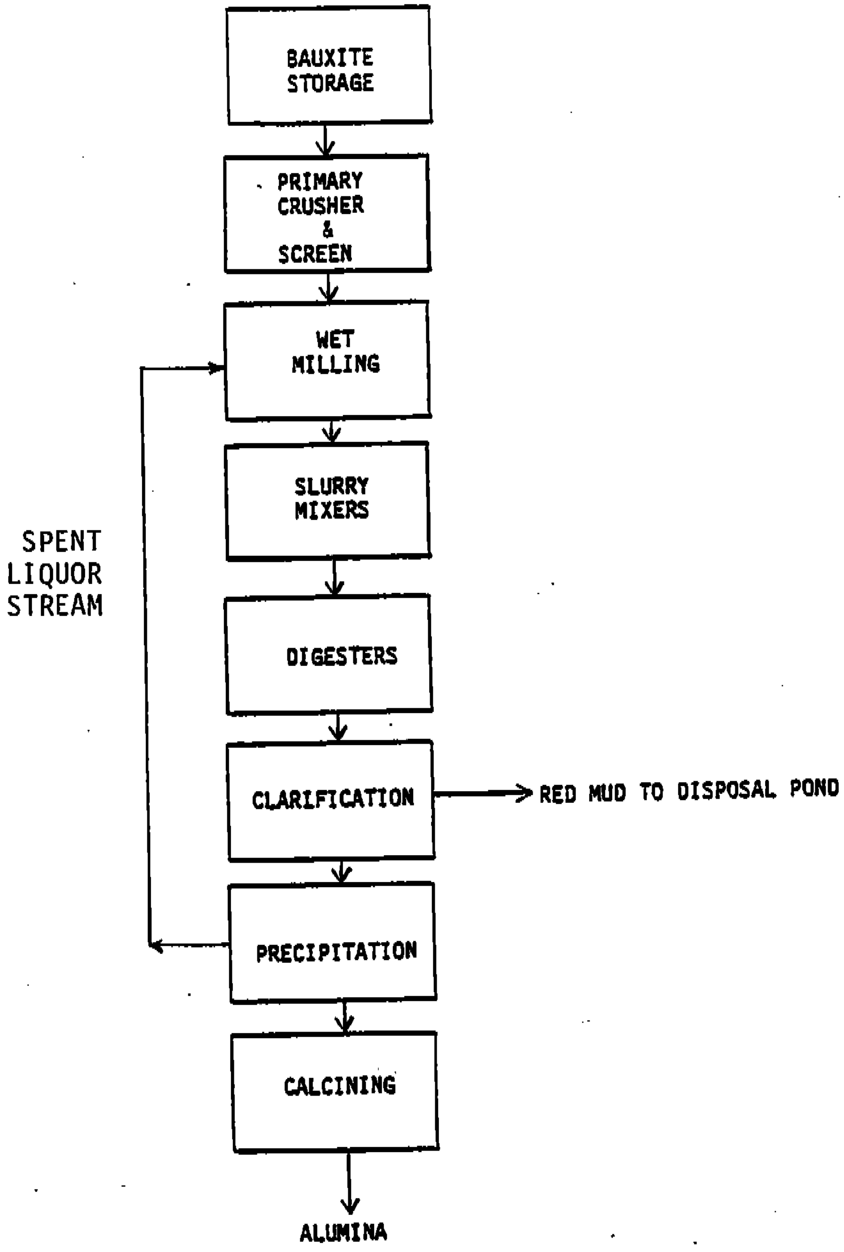


Figure 3-16. Simplified process flow diagram for alumina production.

as "red mud" and are pumped to a disposal pond. The sodium aluminate solution from the settling tanks passes through filters to remove suspended solids. The clear sodium aluminate solution is then cooled, agitated, and seeded with a small amount of aluminum hydroxide crystals to precipitate aluminum hydroxide. The precipitated aluminum hydroxide is separated, filtered, and then calcined to produce alumina.

The Bayer-Sinter method for processing high silica, low-grade, Arkansas Bauxite was developed by the Aluminum Company of America (Alcoa) in 1942.[45] This process is a modification of the Bayer process to recover most of the alumina and caustic soda from the red mud. The red mud of the Bayer process is sintered with limestone and soda ash. The silica forms a water-insoluble dicalcium silicate, and the soda ash is converted to water-soluble sodium aluminate, which is separated and returned to the Bayer process. The Bayer-Sinter process is also known as the Alcoa Combination process and is used at two plants in the United States.

3.2.1.2.2 Calcining. The calcining step in the production of alumina occurs in either rotary calciners (76 percent of the U.S. alumina production capacity in 1983) or flash calciners (24 percent of the U.S. alumina production capacity in 1983). The design production capacity of alumina rotary calciners ranges from 15 to 45 Mg/h (20 to 50 tons/h). The production capacities of alumina flash calciners are confidential.

The retention time of rotary units ranges from 45 to 180 minutes. The calciners are fired with either natural gas or fuel oil, and the heating method is countercurrent. The feed material to the calciners contains about 10 percent free moisture and about 31 percent bound moisture. The calcined alumina contains less than 1 percent bound moisture.

Although flash calcining is a relatively new technology, the industry trend appears to be toward flash calciners. The following are the main advantages of flash calciners over rotary calciners.[46]

1. Heat consumption is 25 to 33 percent lower.
2. Investment costs are lower.
3. Flash calciners require less floor area due to a more compact design.

4. Maintenance costs are lower, mainly due to a prolonged life of the calciner lining.

There are also some drawbacks to the use of flash calciners compared to rotary calciners.[46]

1. Power consumption is 53 to 61 percent higher.
2. There is less product flexibility with respect to the product quality produced.
3. Degree of particle breakdown is generally higher.

3.2.2 Ball Clay

3.2.2.1 Background. Ball clay is a fine-grained, sedimentary-type material composed of clay and nonclay materials. The principal component of ball clay (greater than 70 percent) is kaolinite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$). Clay minerals other than kaolinite in ball clay are illite, smectite, chlorite, and mixed-layer clay. Quartz is the most abundant nonclay mineral found in ball clay and ranges from 5 to approximately 30 percent of the clay. Other non-clay minerals present in minor amounts are plagioclase, potassium feldspar, and calcite. Organic matter is also common in most ball clays.

The color of ball clay deposits ranges from light buff through shades of gray to nearly black, depending on the amount of carbonaceous material present. Properties of ball clay are high plasticity, high wet and dry strength, high shrinkage due to drying and firing, and a wide vitrification range. The fusion or melting point is usually slightly lower than that for pure kaolins, and the fired colors are light ivory to cream. Specifications for ball clays are based on the method of preparation (crude, shredded, air-floated, water-washed, or slurry) and pertinent hysical and chemical tests, which are much the same as those for kaolin.[47]

Ball clay production in 1980 was reported from 42 mines in eight ates. Tennessee provided 65 percent of total production, followed in der by Kentucky, Mississippi, Texas, Maryland, New York, and California. ll clay is primarily mined in a 48-kilometer (km) (30-mile [mi]) -wide a extending southward from Mayfield, Kentucky, to Huntingdon, Tennessee. ason, Tennessee, is roughly the center of the industry.

Most ball clay plants are highly integrated operations capable of mining, processing, packaging, and shipping the finished product. Major uses for ball clay are as follows: sanitary ware--24 percent; pottery--22 percent; tile--16 percent; china/dinnerware--6 percent; electrical porcelain--2 percent; firebrick--2 percent; exports--11 percent; and other--17 percent. Other uses include adhesives, animal feed, drilling mud, paper coating, and pesticides.[48]

3.2.2.2 Process Description. A general process flow diagram for ball clay production is shown in Figure 3-17. Ball clay is strip mined without blasting and trucked about 1.6 to 8 km (1 to 5 mi) to mills. The crude clay, containing 27 to 28 percent moisture, is stockpiled in drying sheds for approximately 2 months. During shed drying, the moisture content is reduced to 20 to 24 percent. Approximately 7 percent of the clay is marketed in this form.[49]

The clay is then passed through a "disintegrator" that slices or chops the material into 1.3- to 2.5-cm (0.5- to 1-in.) pieces before it is conveyed to the dryer. Both indirect-fired rotary and indirect-fired vibrating-grate dryers are used in ball clay production. According to an industry spokesperson, direct-fired rotary units were once used by some ball clay producers; however, these units have been replaced by vibrating-grate dryers.[50]

In rotary dryers, indirect heating is accomplished by having the combustion gases from the firebox pass through a cylinder mounted on the dryer axis. The clay is dried by radiant and convective heat transferred from the cylinder to the air in the dryer. The vibrating-grate dryers are also indirect-fired. The combustion gases from the firebox pass through an air-to-air heat exchanger to heat the drying and fluidizing air to 300°C (575°F). This air is injected below, and passes up through, a screen over which the clay travels in air suspension. The screen bed vibrates horizontally along the longitudinal axis of the dryer. This motion and a slight drop in the dryer bed cause the clay to move toward the discharge end. Heat is introduced below the dryer bed over about 80 percent of its length. The clay leaves the dryer at a temperature of about 24°C (78°F). The moisture content of the clay after drying ranges

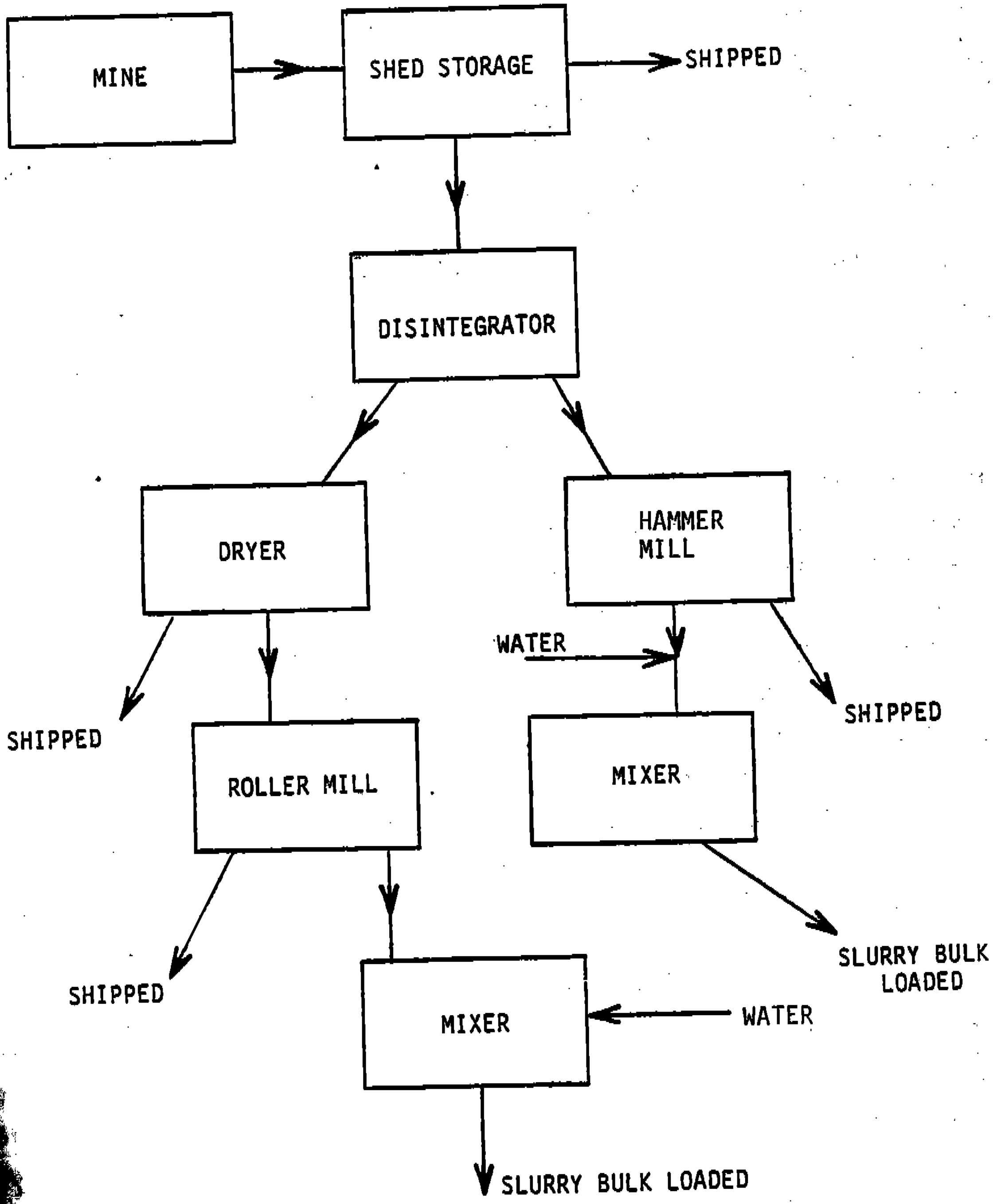


Figure 3-17. Ball clay process flow diagram.

from 8 to 10 percent.[51] Overdrying often results in a significant reduction of the clay's plasticity, thus lowering its value.

3.2.3 Bentonite

3.2.3.1 Background. Bentonite is a clay consisting essentially of smectite minerals (montmorillonite group). The montmorillonite group can be represented by means of ion substitutions in the chemical formula of the related mineral pyrophyllite ($Al_2Si_4O_{10}(OH)_2$). In a typical montmorillonite ore, about one-sixth of the aluminum is replaced by magnesium and such exchangeable ions as calcium, sodium, and potassium.[52] All bentonite contains mineral impurities that vary considerably in type and quantity.

Bentonite can be classified based on its swelling capacities when wet. Bentonite with sodium as the dominant exchangeable ion typically has very high swelling capacities and forms gel-like masses when added to water.[52] Bentonite with calcium as the more abundant ion is termed a low-swelling bentonite because it swells little more than common clay. Mixed types contain both calcium and sodium in sizable concentrations and swell moderately. Types of bentonite outside these groups are hectorite (a high-swelling lithium-bearing variety of smectite occurring in California and adjacent States), the potassium type (K-bentonite which occurs in the Appalachian and Mississippi Valley regions), and other bentonites with magnesium or hydrogen as the most abundant exchangeable ions.[52]

The high-swelling (sodium) bentonite deposits are located primarily in Wyomimg and adjacent States and are often called "Wyoming" or "Western" bentonites. Low-swelling (calcium) bentonite occurs in States bordering the Gulf of Mexico and is commonly called "Southern bentonite." Wyoming led all States in 1980 production with 69 percent of the total production, followed by Montana and Mississippi with 14 and 7 percent, respectively.[53]

Bentonite was first used as a drilling mud in the late 1920's and is still one of the most efficient materials for drilling muds where the rock penetrated contains only fresh water. Another use of bentonite, also begun in the 1920's, is to bind foundry sands into desired shapes in which metals can be cast. Because of the fine particle size and the nature of its water adsorption, bentonite gives the mold a higher green, dry, and hot strength than does any other type of clay.[52] Bentonite is also used in the pelletizing of taconite iron ore. The fine iron particles produced during the concentration process are pelletized with the aid of bentonite.

Bentonite is used in making catalysts for petroleum refining, although this market has been declining since World War II. Acid-activated bentonite is used for bleaching oils and in making multiple-copy paper. Bentonite is used as a filtering agent for clarifying water and treating wastewater. It is also used for preventing seepage loss from reservoirs, irrigation ditches, and waste-disposal ponds. Bentonite is also used as an ingredient in cosmetics, animal feed, pharmaceuticals, colloidal fillers for certain types of paints, fire-retardant materials, and as an additive to ceramic raw materials to increase plasticity.

3.2.3.2 Process Description. A simplified flow diagram for bentonite processing is shown in Figure 3-18. Virtually all bentonite is mined by stripping, that is, removing the overburden.[54] After the overburden is removed, the clay is loaded onto trucks using draglines or front-end loaders. The thickness of the overburden varies considerably. Most bentonite in Wyoming has less than 9 m (30 ft) of overburden, although in a few places the overburden can be as much as 12 m (40 ft) thick. The overburden for Southern bentonite can be as thick as 30 m (100 ft). Bentonite deposits can range from 180 m (590 ft) to 320 km (200 mi) in length and from 0.3 to 9 m (1 to 30 ft) in depth.[54]

In Wyoming, the mined bentonite is spread on the ground at the mine ite to air dry. The initial 30 to 35 percent moisture content is duced to 16 to 18 percent moisture to facilitate subsequent drying and inding processes.[54] The field drying is assisted by plowing the ntonite ore. From the mine site, the ore is trucked to the mill and ored in open stockpiles. Because of variable physical properties, tonite from a single location may be separated into as many as three ckpiles at the mill. Bentonite is often blended as it is dumped on ckpiles using earth-moving or cultivating equipment to obtain a orm clay. The bentonite passes through a grizzly and a crusher that ces the ore to less than 2.5 cm (1 in.). The crushed ore is dried

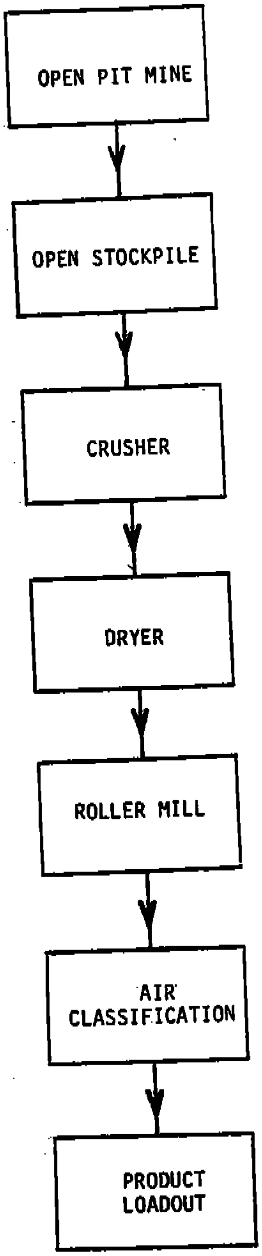


Figure 3-18. Bentonite processing.

by rotary or fluid bed dryers that reduce the moisture from 16 to 18 percent to 7 to 8 percent.[54] Soda ash (Na_2CO_3) may be added to the ore to improve the swelling properties.

Bentonite rotary dryers range from 2 to 3 m (8 to 10 ft) in diameter and 14 to 20 m (45 to 65 ft) in length. Design production rates range from 16 to 55 Mg/h (18 to 60 tons/h). Temperature in the dryer varies with the intended use of the clay.[51] The desirable properties of bentonite are reduced greatly if the clay is overheated. Typical gas temperatures in these dryers are 800°C (1470°F) at the inlet, 400° to 500°C (750° to 930°F) inside, and 100° to 200°C (210° to 390°F) at the outlet.[52] The temperature of the bentonite itself is kept at less than 140°C (300°F). The retention time in bentonite dryers is approximately 20 minutes.[54] In the past, the fuels used most frequently were natural gas and oil. However, since the 1970's, coal has been frequently selected as the primary fuel with natural gas used as a standby.

3.2.4 Diatomite

3.2.4.1 Background. Diatomite is a chalky, sedimentary rock consisting mainly of an accumulation of skeletons formed by diatoms, which are single-celled microscopic aquatic plants. The skeletons are essentially amorphous hydrated or opaline silica, but occasionally include some alumina. The unique physical properties of diatomite derive from the size, shape, and structure of individual diatom skeletons and the packing characteristics of a mass of the particles. Diatoms range in diameter from about 10 μm (4 x10^{-4} in.) to over 500 μm (0.02 in.) and generally have a spiny structure with intricately pitted surfaces. Contact between particles is chiefly at the outer points of the irregular urfaces. Ground diatomite is a microscopically porous material with an parent density of 80 to 255 kg/m^3 (5 to 16 lb/ft^3), giving this terial exceptional filtering and thermal characteristics.[55]

The separation of diatomite products into various grades is based different performance characteristics determined by empirical tests. essed diatomite powders are classified into three general types d on production methods. These types are: (1) natural, which is uced by simple milling, drying, and air classification, (2) calcined nk, which results from further heat treatment of the natural, and

(3) flux-calcined or white, which is from a similar heat treatment but with the addition of a fusible alkali salt. These process designations do not translate directly into the market classifications. The major processed diatomite products are powders and aggregates of variable sizes and grades. Diatomite products are used primarily as filter aids and fillers.

Calcined diatomite has a number of unique physical properties and therefore has diversified uses. The widest use (66 percent in 1980) for diatomite is as a filter aid for the separation of suspended solids from fluids. The greatest growth potential for diatomite use is in this area of application because of increased emphasis on water purification and the removal of objectionable impurities in manufactured products and reusable process fluids. Diatomite is processed into filter aids for all types of food and nonfood processing applications. The more commonly known applications are in the filtration of dry cleaning solvents; pharmaceuticals; beer, whiskey, and wine; raw sugar liquors; antibiotics; industrial, municipal, and swimming pool waters; fruit and vegetable juices; lube, rolling mill, and cutting oils; jet fuels; organic and inorganic chemicals; and varnishes and lacquers.

The second largest use of diatomite is as a filler or extender for paint, paper, asphalt products, and plastic, which accounted for 21 percent of production in 1980. Other uses of diatomite include abrasives, absorbents, catalysts, fertilizer coatings, insulation, and lightweight aggregates, which collectively consumed 13 percent of the total production in 1980.

All domestic diatomite production comes from the western States of California, Nevada, Oregon, and Washington, with California accounting for more than half of the total national production.

3.2.4.2 Process Description. Most diatomite deposits occur at or near the surface and can be mined by open pit methods or quarrying. Diatomite mining in the United States is all open pit, normally using some combination of bulldozers, scraper-carriers, powershovels, and trucks to remove overburden and the crude material. In most cases, fragmentation by drilling and blasting is not necessary. The crude diatomite is loaded onto trucks and transported to the mill or to stock piles. Figure 3-19 shows two alternative flow diagrams for diatomite processing.

The processing of uncalcined or natural-grade diatomite consists of crushing and drying. Crude diatomite commonly contains as much as 40 percent moisture, and in many cases contains over 60 percent. Primary crushing to aggregate size (normally done by a hammermill) is followed by simultaneous milling-drying, with suspended particles of diatomite carried in a stream of hot gases.[57] The suspended particles pass through a series of fans, cyclones, and separators to a baghouse. These sequential operations result in the separation of the powder into various sizes, in the removal of waste impurities, and in the expulsion of the absorbed water. These natural milled diatomite products, without additional processing, are then bagged or handled in bulk, principally for fillers and uses other than filter aids.

For filtration uses, natural grade diatomite is calcined by heat treatment in a rotary calciner, with or without a fluxing agent. For straight-calcined grades, the powder is heated to the point of incipient fusion in large rotary calciners and is then subjected to further milling and classifying. Straight calcining is used for adjusting the particle ize distribution for filter aid applications where medium flow rates re required and results in a product with a pink cast. The color, ich is caused by the oxidation of iron in the crude, becomes more tense with an increasing iron oxide content.

Further adjustment of particle size is brought about by the addition flux, usually soda ash, before the calcining step. The addition of uxing agent sinters the diatomite particles and increases the particle , thereby increasing the flow rate during liquid filtration. The ting products are referred to as flux calcined. Flux calcining es a white product that is believed to be formed by the conversion iron to complex sodium-aluminum-iron silicates rather than con- to the oxide. Further milling and classifying follow calcination.

.4.2.1 Dryers. The presence of moisture and other impurities irable for the many end uses of diatomite. Therefore, nearly nt of the total mined diatomite is dried at low temperatures.

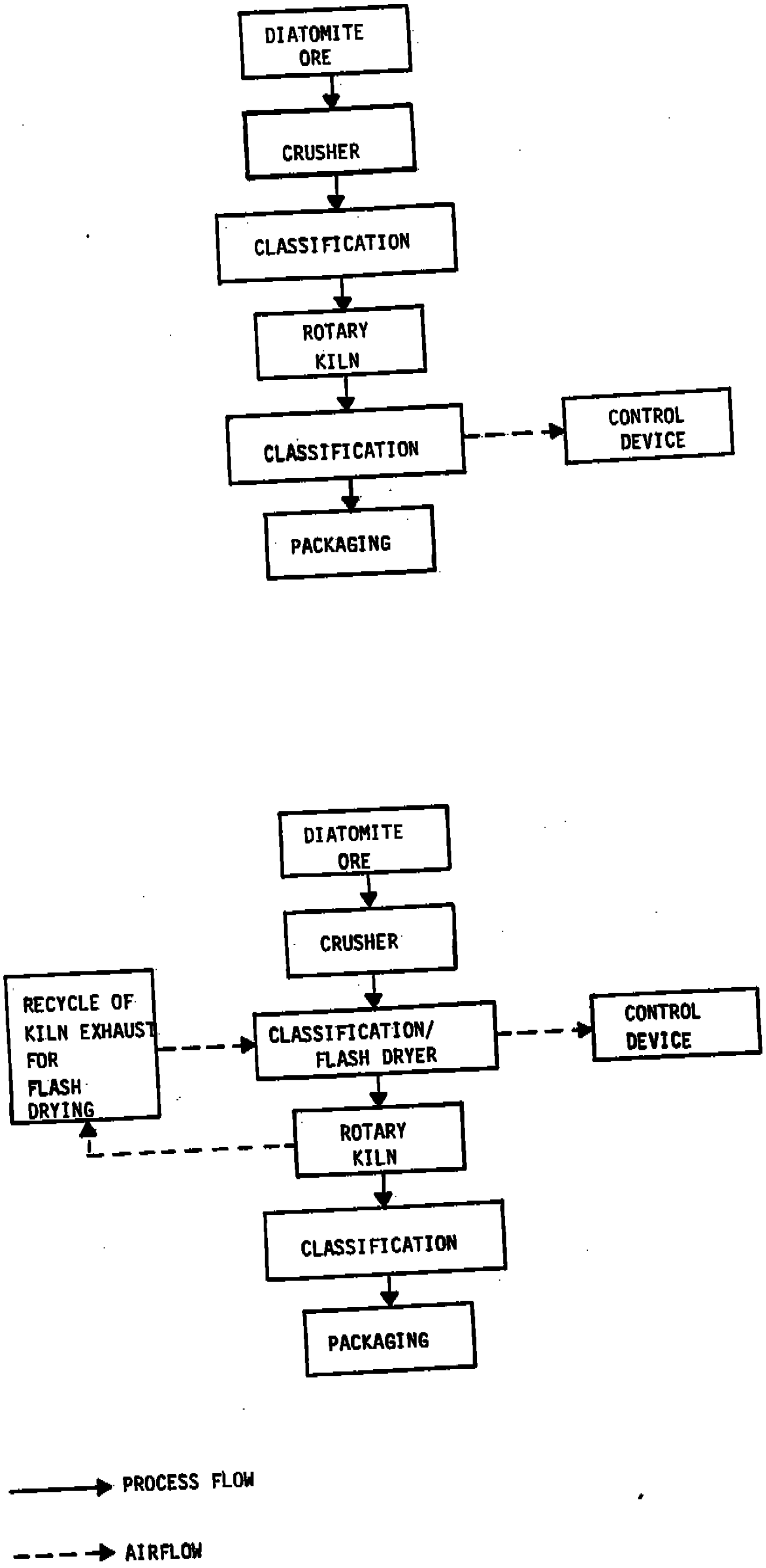


Figure 3-19. Alternate process flow diagrams for diatomite production.[56]

The flash dryer is the most common dryer type, although rotary dryers are also used to produce uncalcined or natural diatomite. The furnace temperature ranges from 760° to 820°C (1400° to 1500°F) in the flash drying system.[56] Operating temperatures within the flash drying system range from 70° to 430°C (150° to 800°F) with an average of about 200°C (400°F). The exhaust gas temperature from these dryers is typically 70°C (150°F). These dryers reduce the moisture content to approximately 15 percent.

As the diatomite is dried within the heated gas stream, it is classified to remove waste materials, such as ash, clay, and opalite (a nonporous mineral not suitable as a filtering medium). These waste materials constitute a small percentage (typically less than 7.5 percent) of the raw diatomite and are disposed of in a tailings pond. After this initial classification, approximately 90 percent of the diatomite particles are less than 44 µm (325 mesh) in diameter.[56] The retention time of the diatomite in the flash dryer is approximately 60 seconds.

3.2.4.2.2 <u>Calciners</u>. Industry representatives indicate that rotary calciners are used for straight-calcined and flux-calcined diatomite processing. Calcining is done in a standard rotary kiln where the flux-mixed crude diatomite is calcined to obtain a desired product. Desired physical properties of the "burn" are achieved by controlling the calciner feed, calciner gas temperature, calciner draft, and variations in the flux additions. The calciner burn is a critical part of the operation. During the burn, a cementing action occurs between the particles of diatomite and the fluxing agent so that the discharge aterial from the calciner is coarser than the calciner feed.

Design production rates in diatomite rotary calciners range from 5 to 10 Mg/h (5 to 11 tons/h). Temperature in the kiln varies and nges from 650° to 1200°C (1200° to 2200°F). Either natural gas or l oil can be used as fuel for the calciner. Residence time of rial in the calciner averages 30 to 80 minutes.

In general, both calciner operating temperature and residence time functions of the type of product being made. Impurities not removed fused slag are subsequently removed in "finish end" separators. ic matter is removed by combustion. Flux calcination is carried out by adding soda ash as the fluxing agent. The product is discharged from the kiln by gravity and goes to the finish and classification system. The waste heat from the calciner (calciner draft) may be used for drying the crude in the secondary drying circuit discussed earlier.

3.2.5 Feldspar

3.2.5.1 Background. Feldspar is the most abundant mineral of the igneous rocks and designates a group of closely related minerals, consisting essentially of aluminum silicates in combination with varying amounts of potassium, sodium, and calcium.[58] Feldspar can be divided into soda feldspar (7 percent or higher Na_2O) and potash feldspar (10 percent or higher K_2O). Feldspar-silica mixtures can either be a naturally occuring material, such as sand deposits, or a processed mixture obtained from flotation of mined and crushed rock. Feldspar flotation concentrates can be classified as either soda, potash, or "mixed" feldspar, depending on the relative amounts of Na_2O and K_2O present.

The three largest feldspar-producing States are North Carolina, Connecticut, and Georgia. These States produced 90 percent of the 1983 production.[59] Approximately 55 percent of the 1983 feldspar production was used in glassmaking, and 41 percent was used for porcelain enamels. The remaining 4 percent was used in miscellaneous applications.[59]

Raw materials most often substituted for feldspar are aplite and nepheline syenite.[60] Aplite, a granitic rock, is mined in Virginia and is used mostly in glassmaking. Nepheline syenite is a coarse crystalline rock resembling granite; all nepheline syenite consumed in the United States is imported from Ontario, Canada. The glass industry, because of its ability to use a variety of alumina sources, can switch from feldspar to nepheline syenite, aplite, or feldspathic sand (feldspar-quartz mixtures) by relatively simple reformulation.[58]

3.2.5.2 Process Description.

3.2.5.2.1 General. Most pegmatite, alaskite, and granite ores containing feldspar are mined by conventional open-pit methods: removal of overburden, drilling and blasting, loading, and transport by trucks.[58] Most feldspar ores are beneficiated by a froth flotation process. The flotation process removes the contaminating impurities, keeps the alumina content at 19 percent, and recovers slime-free granular products, all minus 841 μm (20 mesh), usually with less than 10 percent finer than 74 μm (200 mesh).[61]

A process flow diagram of the flotation process is shown in Figure 3-20. The ore passes through primary and secondary crushers and through fine grinding in jaw crushers, cone crushers, and rod mills, respectively.[60] The ore is then further reduced to 841 μm (20 mesh) by rod mills.[61,62] A three-stage, acid-circuit flotation process occurs next with each stage preceded by desliming and conditioning. The rod mill discharge is deslimed in a rake classifier producing a sand and a slime in a hydroclassifier. The overflow, generally minus 44 μm (325 mesh), is discarded. The underflow enters the rake classifier just above the liquid level. The product enters the first conditioner at 65 to 70 percent solids.[60]

The first flotation step uses an amine collector to float off and remove mica. Sulfuric acid, pine oil, and fuel oil are also added. After the feed is dewatered in a classifier or cyclone for reagent removal, the pH is lowered by addition of sulfuric acid. Petroleum sulfonate (mahogany soap) is used as the collector to remove iron-bearing minerals, most notably garnet. In the last step, the discharge from the cond flotation step is again dewatered, and the feldspar is floated ay from the quartz in a hydrofluoric acid environment (pH of 2.5 to 0) using a cationic amine as the collector.[63]

If feldspathic sand is the raw material, no size reduction may be uired. Also, if little or no mica is present, the first flotation may be bypassed so that the mill feed goes directly to the condiing step before the garnet removal stage. Sometimes the final tion stage is omitted and this product is marketed as a feldspar- mixture (often referred to as sandspar), usually for consumption ssmaking.[60]

The feldspar float concentrate, whether from sands or hard-rock , is dewatered to 5 to 9 percent moisture in drainage bins, over filter, or in a centrifuge.[60] A rotary dryer then reduces the content to 0 to 1 percent.[62,63] Magnetic separation is then backup process to remove any iron minerals present. Dry

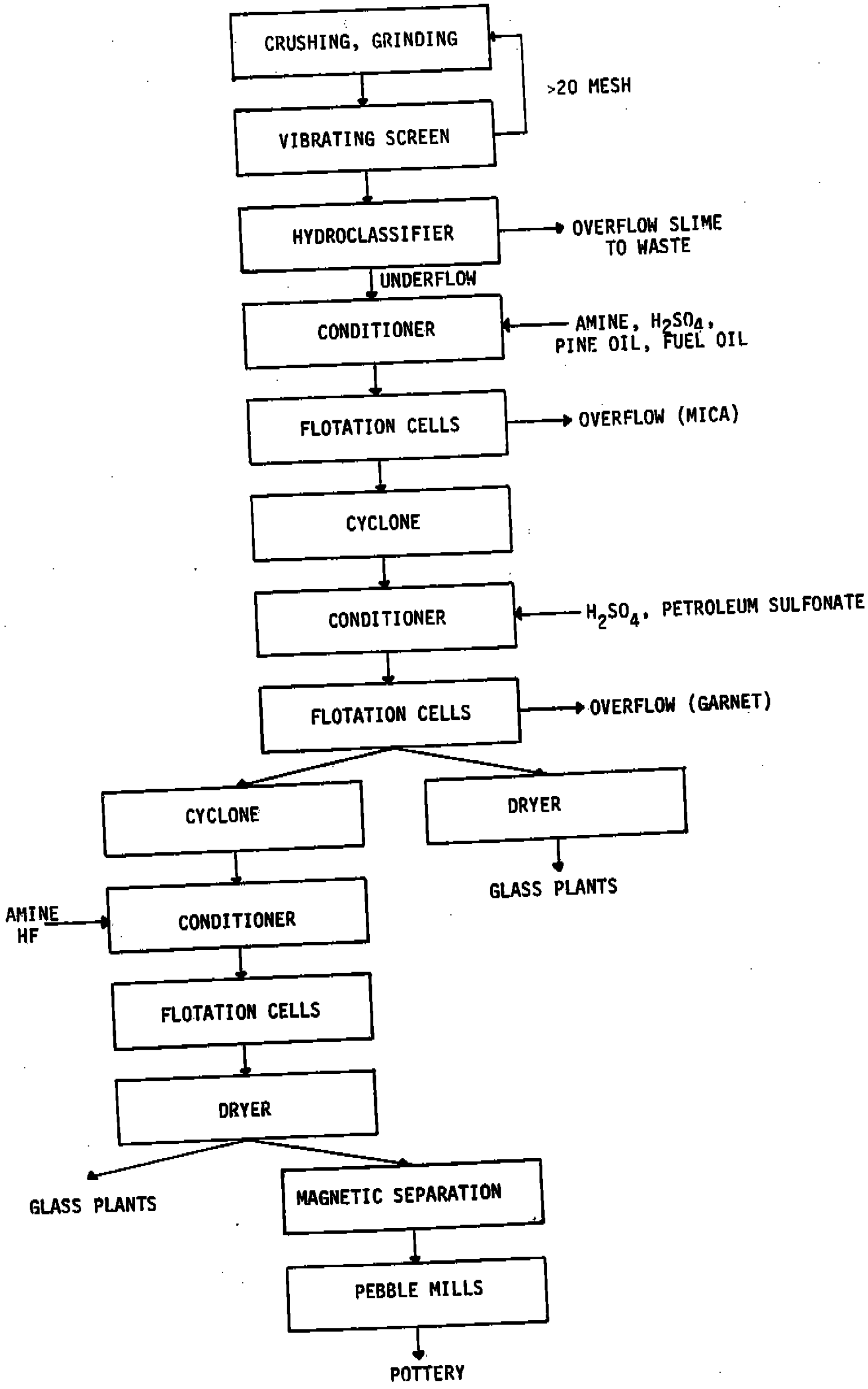


Figure 3-20. Feldspar flotation process.

grinding may then occur to reduce the material to 74 µm (200 mesh) for use in ceramics, paints, and tiles. Final processing steps are often accomplished simultaneously by passing the dewatered cake through a rotating gas-fired cylinder lined with ceramic blocks and charged with ceramic grinding balls.[60] Screening or air classification with oversize return is required to ensure particle-size specifications.

3.3.5.2.2 Dryers. The rotary dryer is the most common dryer type used, although fluid bed dryers are also used. Design production rates for most feldspar dryers are confidential. Some rotary feldspar dryers are fired with No. 2 oil and natural gas, operate at 230°C (450°F), and have a retention time of 10 to 15 minutes. Similar parameters for feldspar fluid bed dryers are confidential.

3.2.6 Fire Clay

3.2.6.1 Background. Fire clay is mineral aggregate composed of hydrous silicates of aluminum ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$) with or without free silica. Fire clay is plastic or formable when sufficiently pulverized and wetted, rigid when subsequently dried, and suitable for use in commercial refractory products.[64] Fire clay deposits are seldom pure hydrous aluminum silicates. The impurities found in the clay deposits help determine the properties of refractory products made from the clay. Often materials from several deposits are mixed to produce fire clay products with differing refractoriness. Refractoriness is the ability of a material to retain its physical shape and chemical identity in the presence of high temperatures.[64] A variety of materials including bauxites, flint clays, ball clays, and kaolin are considered to be fire clay material.

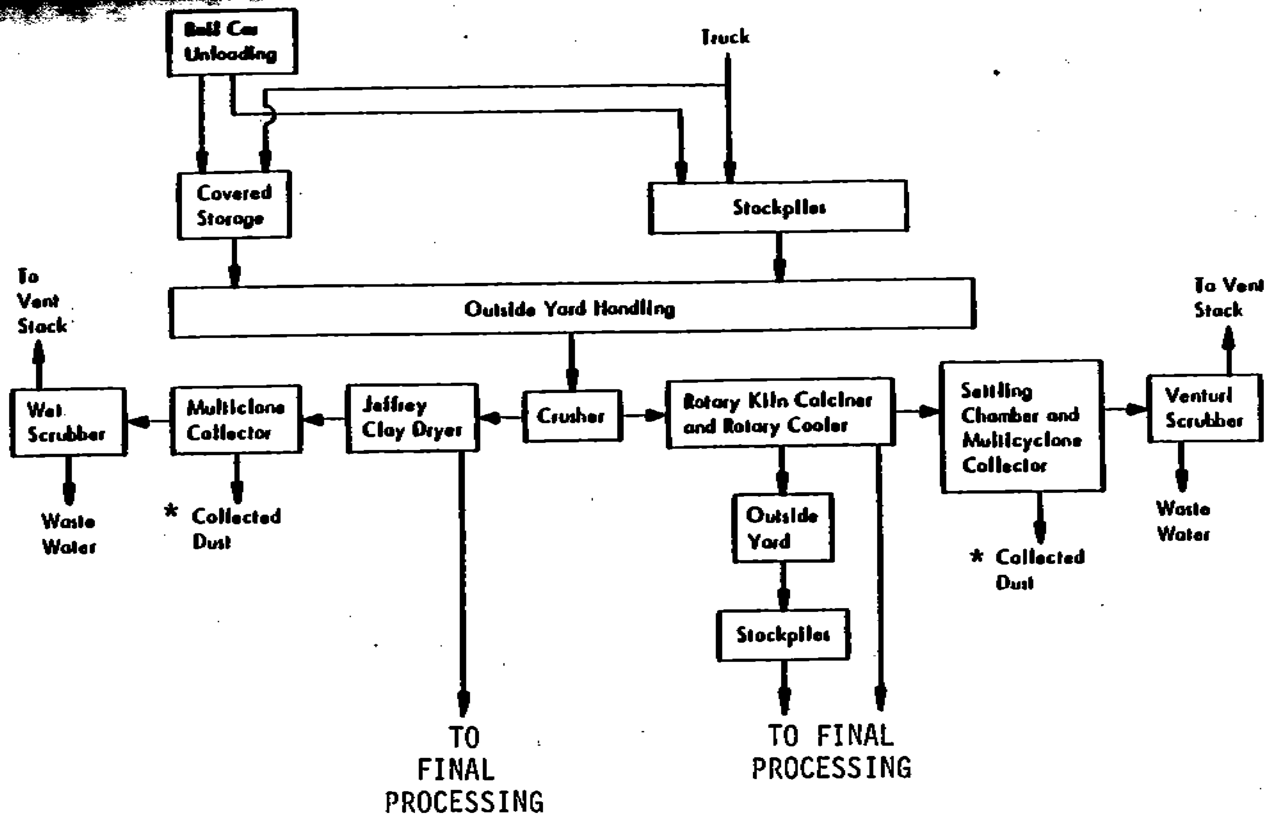
Most fire clay plants are highly integrated operations capable of ing, processing, packaging, and shipping the finished product. As a ult of economic considerations and limited availability from domestic ces, the refractory industry is, however, becoming more dependent imported high alumina and bauxitic clay from South America and . However, these materials are seldom imported as raw clays and ually shipped into the U.S. already calcined.

Raw materials are dried, calcined, and processed into firebrick and other refractory shapes prior to packaging and shipping. Specialty refractory products are generally made from the same raw materials as their brick counterparts and include gunning, ramming, or plastic mixes; granular materials; hydraulic-setting castables; and mortars. Flint clays and high-grade kaolins impart high refractoriness to fire clay products. Plastic clays facilitate forming and impart bonding strength, and calcined clays control the drying and firing shrinkage of fire bricks. The materials used in the production of refractories must be hard, dense, and crushable to form particles that can be accurately sized. Bauxite is normally calcined for refractory use at temperatures of 1650° (3000°F) or less.[65]

In 1982, fire clay was produced at 153 mines in 17 States. In order of decreasing volume, Missouri, Ohio, Pennsylvania, West Virginia, and Alabama accounted for 88 percent of the total domestic output of 986,000 Mg (1,087,000 tons).[66]

3.2.6.2 Process Description. Most materials used in the manufacture of refractories must be dried or calcined, or both, before entering the manufacturing plant for forming, firing, and final processing. A flow diagram of these preliminary processing steps for refractory raw materials at one plant is shown in Figure 3-21. Clays are mined locally or trucked in from other sources and are stored in stockpiles at the plant. There is a trend in the industry toward the increased use of covered storage areas to reduce the cost of drying the raw materials. In some cases, it is beneficial to allow the raw materials to weather (freeze and thaw). Weathering causes the clay platelets to break up, which generates small particles and improves plasticity. Flint clays are allowed to weather for about one year, and plastic clays are allowed to weather for about six months.

Clay is moved from open or covered storage areas to crushing and grinding equipment where the clay chunks are reduced to less than 6.4 cm (2.5 in.). The clay is then stored in bins and removed as needed for drying or calcining. The initial moisture content of most raw materials is 10 to 15 percent. If the desired final moisture content is in the range of 0 to 7 percent, the material must be mechanically dried. Rotary



* Collected dust is mostly returned to process.

Figure 3-21. Partial flow diagram for fire clay plant (handling and processing of raw materials prior to use in refractory manufacturing plant).[67]

and vibrating-grate dryers are used to accomplish this procedure. Overdrying often results in excessive dusting; therefore, dried material may be blended with wet stockpile material to improve its handling characteristics and to achieve the desired moisture content for further processing.

Rotary dryers used in the fire clay industry range from 2.3 to 2.4 m (7.5 to 8 ft) in diameter and 15 to 18 m (50 to 60 ft) in length. A typical vibrating-grate dryer is 1.5-m (5-ft) high, 1.5-m (5-ft) wide, and 18-m (60-ft) long. Production rates are 7 to 35 Mg/h (8 to 40 tons/h), and drying temperatures are in the range of 80° to 260°C (180° to 500°F). The retention time varies between 15 and 60 minutes. Both cocurrent and countercurrent heating methods are used. The dryers operate in a continuous mode. Natural gas and No. 2 fuel oil are the most common fuels for fire clay dryers. Fuel use rates range from 420 to 900 kilojoules per kilogram (kJ/kg) (3.6 to 7.7 $\times 10^5$ British thermal units per ton [Btu/ton]) of product. Personnel at one plant indicated that fuel-efficient units such as fluid bed dryers or multiple hearth furnaces would be considered if additional capacity were needed.

Calcining of fire clay materials is necessary to produce products with refractoriness greater than that of only dried materials. Calcining removes all moisture and volatile material and causes a chemical reaction to take place between the alumina and the silica, resulting in the formation of "mullite." This material has better mineralogical properties with respect to refractories production (hard, dense, and crushable) than does noncalcined material.

After drying and/or calcining, the raw materials are crushed, ground, and screened to proper sizes for making brick or specialty products. After screening, the materials are blended in proper proportions and thoroughly mixed--often with the addition of organic or other types of binders--and the prepared batches are fed to the forming machines. In the production of bulk refractory products such as high-temperature mortars, ramming mixes, and castables, blending and mixing usually complete the process of preparation.

Molded refractory bricks or shapes are typically dried in long, heated chambers (tunnel dryers) under controlled temperature and humidity conditions. Most refractory bricks are then fired in tunnel kilns at high temperatures to give the brick permanent strength.

A unique process of preparing the raw material for calcining, which may be the future trend in the industry, is currently used at one plant. Mixed, pulverized clay is extruded to form pellets. The pellets are dried to remove surface moisture and are then used as feed material for the rotary calciners at this plant.

3.2.7 Fuller's Earth

3.2.7.1 Background. Fuller's earth is a category of mineral materials that consists chiefly of nonplastic clay or claylike materials. It is usually high in magnesia and has specialized decolorizing and purifying properties.[68] Major uses of fuller's earth by U.S. producers in 1981 were as follows: oil, grease, and pet waste absorbents (59 percent), pesticide carriers and related products (13 percent), drilling mud (13 percent), fertilizers (5 percent), oil treatment (1 percent), and miscellaneous uses (7 percent). Miscellaneous uses include adhesives, animal feed, medical-pharmaceutical-cosmetic, paint, paper filling, and rubber products.[68]

Two types of material are considered to be fuller's earth clay.
ttapulgite is a lath-shaped clay mineral that occurs in deposits pre-
minantly in Decatur County, Georgia, and Gadsden County, Florida. It
used as both an absorbent and a thickener. Mineral thickeners are
d in such diverse markets as paints, joint compound cement, polishes,
plastics. Most of the fuller's earth produced in the United States
r than in Florida and Georgia contains varieties of the second type
ller's earth clay, montmorillonite. Granular products produced
ontmorillonite are used as all-purpose oil and grease absorbents.
uller's earth production in 1982 was reported from 30 mines in
es. Georgia (34 percent) and Florida (52 percent) accounted for
ent of the 780,000 Mg (860,000 tons) of attapulgite produced.
nd Texas produced the remaining 14 percent. In 1982, 750,000 Mg
tons) of montmorillonite was produced in the U.S. Approximately
t of the montmorillonite produced came from Georgia, with the

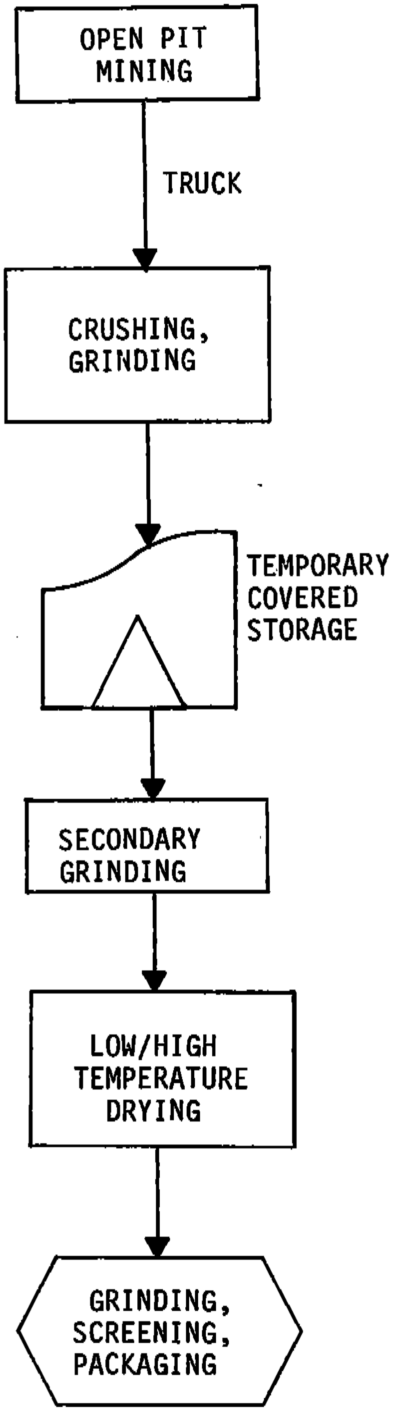
remaining 71 percent coming from Illinois, Mississippi, Missouri, Nevada, South Carolina, Tennessee, Utah, and Virginia.[68]

3.2.7.2 Process Description.

3.2.7.2.1 General. Figure 3-22 shows a general process flow diagram for fuller's earth production. Fuller's earth is usually mined by dragline from open pits and hauled to the plant by truck. At the plant, the material is typically processed through crushing and/or grinding equipment prior to temporary storage in covered sheds. The material withdrawn from storage is further reduced in size to increase the bulk surface area and facilitate moisture removal. The material is dried or calcined, ground, screened, and packaged according to the specific product requirements.

3.2.7.2.2 Drying. In the fuller's earth industry, the drying process is of fundamental importance in producing a marketable product. Process parameters (i.e., temperature, degree of drying, residence time in dryer, and process rate) vary with the intended end-use of the product. Typically, either low- or high-temperature drying is used. Both cocurrent and countercurrent heating methods are used. Operating temperatures range from 100°C (210°F) for colloidal grades (attapulgite) to 675°C (1250°F) for absorbent granules (attapulgite and montmorillonite). The desirable properties of the product are substantially lost if the material is overdried. In most cases, the moisture content is reduced from an initial 40 to 50 percent to 0 to 10 percent.

Rotary dryers are the most common dryer type used in the fuller's earth industry, and they range from 1.8 to 3.1 m (6 to 10 ft) in diameter and from 12 to 37 m (40 to 120 ft) in length. Fluid bed dryers are also used at one plant. Production rates range from 5 to 55 Mg/h (6 to 60 tons/h). Natural gas is the most common fuel used in the fuller's earth industry, with Nos. 4 and 5 fuel oils and propane used as alternate fuels in some cases. Personnel at one facility indicated that fuel-efficient fluid bed dryers would be installed in the future if additional drying capacity was required.[69]



ure 3-22. General flow diagram for fuller's earth production.

3.2.7.2.3 Calcining. A small number of plants use rotary calciners to process fuller's earth raw material. These calciners operate with material flow countercurrent to the gas flow and are fired with natural gas. The operating temperature in these units is approximately 675°C (1250°F).

3.2.8 Gypsum

3.2.8.1 Background. Gypsum is calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$), a white, crystalline, naturally occurring mineral. Mined gypsum ore is processed into a variety of products. The ore can be (a) sized and screened for use as an additive for Portland cement; (b) sized, screened, dried, and ground for use as an agricultural fertilizer; or (c) sized, screened, dried, and calcined to $CaSO_4 \cdot \frac{1}{2}H_2O$ for use in plasters and pre-fabricated building products.[70]

3.2.8.2 Process Description. A flow diagram for a typical gypsum plant producing both crude and finished gypsum products is shown in Figure 3-23. Gypsum ore, mined from quarries and underground mines, is stockpiled at the plant. The mined ore is crushed and screened, with oversize ore returned to the crusher. If the free moisture content of the mined rock is greater than about 0.5 percent by weight, the sized ore is dried, typically in a rotary dryer.

3.2.8.2.1 Ore dryers. The feed to the dryer consists of crushed and screened gypsum ore, generally minus 5 cm (2 in.) in diameter. In its mined form, the ore typically contains from 5 to 10 percent gangue (clays and other insoluble impurities) and varying amounts (usually less than 10 percent) of free water. The wet ore is heated in the dryer to about 65°C (150°F), and essentially all of the free water is evaporated. The length of time required to dry the ore is a function of both the temperature of the heated air and the amount of water to be removed. For an ore containing 8 percent free moisture, the appropriate drying time and temperature are 6 to 10 minutes at 100°C (220°F).[71]

In most plants, clean fuels, such as natural gas and distillate oil, are used to fire rotary dryers. Natural gas is currently the most common fuel source. One industry spokesman indicated that some plants are choosing to dry the ore in Raymond roller mills instead of rotary dryers. However, rotary dryers will still be used and will continue to

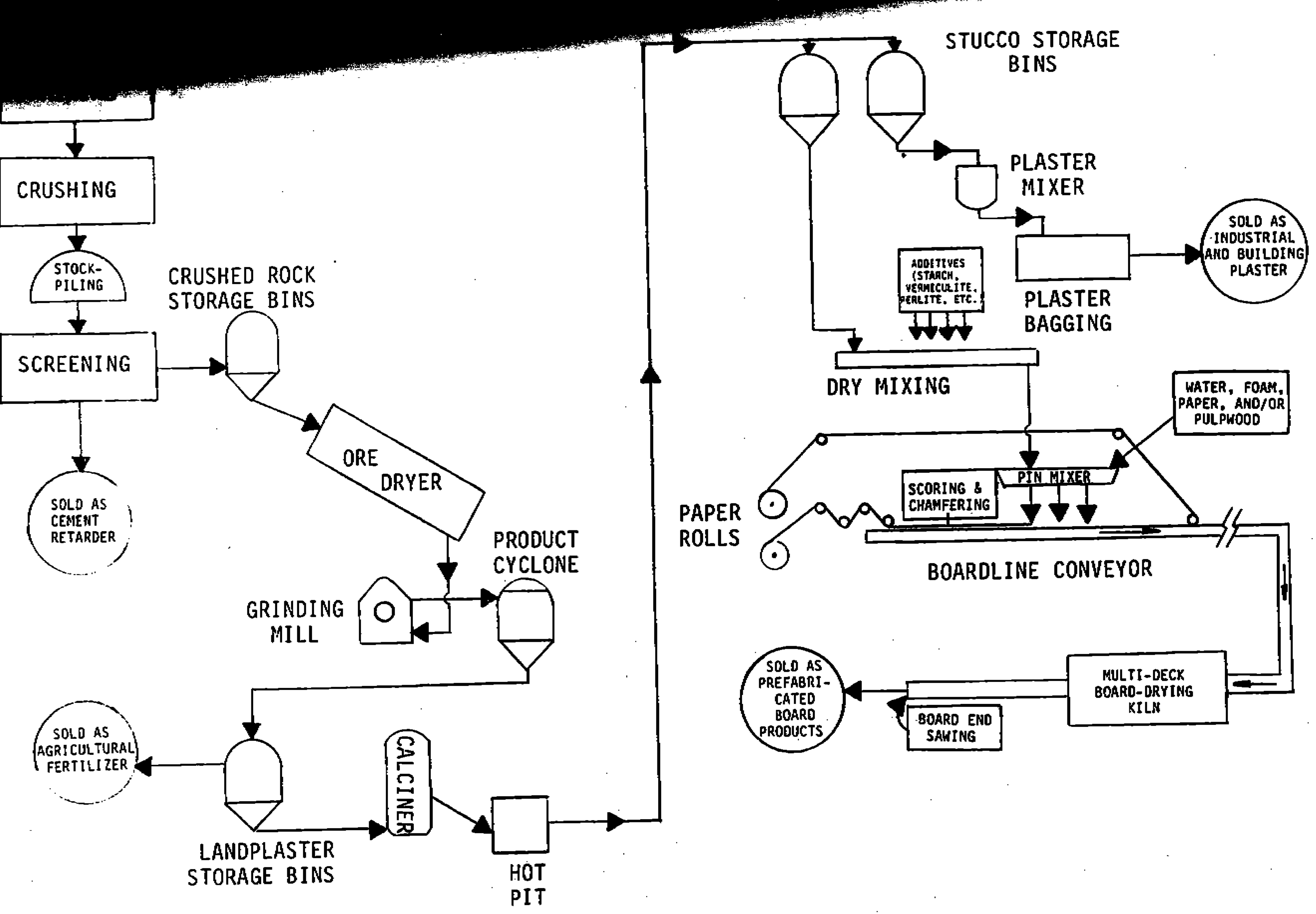


Figure 3-23. Process flow diagram for gypsum production.

be of the direct-fired type. Natural gas and distillate oil will also continue to be the primary fuels.[72,73] The design capacities of most ore dryers employed by the gypsum industry range from 45 to 80 Mg/h (50 to 90 tons/h). Operating capacities of these dryers range from 50 to 100 percent of the design capacities.

3.2.8.2.2 Calciners. Kettle and flash calciners are employed in the gypsum industry to remove three quarters of the chemically bound water of hydration from $CaSO_4 \cdot 2H_2O$ to form $CaSO_4 \cdot \frac{1}{2}H_2O$. The heat required for the calcination reaction represents a major portion of the energy required for the processing of gypsum. The crushed, ground gypsum fed to the calciners contains less than 20 percent (by weight) chemically bound water and has a particle size of about 90 percent minus 149 µm (100 mesh). The stucco produced contains from 4 to 6 percent chemically bound water.

Kettle calciners can be operated in either the batch or continuous mode. In batch calcining operations, the gypsum ore is heated to between 150° and 175°C (300° and 350°F) before the kettle is emptied. The time required for batch calcination varies from 1 to 3 hours depending on the quality of the gypsum feed, the kettle size, and the firing rate.

In continous kettle calcining operations, the stucco is maintained between 90° and 120°C (200° and 240°F) by varying the gypsum feed rate to the kettle while the fuel firing rate is held constant. The production rate averages 10 Mg/h (11 tons/h).

Flash calciners operate only in a continuous mode. Fine gypsum dust is fed spirally downward through a cylindrical zone into which heated air is injected tangentially. The stucco product formed in the cylindrical heating zone of the calciner is removed at a temperature of about 180°C (360°F).[74,75] The production rate in gypsum flash calciners is approximately 6 Mg/h (7 tons/h).

3.2.9 Industrial Sand

3.2.9.1 Background. Industrial sand is defined as naturally occurring unconsolidated or poorly consolidated rock particles that pass through a 4.8 mm (4 mesh) sieve and are retained on a 74 µm (200 mesh) sieve.[76] Industrial sands are often called silica sands and are composed primarily of quartz (SiO_2).[77] The quartz content is typically greater than 95 percent with some ores containing more than 99 percent. In order of decreasing volume, the five leading States in the production of industrial sand in 1983 were Illinois, Michigan, New Jersey, Texas, and California. Their combined production represented 51 percent of the national total. Only 17 States did not produce industrial sand in 1983. By region, the production quantity was North Central--44 percent, South--33 percent, and West--11 percent.[76]

The most frequent use of industrial sand is for glassmaking. In 1983, approximately 43 percent of the industrial sand product was used in glassmaking, that is, in the manufacture of glass containers, windows, fiberglass, and specialty glass. The iron content of the product is less than 1 percent. Other impurities present to a minor extent are clay slime, garnet, zircons, alumina, and calcium or magnesium oxides.

The second most frequent use (25 percent) of industrial sand is for foundry sands, which are used for cores and molds for casting of common metals and as a component of refractory products.[77] Industrial sand is most commonly used for foundry and molding sands although materials such as zircon, olivine sands, staurolite, or chromite sands may be also used. In some uses, such as in steel foundries, these materials are preferred over industrial sand due to their lower thermal expansion rates.

3.2.9.2 Process Description. Figure 3-24 is a process flow diagram
or industrial sand processing. Industrial sand is frequently mined by
en pit methods from naturally occurring quartz-rich sand and sandstone.
ore is typically crushed at the mine site before being transported
trucks to a crushing, screening, and grinding process. The sand is
hed to remove detrital material, screened to produce a minus 841 µm
mesh) product, and then classified. From classification, the sand
taining 25 to 30 percent moisture) goes to an attrition scrubbing
that removes surface stains from the sand grains by rubbing the
in an agitated, high density pulp. The scrubbed sand is diluted
ater to 25 to 30 percent solids and pumped to a set of cyclones
rther desliming. Some sands require a two-stage attrition scrubbing
assification and slime removal between stages. If the deslimed
ntains mica, feldspar, and iron bearing minerals, the sand enters

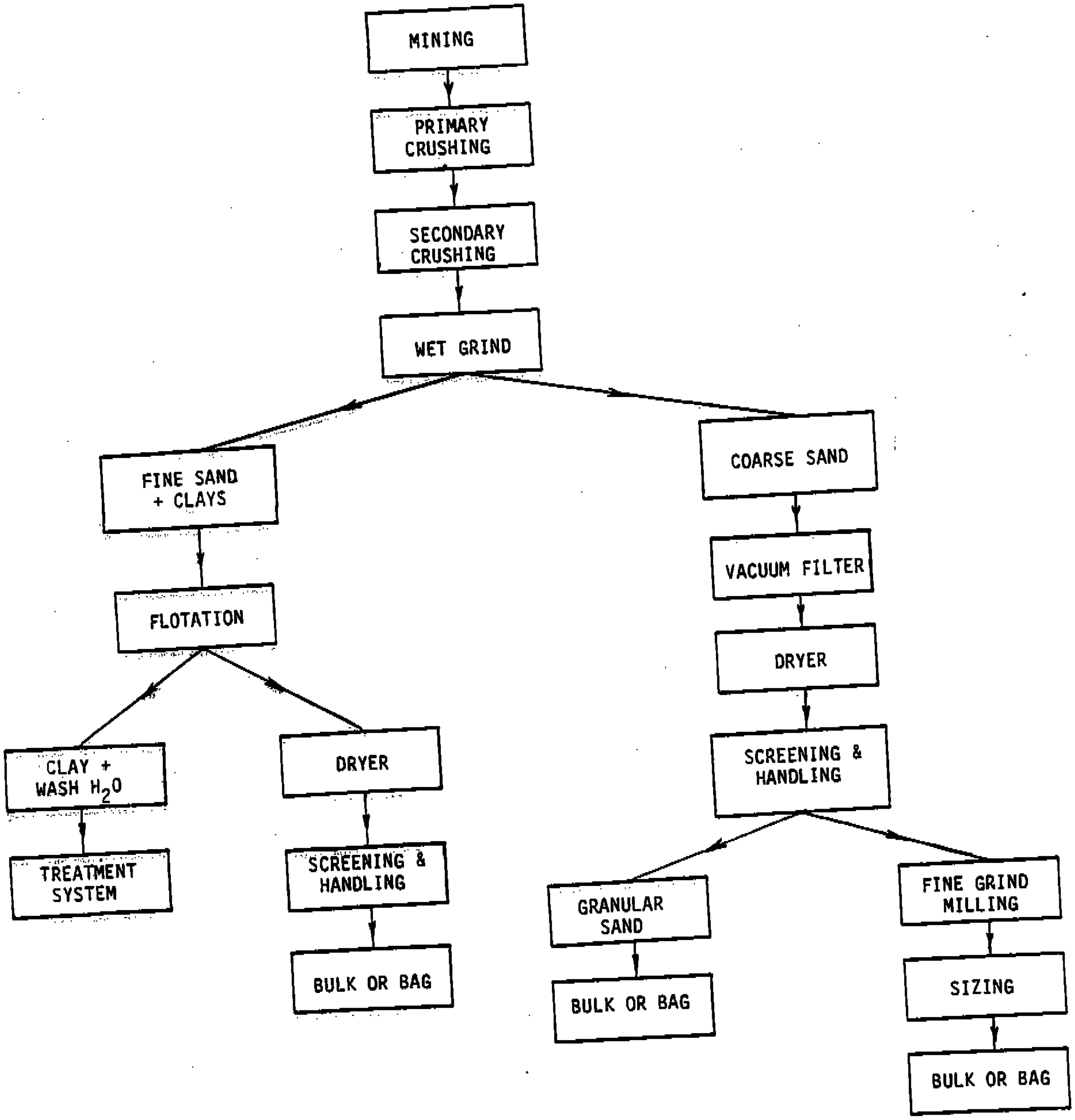


Figure 3-24. Process flow diagram for industrial sand production.[79]

a froth flotation process where sodium silicate and sulfuric acid are added. For foundry sand, the flotation circuit may be bypassed. By entering a series of spiral classifiers, the impurities are floated in a froth product and are diverted to waste. After being classified, the flotation product has a moisture content of 15 to 25 percent and is belt conveyed to drainage bins where moisture is reduced to about 6 percent. After being stored for a day or more, the drained sand is dried and then conveyed to a size classification or screening process. The screened sand is either conveyed to mills for size reduction or sent as unground sand directly to bulk storage. The industrial sand product is then shipped by truck or rail car.

3.2.9.2.1 Dryers. Dryers in the sand industry reduce the moisture content of the sand from 4 to 9 percent to less than 0.5 percent.[78] Types of dryers used in the industry are rotary and fluid bed. According to several industry representatives, the trend is towards the fluid bed dryer because of its fuel economy compared to rotary units.[80,81] However, another industry representative predicts that the trend will be an equal split in the use of rotary and fluid bed dryers.[82]

The feed rate for fluid bed dryers varies from 7 to 160 Mg/h (8 to 180 tons/h) with an average process rate of about 90 Mg/h (110 tons/h). For rotary dryers, the feed rate varies from 14 to 140 Mg/h (15 to 150 tons/h) with an average of 60 Mg/h (70 tons/h). Rotary units are 1.8 to 2.4 m (6 to 8 ft) in diameter and 10.7 to 12.7 m (35 to 40 ft) in length. A typical fluid bed dryer is 3.3-m (11-ft) high, 6.3-m (21-ft) wide, and 9.6-m (32-ft) long. Before drying, the process material has n unbound moisture content of 5 to 6 percent. In addition, 12 percent f the sand is less than 420 µm (40 mesh), and 77 percent of the sand is s than 210 µm (70 mesh).

2.10 Kaolin

3.2.10.1 Background. Kaolin is a clay that consists primarily of linite, which is a hydrated aluminum silicate ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$). kaolin particles are hexagonal, flat platelets. Above the 2 µm 10^{-5} in.) particle size, the particles usually consist of stacks of s ("books"), while below the 2 µm size they occur as individual lets. Because these individual platelet particles have the most desirable coating and flow characteristics, particle size fractions of 2 μm and smaller comprise the largest part of industry production.[82]

Commercial deposits of kaolin occur in several areas of the U.S., but approximately 93 percent of the kaolin produced in this country comes from Georgia and South Carolina.[83] A total of 5.7 $\times 10^6$ Mg (6.4 $\times 10^6$ tons) were produced in 1982. Twelve other States contributed to the total. Major end uses of kaolin sold or used in the U.S. in 1982 were as follows: paper coating (39 percent), paper filling (17 percent), refractories (8 percent), alum (6 percent), oil refining catalysts (4 percent), rubber (4 percent), paint (2 percent), and miscellaneous uses such as pesticides and waterproofing and sealing materials (2 percent).[84] Under normal conditions, kaolin is chemically inert to the action of acids and alkalis. It is this inertness, along with other physical characteristics such as high reflectance and index of refraction, particle shape and size distribution, and compatibility with other chemicals and minerals, which has given kaolin its wide range of end uses.[85]

Most kaolin plants are highly integrated operations capable of mining, processing, packaging, and shipping the finished product. The processing of kaolin is complex and is accomplished with many different types of equipment. Dryers and calciners are used in 90 percent of the kaolin production. The dry process is simple, yields a low cost and low quality product, and accounts for 20 percent of dried/calcined kaolin products. The wet process comprises the remaining 70 percent of the dried/calcined kaolin production and is much more complex than the dry process.

3.2.10.2 Process Description.

3.2.10.2.1 Mining and degritting. Kaolin is mined using standard equipment such as shovels, draglines, front-end loaders, and scrapers. If the material is to be dry-processed, the mined clay is dried and pulverized, and coarse material removed by an "air-floated" process. Grinding occurs in Raymond roller mills incorporating whizzer separators and cyclone collectors. If the material is to be wet-processed, the crude clay is fed into a blunger (agitator), which breaks down the clay and disperses it, with the aid of a dispersing agent, to form a slurry.

Grit is removed by passing the material through screens, a hydrocyclone circuit, or a drag classifier. The material then passes to preliminary holding or dewatering tanks to await refining.

Significant processing losses result during the production of kaolin; as much as 40 percent of the material delivered to the processing plant is discarded. Waste material from processing consists mostly of off-grade clays and minor quantities of quartz, mica, feldspar, and iron minerals. The bulk of the loss is discharged with the wastewater to settling ponds for potential recovery and use.

3.2.10.2.2 Dry processing. A general process diagram for dry processing is shown in Figure 3-25. In the dry process, the physical properties of the finished kaolin are similar to the physical properties of the crude kaolin. Therefore, deposits containing the desired qualities of brightness, low grit content, and particle size distribution must be located by drilling and testing. In the dry process, the kaolin is crushed to the desired size, dried in rotary dryers, pulverized, and ir-floated. The air-floating process removes most of the coarse grit. he product of the dry process is used mainly in the rubber industry, th lesser amounts going into fiberglass, paper filling, and sanitary re.

3.2.10.2.3 Wet processing. Figure 3-26 shows the basic steps in wet processing of kaolin. During wet processing, clay is fed into a ger to produce a kaolin slurry. The slurry is degritted using drag s, bowl classifiers, or cyclones before being dried or stored for er processing. Wet processed kaolin is used extensively in the manufacturing industry.

arious chemical, physical, and magnetic methods are used to improve ay's whiteness and brightness. For example, kaolin used in the ndustry is bleached to remove iron-bearing minerals. During this , sodium hydrosulphite or a similar reducing agent is added to in in a low pH environment, flotation is used to remove iron and minerals, and delamination is used to break down the books of to individual platelets by attrition grinding or extrusion. iltration uses high intensity magnets to remove fine particles tania, mica, etc.

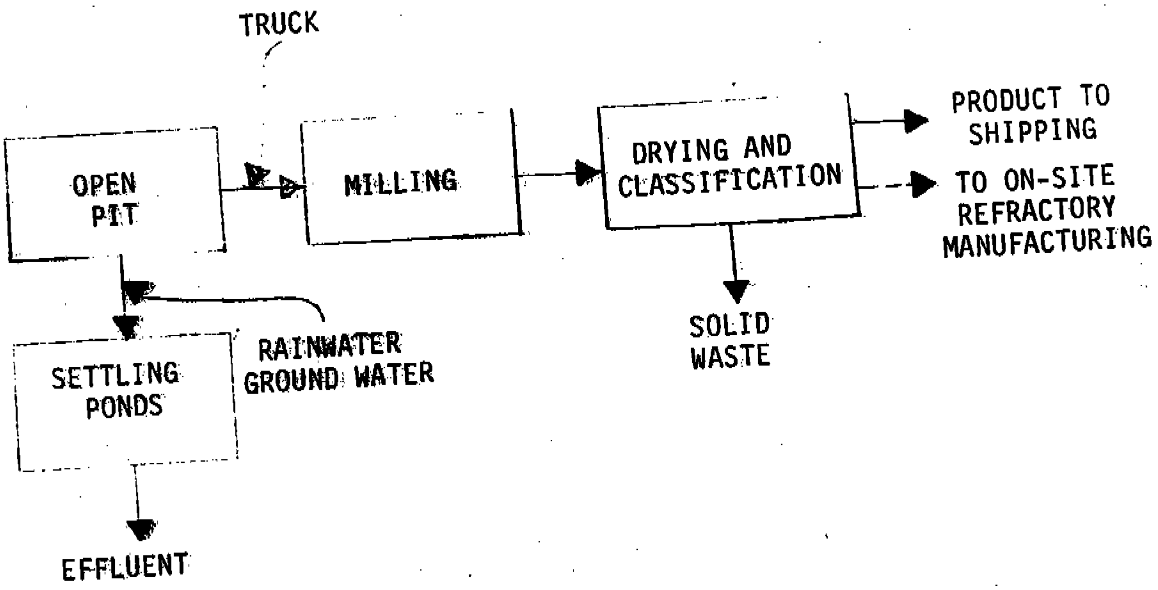


Figure 3-25. Dry kaolin mining and processing.[86]

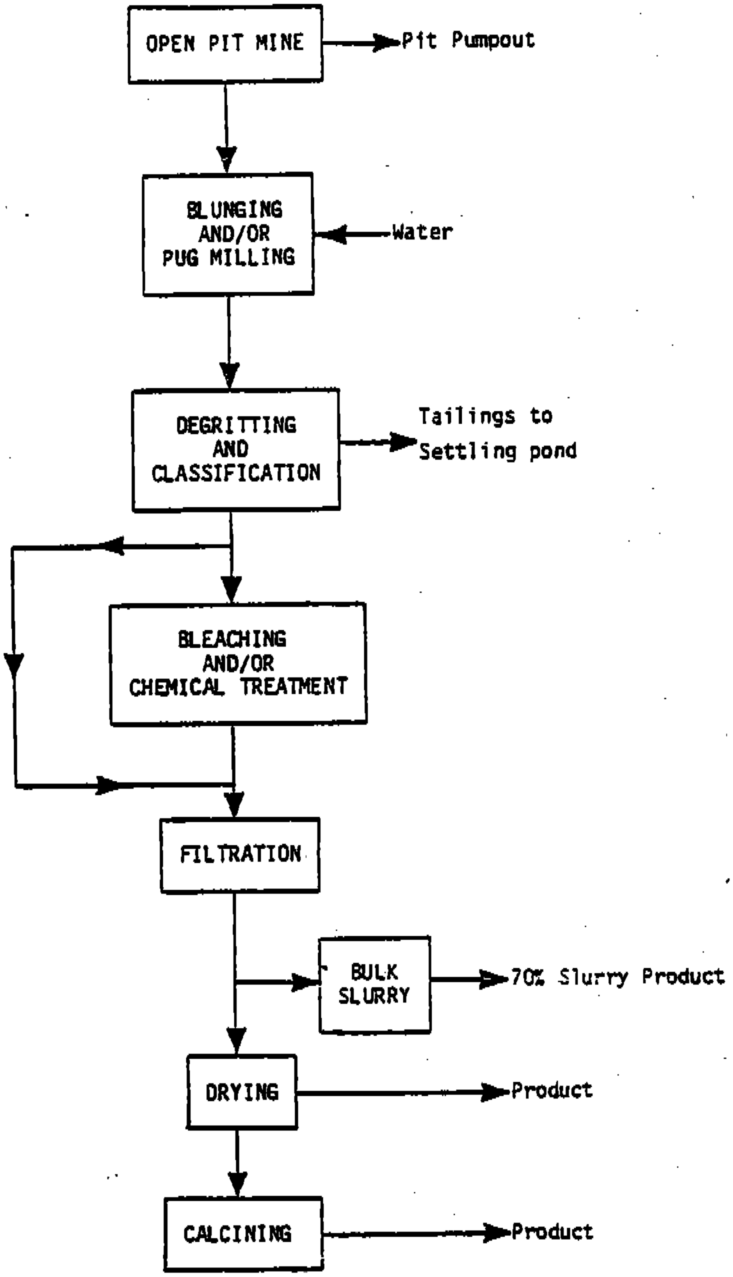


Figure 3-26.. Typical wet mining and process for high grade kaolin products.[88]

Before drying, the slurry (55 to 70 percent solids) is dewatered using either a filter press, centrifuge, rotary vacuum filter, or tube filter. The various types of equipment used for drying include apron, rotary, and spray dryers, and cage mills. Recent trends indicate that spray dryers and cage mills are being selected to fill the need for additional drying capacity. This trend is anticipated to continue, although an increase in the shipment of high-solid slurry may tend to decrease the need for additional drying capacity. The number of drying units depends on the size of the plant and presently ranges from 1 to 10 units per plant.

Approximately 73 percent of the total amount of kaolin produced is dried.[87] Kaolin to be calcined is always dried first. Calcination is a process used to produce either a filler (low temperature) or refractory (high temperature) kaolin. When kaolin is heated to approximately 1050°C (2000°F), it is converted to mullite. The product is whiter, brighter, has better hiding properties when used in thin film applications, and is more abrasive than noncalcined kaolin. Calcined kaolin is being used in increasing quantities as a paper filler and in the manufacture of paint, rubber, and plastics. According to the industry trade association, there are currently no more than 20 calciners operated by kaolin producers in Georgia; however, the demand for calcined kaolin is growing, and it is expected that additional calciners will be added in the next 5 years.[87]

Kaolin products are shipped in bulk form from beneficiation plants in boxcars or in covered hopper cars, and in slurry form (70 percent solids) in tank cars or in tank trucks. Kaolin is also shipped in 25-kg (50-lb) multi-wall bags when the customer cannot handle the material in bulk. Kaolin is supplied commercially in pulverized form, in lump form (generally in the shape of small extruded noodles), in spray-dried bead form, in small pellets, or in flake form. The density of the kaolin will vary depending on its form.

Although the traditional method of shipping kaolin in the dried state still dominates, slurry transportation is increasing in popularity. A number of the kaolin industry's customers, the paper industry in particular, use kaolin in a wet process. Therefore, if the clay can be shipped economically in a slurry form, the cost of filtering and drying the kaolin during production can be reduced, and the savings is passed on to the consumer.

3.2.10.3 Drying. Over 90 percent of the kaolin processing plants that use dryers and/or calciners are located in Georgia. Most (60 to 65 percent) of the kaolin industry wet processors use spray dryers. The remaining wet processing plants and the plants that use the air-floated dry processes utilize rotary and other types of dryers.

When the filter cake from the wet process is discharged from the filter, it is in a plastic state and has an acid pH (3.5 to 4.0). If it is dried in this condition, it is known as an acid clay. However, by adding a dispersing agent and repulping the cake, it becomes fluid even at the high solids concentration of 60 to 65 percent. When dried, this cake is known as dispersed or pre-dispersed clay. Rotary dryers are used for drying acid cakes. The feed must be mixed with recycled dry material to produce a friable, non-balling material.[82] Kaolin rotary dryers have production rates ranging from 7 to 25 Mg/h (8 to 28 tons/h).

For drying dispersed clay slurries, the spray dryer has found wide acceptance in recent years. Spray dryers are simple, inexpensive, and fficient. In general, feed must be wet enough to spray; therefore, olutions, thin slurries, or pumpable paste are possible candidates for is device. Typically, in a spray dryer the predispersed filter product 55 to 70 percent solids is mechanically atomized through a spray hine. Kaolin particles are dried by a stream of hot air, fall to the tom of the collection chamber, and are discharged through a rotary lock. Fabric filters collect most of the 20 percent of the product is carried out with the outlet air. The recovered dust is usually d with the dryer product. The spray dryer product consists of beads 45 to 180 μm (325 to 80 mesh) in diameter that are free-g and relatively dust free.[89] Kaolin spray dryers are typically 2 ft) in diameter and 26 m (85 ft) in height, and they have ion rates ranging from 11 to 28 Mg/h (12 to 30 tons/h).

Coating-grade clays are those with all particles smaller than 15 µm (6 x10^{-4} in.) and at least 70 percent of the particles less than 2 µm (8 x10^{-5} in.). These clays also have 50 percent or more of the particles smaller than 1 µm (4 x10^{-5} in.) in size. The extremely fine grades of coating clay currently being produced approach the range of 100 percent minus 2 µm (8 x10^{-5} in.).[82]

3.2.10.4 Calcining. Because kaolin consists primarily of the mineral kaolinite, it is considered to be a fire clay. Low-temperature calcining produces a kaolin used for filler. High-temperature calcining produces a kaolin for use in the refractory industry. Section 3.2.6 (Fire clay) discusses kaolin use as a refractory material. Multiple hearth furnaces are the most common type of calciner; however, flash and rotary calciners are also used. Multiple hearth furnaces require less space and maintenance than flash calciners although they have a longer startup time.

3.2.11 Lightweight Aggregate

3.2.11.1 Background. The lightweight aggregate (LWA) industry encompasses the processing of clay-like materials into a low-density product. Lightweight aggregate is produced by calcining clay, shale, or slate. The raw materials used to produce LWA are chosen for their bloating properties when heated. When these materials are heated to temperatures of about 1000°C (1800°F), they become plastic and begin to flow like a viscous fluid.[90] As the plastic state is achieved, carbonaceous compounds in the material form gas bubbles, the material begins to expand, and the gas bubbles are trapped in the viscous plastic material. The material is then cooled in the expanded condition to form a porous, solid LWA. Substitutes for the more common raw materials in the production of LWA products are natural pumice and blast furnace slag.

Lightweight aggregate is used principally for the manufacture of structural concrete products such as concrete blocks and prestressed structural units. Concrete made with LWA has about the same strength and approximately two-thirds the weight of concrete made with natural aggregate. Other properties of concrete made with LWA, such as fire resistance and thermal and accoustical insulating qualities, make it desirable as a building material. Lightweight aggregate is a substitute for more dense, naturally occurring aggregate (granite, limestone) and is used by companies that further process the material into other products. Other applications of LWA include accoustical plaster, roofing granules, highway surfacing, insulating fills, horticulture applications, and running tracks.[91] The end uses of LWA in 1980 were: concrete block (65 percent), structural concrete (25 percent), highway surfacing (6.5 percent), and other uses (3.5 percent).[92] Fine, medium, and coarse grades of LWA are available, ranging in diameter from dust to 3.8 cm (1.5 in.). Seven companies produce approximately 50 percent of the LWA processed in the United States. Typically, LWA cannot be economically shipped beyond approximately a 480-km (300-mi) radius of the production facility. Local demand for LWA may be greater in areas where natural aggregates are scarce.

The U.S. Bureau of Mines (BOM) categorizes the raw materials used to produce LWA as clays and stone. Clays are classified as kaolin, ball clay, fire clay, bentonite, fuller's earth, and common clay and shale. Approximately 11 percent of the clays mined in the U.S. in 1980 were used for the production of LWA.[91] Crushed slate is the only stone used in LWA production. Approximately 0.05 percent of the crushed stone ined in the U.S. in 1980 was used for the production of LWA.[91] Light- ight aggregate was produced at 34 plants in 24 States in 1981. The M estimated that consumption of clay and shale used in the production LWA was 4.4 x10^6 Mg (4.9 x10^6 tons) in 1981, compared to 2.15 x10^5 Mg 4 x10^5 tons) of slate and 7.3 x10^5 Mg (8.0 x10^5 tons) of slag.[91]

Two methods are used to produce LWA. The rotary kiln method is by approximately 88 percent (30 of 34) of the operating plants in nited States. The remaining 12 percent of the operating plants use aveling-grate method, or process naturally occurring LWA. Because energy intensive nature of the traveling-grate process, no future in the use of this process for LWA production is anticipated.

.11.2 Process Description.

.11.2.1 General. The operations involved in producing LWA are or mining, crushing and screening, calcining or sintering, ooling, and materials handling and storage. Figure 3-27 shows

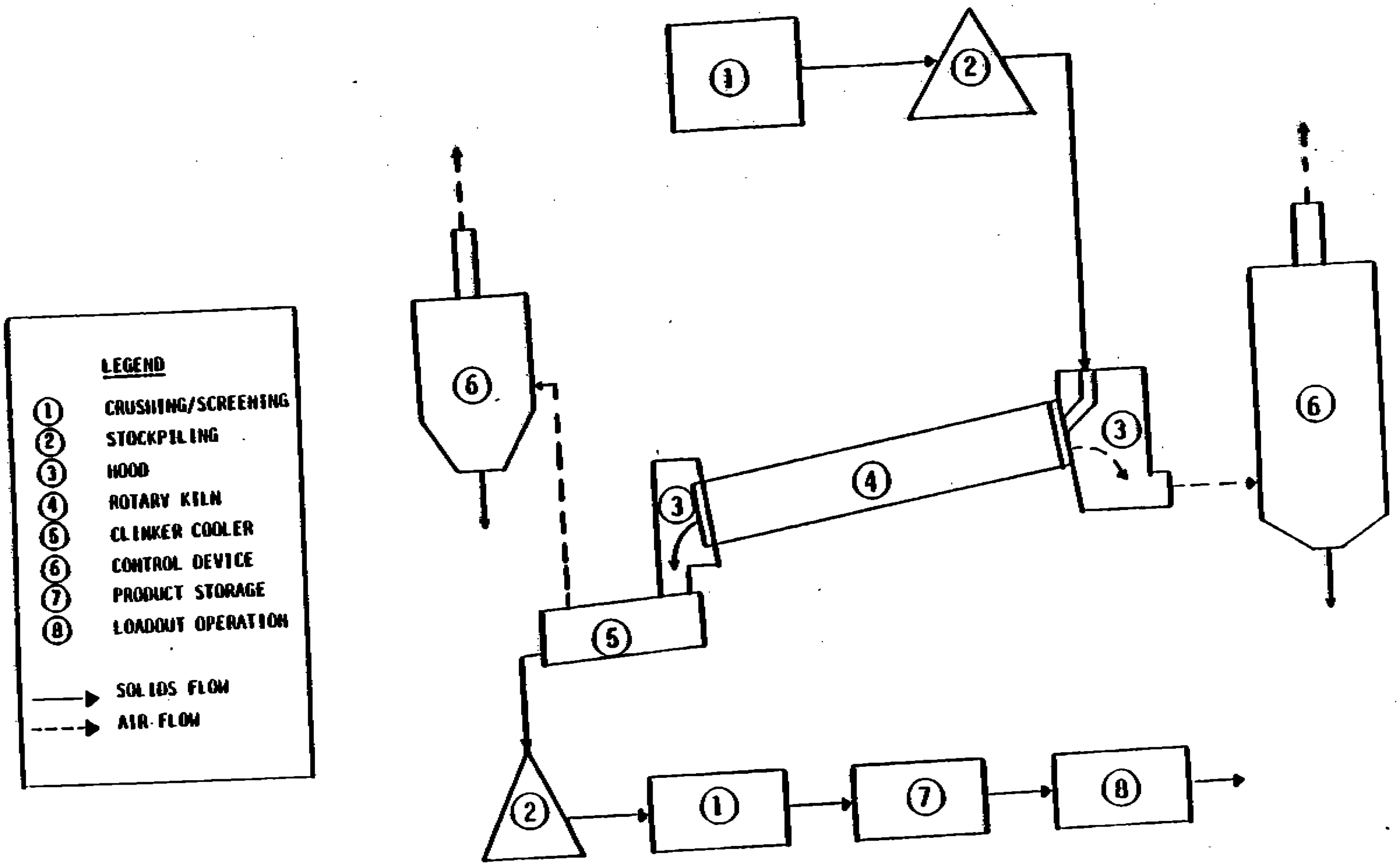


Figure 3-27. Schematic of a typical LWA plant.

a diagram of a typical LWA plant. Raw material is usually strip-mined from open fields by earth movers. Cone crushers, jaw crushers, hammermills, or pugmills are used to reduce the size of the raw material, which is then passed through screens. Any oversize material that does not pass through the screens initially may be returned to the crushers for secondary crushing. Material passing through the screens (about minus 3.8 cm [1.5 in.] in diameter) is transferred by conveyor belts to feed hoppers for charging to the calciner.

3.2.11.2.2 Rotary calciners. Rotary calciners are fired from the discharge end with fuel oil, natural gas, or coal. As the cost of fuel oil and natural gas increases, the trend is toward the use of pulverized coal. The burner used to fire the calciner is installed in the center of a fixed or movable calciner hood. The pilot flame of the burner is normally fueled by natural gas.

Rotary calciner production capacities range from 230 to 910 Mg (250 to 1,000 tons) per day per calciner.[90] Lightweight aggregate plants typically have two or three rotary calciners. One manufacturer of rotary calciners states that the smallest rotary calciner considered to be eco-
omical for LWA production in the U.S. is one that produces 450 Mg
00 tons) per day and that is approximately 3.4 m (11 ft) in diameter
d 50 m (175 ft) long.[93]

Normal feed sizes range from 2.4 mm (8 mesh) to 33 mm (1.5 in.).[90]
n the clay, shale, or slate is not closely screened, segregation of
various size chunks of raw material occurs as the calciner rotates.
segregation of particles is avoided by some calciner operators who
n the feed material so that a narrow range of particle sizes is fed
calciner.[92] The fines are calcined by direct solid-to-solid heat
fer from the calciner walls, and the larger (coarser) particles are
d by solid-to-gas heat transfer from the hot gas. The intermediate-
rticles are protected from the heat by the layers of fine and
particles and may not be completely calcined.

Magnesium Compounds

.12.1 Background. Natural brine solutions, such as sea, lake,
waters are the primary source of domestically produced magnesium
. Magnesium compounds are also produced from natural magnesite

deposits found in Nevada. The magnesium compounds produced are mainly magnesia (magnesium oxide), magnesium hydroxide, magnesium chloride, magnesium sulfate, and precipitated magnesium carbonate. Only magnesia producing plants are significant users of dryers or calciners; therefore, this study focused only on magnesia producing plants.

Two types of magnesium oxides (MgO) are produced on commercial scale. These are dead-burned magnesia (also called refractory magnesia) and caustic-calcined magnesia (includes specified magnesia). Dead-burned magnesia is produced at temperatures in excess of 1450°C (2640°F), while caustic-calcined magnesia is produced at temperatures lower than 900°C (1650°F).[94,95]

The term "high-grade" refers to refractory magnesia containing roughly 96 percent MgO and having a specific gravity greater than 3.2.[94] The terms "high-purity" or "super high-purity" have been used in the industry for magnesia being supplied to the refractory industry and refer to the amount of accessory oxides rather than to a specific amount of MgO.[94]

Dead-burned magnesia is used almost entirely as a refractory material. It can be used directly or as a constituent of brick, ramming mixes, gunning mixes, or castables. Refractories made from magnesia are used mainly in the steel, cement, glass, and copper industries. The desirable features of magnesia-based refractories are their ability to resist basic slags at high temperatures and their low cost.[96]

Caustic-calcined magnesia is used in the production of magnesium oxychloride and oxysulfate cements, animal feeds, fertilizers, rayon, pulp and paper, construction materials, chemicals, electrical heating rods, fluxes, and petroleum additives.

3.2.12.2 Process Description.

Most of the plants in the U.S. produce magnesias from natural brine solutions. Only one plant uses magnesite ore to produce magnesia, and the plant considers its process confidential. Therefore, only the process that uses natural brine solution is described below.

A typical flow diagram for the production of magnesias from natural brine solutions is shown in Figure 3-28. Magnesium-rich brine, which contains magnesium chloride, is reacted with dolomitic lime (CaO·MgO) in

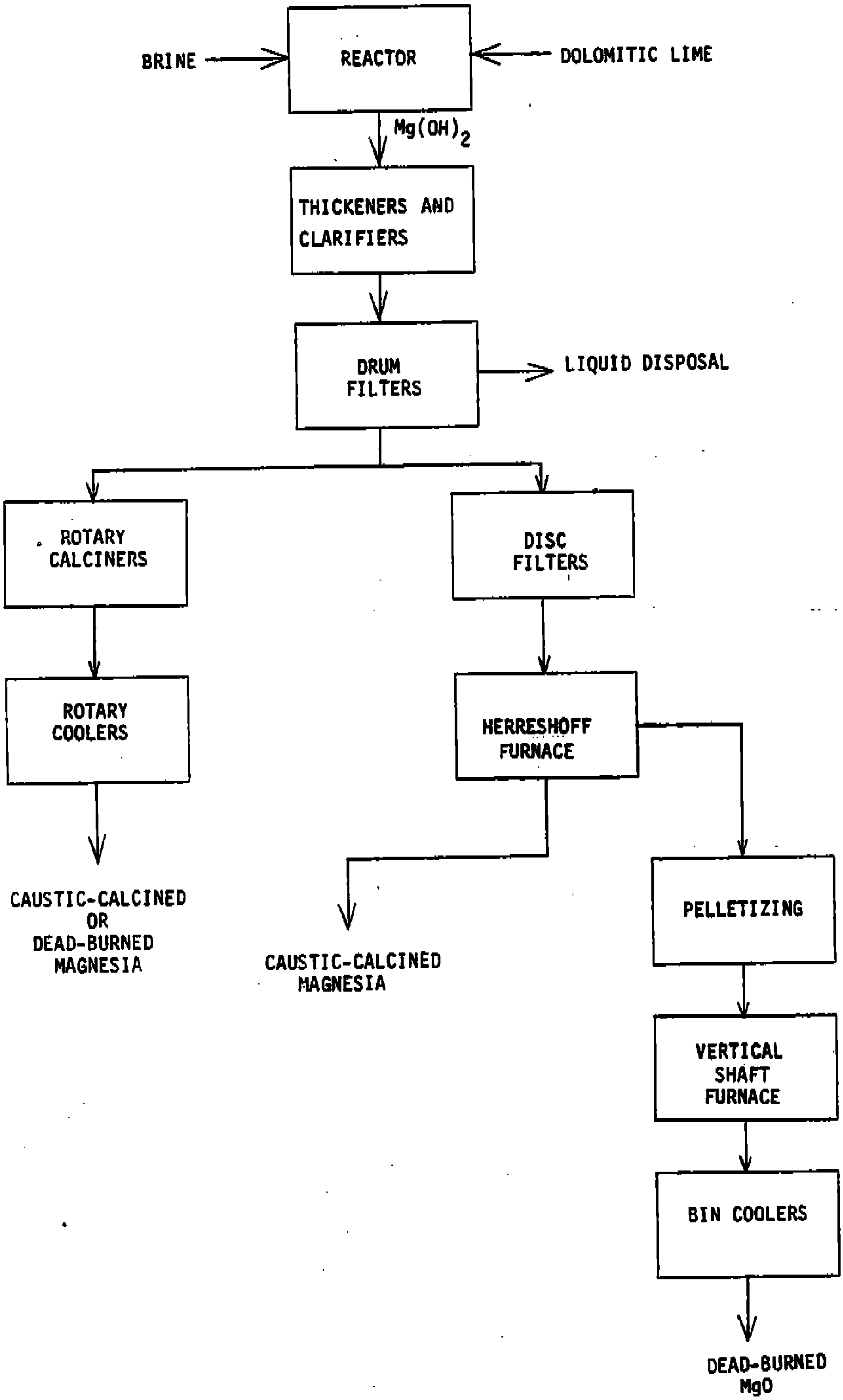


Figure 3-28. Typical process flow diagram for the production of magnesias from natural brine solutions.

reactors to form magnesium hydroxide ($Mg(OH)_2$). The magnesium hydroxide is insoluble and precipitates out as a slurry. The slurry is thickened, washed, and filtered before being calcined in rotary calciners or in Herreshoff furnaces (multiple hearth furnaces). Occasionally additives such as lime are added prior to calcination to meet the product specifications of customers. Rotary calciners can produce either caustic-calcined magnesia or dead-burned magnesia. Herreshoff furnaces produce caustic-calcined magnesia. Vertical shaft kilns are also used in the production of dead-burned magnesia. However, these kilns are used to sinter the calcined product from Herreshoff furnaces. They are not used to calcine the magnesia slurry.

3.2.13 Perlite

3.2.13.1 Background. Perlite is a glassy, volcanic rock having a pearl-like luster and usually exhibiting numerous concentric cracks that cause it to resemble an onion skin in appearance. Chemically, crude perlite is an amorphous aluminum silicate. A typical chemical analysis of perlite would show 71 to 75 percent silicon dioxide (SiO_2), 12.5 to 18.0 percent alumina (Al_2O_3), 4 to 5 percent potassium oxide (K_2O), 1 to 4 percent sodium and calcium oxides, and trace amounts of metal oxides.[97]

When particles of crude perlite are heated to a plastic state (softening point), the combined water (2 to 5 percent) vaporizes, forming steam that expands each particle into a mass of glass foam. The original volume of the crude perlite may be expanded 4 to 20 times at temperatures between 760° and 1090°C (1400° and 2000°F). Expanded perlite can be a fluffy, highly porous material or can be composed of glazed, glassy particles having a low porosity.[98]

Crude perlite ore is normally dried, crushed, and screened at the mine before shipment to expansion plants. The normal size of crude perlite expanded for use in plaster aggregates ranges from plus 250 µm (60 mesh) to minus 1.4 mm (12 mesh). Crude perlite expanded for use as a concrete aggregate ranges from 1 mm (1/8 in., plus 16 mesh) to 0.2 mm (1/2 in., plus 100 mesh). Crude perlite ore expanded for horticultural uses is 90 percent greater than 841 µm (20 mesh).[99]

Industrial uses for expanded perlite are many and varied. In 1981, the percentages of expanded perlite sold and used by U.S. producers were: formed products (accoustical ceiling tile, pipe insulation, roof insulation board, etc.) (54 percent), filter aid (20 percent), horticultural aggregate and fertilizer carriers (9 percent), concrete aggregate (5 percent), masonry and cavity fill insulation (4 percent), plaster aggregate (4 percent), fillers (1 percent), low-temperature insulation (1 percent), and other uses (includes high-temperature insulation, paint texturizer, and refractories) (3 percent).[100] A total of 430,800 Mg (475,000 tons) of expanded perlite were sold and used in 1981. To produce this amount of expanded product, 644,100 Mg (710,000 tons) of crude perlite were mined, and 536,200 Mg (591,000 tons) were sold to or used by expanders.[100]

In the U.S., perlite rocks are widely distributed throughout the western States; deposits are known in 12 States. New Mexico deposits account for 80 to 90 percent of the total U.S. crude perlite mined on an nnual basis.[97] In 1982, crude perlite was produced by 10 companies at 2 mines in 6 States.[101]

Crude ore is mined, crushed, dried in a rotary dryer, ground, reened, and shipped to expansion plants. Expansion takes place in izontal rotary, or vertical stationary expansion furnces. In 1982, nded perlite was produced by 42 companies at 73 plants in 32 States.[101]

3.2.13.2 Process Description.

3.2.13.2.1 Crude ore. Crude perlite is mined by open pit methods oved to the plant site where it is stockpiled. Figure 3-29 is a iagram of crude ore processing. The first processing step is to the ore to approximately 1.6 cm (0.6 in.) in a primary jaw crusher. de ore is then passed through a rotary dryer to reduce the moisture from an initial 4 to 10 percent down to less than 1 percent. r the ore is dried, secondary grinding is accomplished in a rcuit system using screens, air classifiers, hammer mills, and [97] The various-sized materials are then stored for later d shipment to expansion plants. Any oversized material om the secondary circuit is returned to the primary crusher. ties of fines, up to 25 percent of the mill feed, are

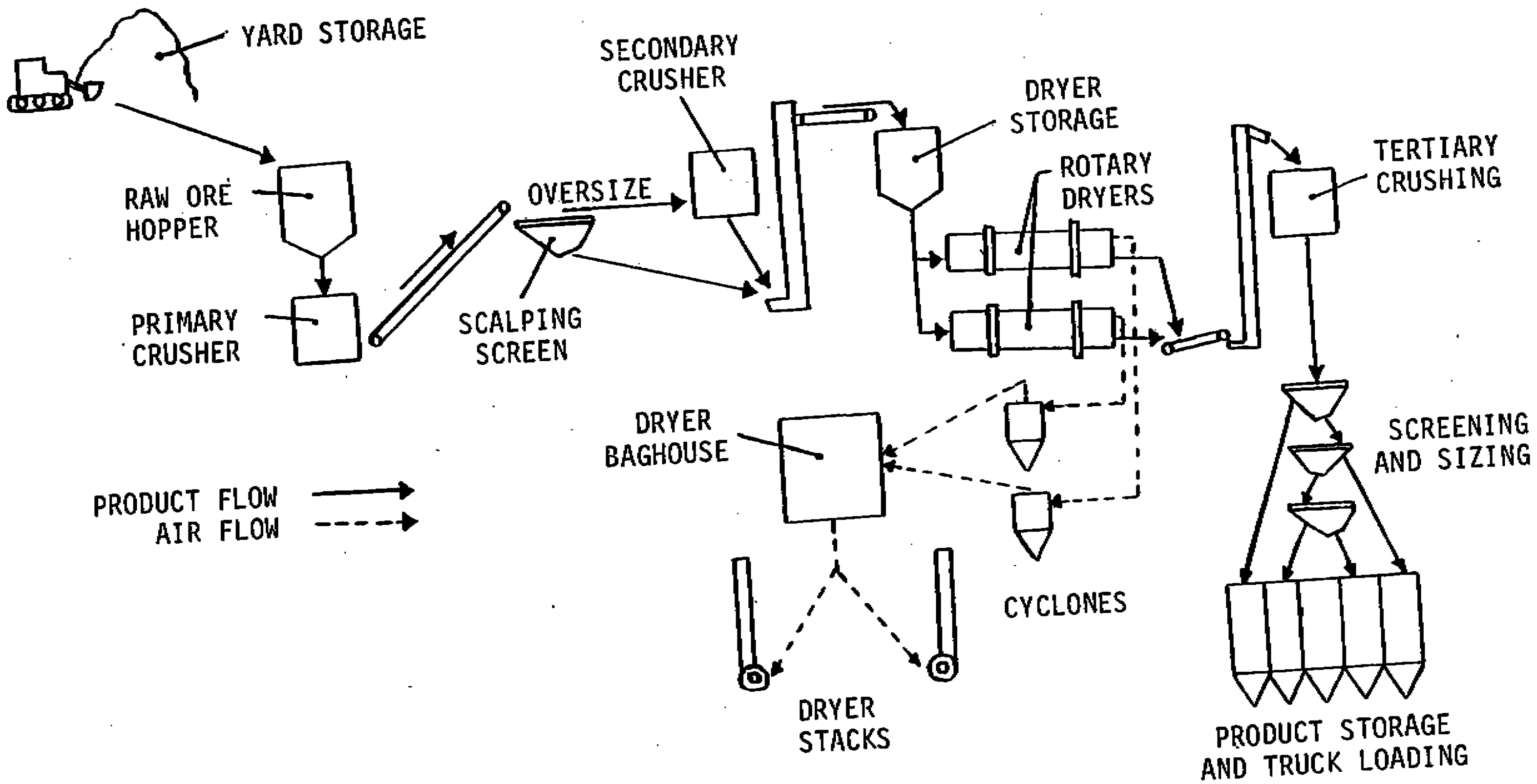


Figure 3-29. Flow diagram for perlite ore processing.[102]

produced throughout the processing stages but are removed by air classification at designated stages.[97]

3.2.13.2.2 Expanded perlite. Because of the low density (48 to 320 kg/m^3 [3 to 20 lb/ft^3]) of expanded perlite, it is not economical to ship the expanded product long distances. Therefore, many small perlite expansion plants are utilized to produce the expanded product near market areas. Different furnace types have been designed for expanding perlite, but the two most common types in use today are variations of the horizontal rotary furnace and the stationary vertical furnace.[97]

The expansion characteristics of the crude perlite are influenced by factors such as the amount of combined water present and the amount of moisture driven off in the furnace. The processing temperature used is influenced by the softening point of the sized crude product. It is, therefore, often necessary to have a preheater attached to the furnace to preheat the crude perlite to approximately 430°C (800°F) before its injection into the furnace. Preheating reduces the amount of fines produced in the expansion process, which increases usable output and controls the uniformity of product density.[97] When the perlite ore has reached a temperature of 760° to 980°C (1400° to 1800°F), it begins to soften to a plastic state, and the entrapped combined water is released as steam. This causes the hot perlite particle to be expanded.[103] The retention time in the furnace is 2 to 3 seconds. In most cases, fines are removed at the mill by air classifying during screening. This also duces the amount of fines in the ore to be expanded.

After the perlite particles in the furnace expand 4 to 20 times ir original volume, they are drawn out of the furnace by a suction and are transported pneumatically to a cyclone classifier system for ection. The air-suspended perlite particles are also cooled as they l through the ductwork to the collection equipment. The cyclone ifier system collects the sized products, removes the excessive and discharges gases to a baghouse or wet scrubber for air pollu- ntrol.

grades of expanded perlite produced can also be adjusted by various crude sizes, changing the heating cycle, and altering ff points for size collection. All processed products are graded for specific uses and are usually delivered to storage bins or surge hoppers prior to bagging and shipping.[97] Most production rates are less than 1.8 Mg/h (2 tons/h), and expansion temperatures range from 870° to 980°C (1600° to 1800°F). Natural gas is the most common fuel with No. 2 oil and propane used in a few cases. Fuel consumption varies from 2,800 to 8,960 kJ/kg (2.4 to 7.7 x10^6 Btu/ton) of product. Expanded perlite is graded by density and classified by product number or trade name for producer and user identification. The most common product density range is 112 to 240 kg/m^3 (7 to 15 lb/ft^3).

3.2.14 Roofing Granules

3.2.14.1 Background. Roofing granules are defined as particles of rock or fired clay, about 0.9 mm (9 mesh) in size, used in the manufacture of asphalt roofing shingles.[104] Roofing granules may be coated with sodium silicate pigmented with iron oxides. Coating helps to protect the roofing base material, which is usually asphaltic, from embrittlement and rapid breakdown by ultraviolet light.[105]

No single type or family of rock or minerals is considered as a class to be an acceptable ore source, but rigid physical and chemical specifications must be met. The following rock types found in the United States are being used as a granule base: East Coast--rhyolite, diabase, greenstone, arkosic quartzite; Midwest--andesite, graystone, granite, nepheline syenite; West--basaltic river gravels, dacite porphyry.[106] Rock deposits must provide enough raw material for a 30- to 50-year period to justify the capital expenditure required for a new plant.[106]

Other required properties for rock deposits used in the manufacture of roofing granules are:[106]

1. Weathering resistance. Granules provide necessary protection to the asphalt product from differential thermal expansion of the various rock-forming minerals and by moisture that seeps into voids around mineral crystals causing disintegration of the rock upon freezing. Also, chemical weathering results chiefly from the dissolution of carbonates and sulfates in the rock and from the hydration or oxidation of certain mineral substances;

2. Acceptance of coloring process. After crushing, the surface characteristics of many rocks make it difficult to apply a coating. If the rock has a high percentage of iron compounds, the rock becomes brownish-red when heated and changes the appearance of the coated granules;

3. Uniformity. To conform to customer specifications, the rock should be uniform in quality and physical properties, and homogeneous in color;

4. Low porosity. High porosity granules would allow the seepage of water into the interior of the asphalt shingle, causing blistering and cracking;

5. Complete opaqueness to ultraviolet light. Ultraviolet light can rapidly deteriorate roofing asphalt;

6. Toughness. This minimizes attrition breakdown in handling; and

7. Ability to fracture equidimensionally upon crushing. A cubical fracture helps to eliminate color differences that result from the viewing at different angles of flat, roll, or splintery granules.

3.2.14.2 Process Description. The mineral types suitable for use as a roofing granule are basalt, dorite, porphyry, andesite, argillite, granite, nepheline syenite, rhyolite, diabase, greenstone, and arbosic quartzite.[106] A process flow diagram showing the steps involved in roofing granule production is presented as Figure 3-30. In many respects, the operation of a roofing granule quarry is similar to that of crushed rock aggregate quarry. The main difference is the need for uniform quality in the mineral. The mining operation consists of over-rden removal, drilling and blasting, followed by secondary breakup. mineral is then loaded by power shovel into quarry trucks and hauled the mill site. At the mill site, the mineral passes through a primary sher, which is a jaw or gyratory type. Secondary crushing is then formed by cones, crushers, or roll or hammer mills in closed circuit vibrating screens. Next the crushed rock is dried, usually in a ry dryer, and screened prior to tertiary crushing.

The crushed rock is trucked or belt-conveyed to the coating plant it is further crushed to granule size. The granules are mixed pigments and other coating materials in rotary-type mixers. The

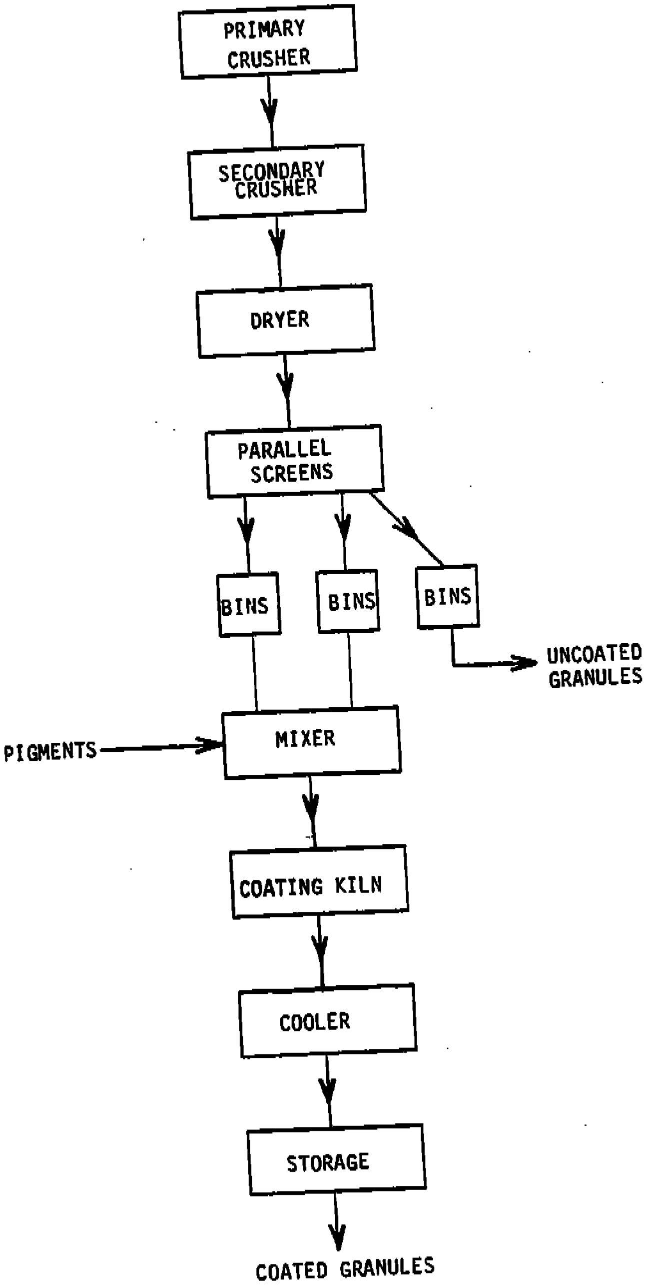


Figure 3-30. Roofing granules production.[106]

silicate-clay process is the basis for much of the present technology and consists of coating the granules with a mixture of sodium silicate and inorganic clay pigments.[106] The coated granules are fed to a coating kiln where they are dried and fired. Granules are discharged from the kiln into a rotary-type cooler or similar device. Rescreening on vibrating screens is usually necessary after the firing and cooling process to maintain granule grade. The rescreening is performed before storage or in the shipping and loading process.

3.2.14.2.1 <u>Dryers</u>. Rotary dryers are the primary ore dryer type used in the industry. (Fluid bed dryers are used by one company to dry a coal-fired boiler slag, which is an atypical granule material.) The function of the ore dryer is to process the crushed rock so that it will not clog the screens that are used to classify the rock.

3.2.15 Talc

3.2.15.1 <u>Background</u>. Talc is a soft, hydrous magnesium silicate ($3MgO \cdot 4SiO_2 \cdot H_2O$), theoretically composed of 63.4 percent SiO_2, 31.9 percent MgO, and 4.7 percent H_2O.[107] The actual composition of commercial talc may vary widely from these levels. Talc may also contain one or more of the following oxides, ranging in concentration from a race to several percent: iron, titanium, aluminum, calcium, potassium, odium, nickel, chromium, cobalt, and phosphorus. For most end-uses, se impurities are undesirable and are removed to the extent feasible. color of talc varies from snow-white to greenish-gray and various des of green. Its specific gravity ranges from 2.6 to 2.8.[108]

Talc deposits can be found in many parts of the world. In 1980, minerals were produced at 40 mines in 11 States. Mines in four s produced about 90 percent of the nationwide annual total.[109] The s producing the highest tonnage, in decreasing order, were Montana, New York, and Vermont.[109]

The word talc refers to a wide variety of rocks and rock products. one reportedly contains up to 50 percent talc.[109] It has a y feeling and can be carved by hand. Steatite contains a rity talc suitable for making electrical insulators. These talc-containing minerals (soapstone and steatite) will be treated as talc in this section.

Talc is one of the most versatile inorganic materials used by industry. The end-uses for talc are determined by variables such as chemical and mineralogical composition, particle size and shape, specific gravity, hardness, and color. According to 1981 statistics, the largest use of talc-group minerals is for the manufacture of ceramics (31 percent), which includes kiln furniture, sanitary ware, floor and wall tile, dinnerware glazes, and electrical porcelains. For these end-products, the addition of talc to the usual clay-silica-feldspar body mixtures facilitates the firing of the ware and improves the quality.[109]

The second major use of talc minerals is as a filler and/or a pigment for paints (22 percent of total 1981 U.S. production).[109] The plastics industry is the third major user (12 percent) of talc, followed by coating and/or loading of high-quality papers (11 percent). Other applications for talc are cosmetics (7 percent), rubber (4 percent), and roofing (2 percent).[109]

Grades of talc are most frequently identified with the end use. Some of the important desirable properties are softness and smoothness, color, luster, high slip tendency, moisture content, oil and grease absorption, chemical inertness, fusion point, heat and electrical conductivity, and high dielectrical strength.

More specific requirements for talc are described below for the major end uses.[107]

Ceramics. Uniform chemical and physical properties are required. Manganese and iron are objectionable, and for high-frequency insulators, no more than 0.5 percent CaO, 1.5 percent iron oxide, and 4 percent Al_2O_3 are usually tolerated.

Paints. Impurities that turn the talc to colors other than white are highly objectionable. To obtain the desired smooth paint film, at least 98.5 percent must pass a 44 μm (325 mesh) screen.

Paper. The main requirements are chemical inertness, softness, freedom from grit, satisfactory ink acceptance, brightness, and dispersibility in water.

Rubber. Ground talc is used as filler in the compounding formulations of synthetic rubbers. Volume changes, amount of filler, and particle size all affect the stress-strain relationship of the product.

Roofing. A low-grade, offcolor, and impure talc is acceptable.

Insecticides. The main requirements are chemical inertness with respect to toxicants, satisfactory bulk density, and low abrasive characteristics.

Cosmetics and Pharmaceuticals. Talc must be grit free, finely sized, chemically pure, and pleasing in color.

3.2.15.2 Process Description. More than half the total domestic output of talc is derived from open-pit operations, although underground mines continue to be important sources of this mineral. Mining operations usually consist of conventional drilling and blasting methods.[107] The softness of talc makes it easier to mine and process than most other minerals.

3.2.15.2.1 Dryers. Figure 3-31 is a process flow diagram for a ypical Eastern U.S. talc plant. Talc ore is generally trucked to the ant from a nearby mine. The ore is crushed and screened, and coarse ersize) material is sent through a gyratory crusher. Drying of the separate fractions is accomplished by a rotary dryer. Secondary ding is achieved with pebble mills and/or roller mills, producing a uct that is 44 to 149 μm (325 to 100 mesh) in size.[110] Air classifiers rators), generally in closed circuit with the mills, separate the ial into coarse, coarse plus fine, and fine fractions. The coarse arse plus fine fractions are then stored. The fines undergo a g process to remove sulfides (about 1 to 2 percent) and a one-step on process. The resultant talc slurry is dewatered and filtered o passing through a flash dryer. The flash dried product is then or shipment, or it may be further ground to meet customer ations.

15.2.2 Calciners. Talc deposits mined in the Western U.S. ganic impurities and must be calcined prior to additional to yield a product with uniform chemical and physical Generally, a separate product line will be used to produce

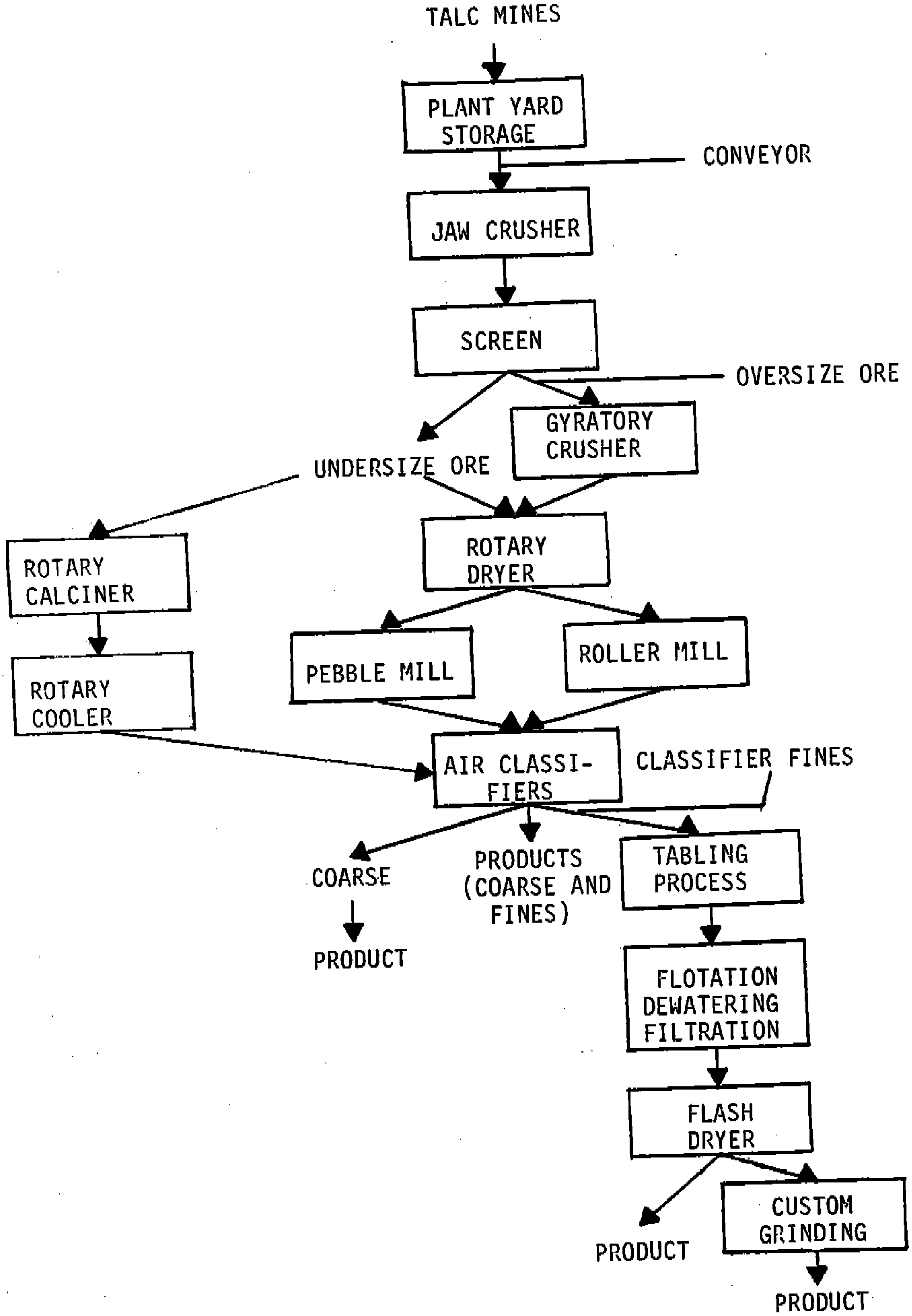


Figure 3-31. Process flow diagram for talc processing.[110]

the calcined talc. Prior to calcining, the mined ore passes through a crusher and is ground to a specified screen size. After calcining is accomplished by a rotary kiln, the material passes through a rotary cooler. The cooled calcine (0 percent moisture) is then stored for shipment or it may be further processed. Calcined talc may be mixed with dried talc from other product lines and passed through a roller mill prior to bulk shipping.

3.2.16 Titanium Dioxide

3.2.16.1 Background. Titanium dioxide (TiO_2) pigments are produced by two processes, the chloride process and the sulfate process. For the chloride process, rutile or ilmenite ore may be used; however, rutile ore is the preferred raw material because the chloride-ilmenite process involves simultaneous beneficiation and chlorination. The sulfate process uses ilmenite or a titanium slag as the raw material. The final product is an anatase pigment, although a rutile pigment can also be produced.

Rutile ore occurs as reddish-brown to red crystals of tetragonal
tructure or in granular masses. It contains 94 to 98 percent TiO_2.
rtually all of the rutile ore used in the United States is imported.
enite is iron black and crystallizes in the hexagonal system. It
tains 37 to 65 percent TiO_2, 30 to 55 percent iron oxide, and trace
unts of silica, alumina, and other metals. Titanium slag may also be
idered as an ore. It is produced by smelting a mixture of carbon
itanium-bearing material to yield molten iron and slag containing
90 percent TiO_2.[111]

Of the 1981 production of titanium dioxide, 74 percent was produced
chloride process and 26 percent was produced by the sulfate
. Of the chloride production, 92 percent was rutile pigment, and
nt was anatase pigment. Of the sulfate production, 11 percent
le pigment, and 89 percent was anatase pigment. The rutile
is used primarily in the paint, varnish, and lacquer industry,
anatase pigment is used primarily in the paper industry.
uses of TiO_2 pigment are numerous. Ninety-two percent of the
ium consumption in the United States was in the form of TiO_2
[12] Because of its high refractive index (anatase--2.55,

rutile--2.72), which imparts whiteness, opacity, and brighteners, the largest market for the pigment is in the paint, varnish, and lacquer industry.[113] The tinting strength and opacity of TiO_2 surpasses any other white pigment. Over one-half of all nonpermanent, white, or light-colored surface coatings utilize TiO_2 pigment. A typical exterior white paint contains about 40 percent pigment, of which 60 percent is TiO_2. The remainder is made up of zinc oxide (ZnO) and fillers such as mica, silica, silicates, or calcium carbonate.[114] The paint manufacturer selects which TiO_2 type to use (anatase or rutile). The differences in crystalline structures give different covering and chalking characteristics. Other lower quality paints can be produced by mixing or co-precipitating TiO_2 with cheaper pigments of low hiding power.

Anatase is used as a paper coating or as a paper filler to improve opacity, brightness, and printability. It is used in photographic paper; paper boxes that need a light-colored, high-gloss coating; and in practically all printing paper except newsprint.[112] The purposes of a filler are to occupy space between fibers, thus giving a smoother surface, a more brilliant whiteness, increased printability, and increased opacity.[114]

Titanium dioxide is also used in plastics due to its resistance to degradation by ultraviolet light, high refractive index, whiteness, and chemical inertness to most plastic materials.[112] Miscellaneous uses are as the universal delusterant for all man-made fibers, and in dielectrics due to its high dielectric constant. Also, TiO_2 pigment is used for welding rod coatings, rubber tires, roof coatings, printer's ink, floor coverings, and porcelain enamel.[112]

A number of materials, such as ZnO, talc, clay, silica, and alumina can be used in place of TiO_2 pigment, but a lesser quality pigment (in regard to opacity and brightness) is produced, or higher costs are incurred.[112]

3.2.16.2 Process Description.

3.2.16.2.1 Chloride process. The chloride process is used to produce mostly rutile pigment. It requires a feedstock with a high titanium content and a low iron content. Both rutile and ilmenite ores can be used; however, rutile ore is the preferred raw material. The estimated Mg (tons) of raw materials required to produce one Mg (ton) of TiO_2 are:

Rutile ore	1.0-1.1	(1.1-1.2)
Chlorine	0.09-0.18	(0.1-0.2)
Petroleum coke	0.09-0.18	(0.1-0.2)
$AlCl_3$	0.027	(0.03)

Figure 3-32 is a simplified flow diagram of the chloride process. The ore, after being dried in an ore dryer, is mixed with petroleum coke and is chlorinated in a fluid bed reactor at about 1000° to 1100°C (1830° to 2010°F). The main product is titanium tetrachloride ($TiCl_4$), but iron and other impurities are also chlorinated. Titanium tetrachloride leaves the reactor as a hot vapor in the presence of other vaporized metal chlorides. The $TiCl_4$ prepared usually contains free chlorine and small amounts of dissolved compounds of iron, silicon, vanadium, and other elements and is of a yellowish or reddish color. The discoloration has been ascribed to vanadium oxychloride ($VOCl_3$), ferric chloride, and uncombined chlorine. Ferric chloride is removed by filtration after cooling to room temperature. The other constituents can be readily separated by fractional distillation.[115] In the recovery ystem, the metal chlorides can be totally condensed, forming a slurry $TiCl_4$ and solid metal chlorides. In this case, $TiCl_4$ is separated om the waste solids by settling and decantation. A particle condensaon recovery system can be used where the solid metal chlorides, which less volatile than $TiCl_4$, are condensed as powders. The remaining or, greatly enriched in $TiCl_4$, is then totally condensed giving a id relatively free of the metal chloride solids. Selective reduction r to a final distillation removes $VOCl_3$, or vanadium can be removed sulfide by the addition of hydrogen sulfide.[116]

Purified $TiCl_4$ vapor is fed to a reaction chamber with oxygen to at temperatures above 1000°C (1800°F). Aluminum chloride is added $TiCl_4$ to ensure that virtually all of the titanium is oxidized to ile crystalline form rather than the anatase form. The reactor designed to minimize the accumulation of solid products on the d burner parts and to give a product of optimum crystal size

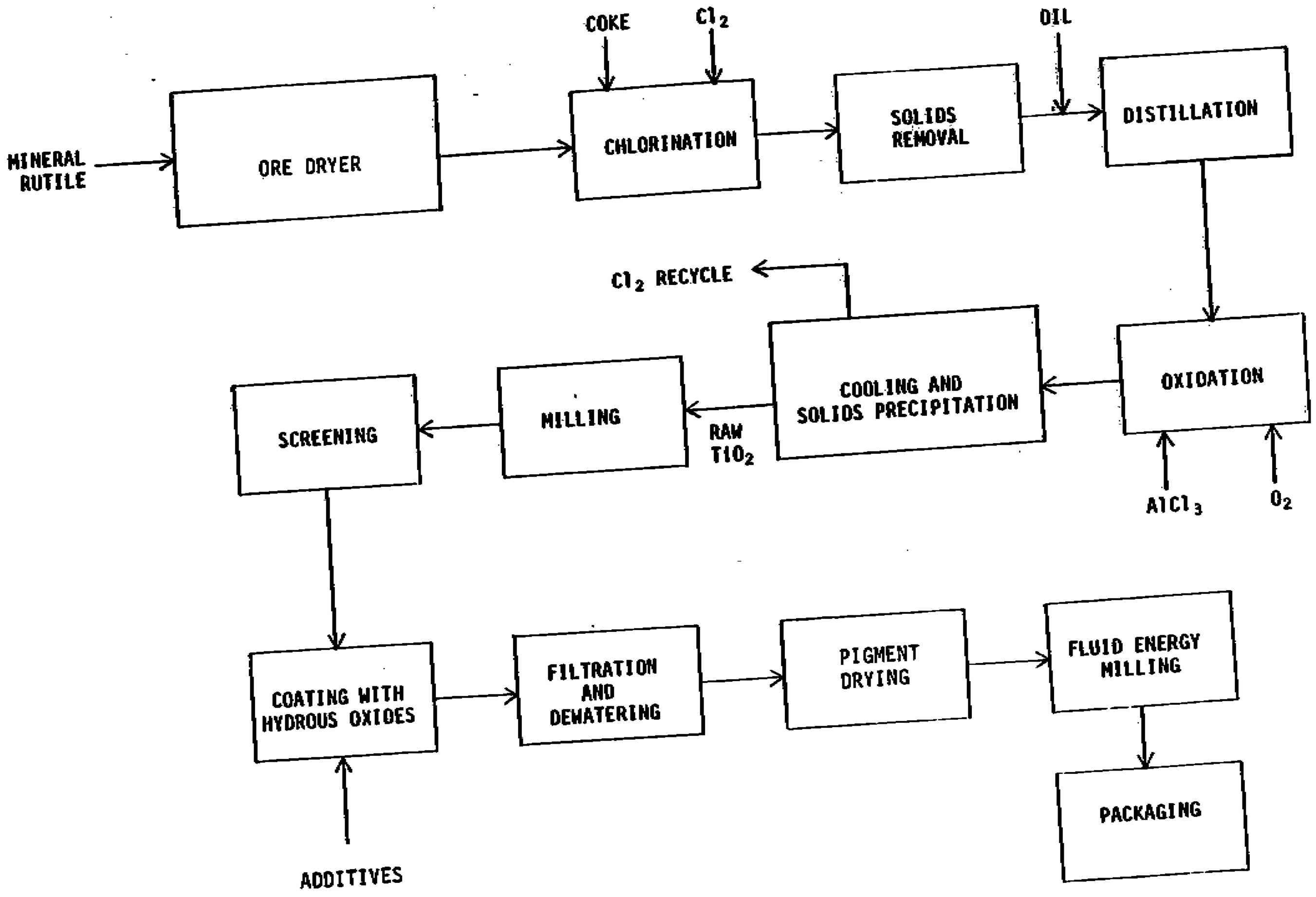


Figure 3-32. Simplified flow diagram of chloride process--TiO_2.[116]

(0.2 μm). Chlorine is regenerated in the oxidation step, and after cooling and separation from the product, it is recycled to the chlorinator.[117]

After being dry milled by ring roller mills or fluid energy mills, or wet milled in ball or sand mills, the raw TiO_2 is coated by adding an aqueous acid or alkali. The individual pigment particles are further coated by the successive addition of salt solutions such as titanyl sulfate, aluminum sulfate, and acids or alkalies to reduce their photocatalytic activity and to improve dispersibility.[117] Many variations of this process are used to optimize the surface characteristics of the pigments for different applications. After coating, the pigments are filtered, washed, dried (in pigment dryers), and enter a fluid energy mill prior to packaging. There is no drying performed at the fluid energy mill.

The several hundred commercial grades of pigments vary in their TiO_2 crystal structure, particle size and shape, type of hydrous oxide coating, and content of additives for specific applications. These pigments contain 80 to 99 percent TiO_2, the remainder being principally alumina and silica hydrates.[117]

3.2.16.2.2 <u>Sulfate process</u>. The sulfate process is used to produce mostly anatase pigment. The raw material used in the sulfate process is finely ground ilmenite or high-TiO_2 slag. There are no rigid specifica-
ions for feed materials, but certain impurities such as chromium,
nadium, manganese, and phosphorus are known to impair pigment properties.
TiO_2 content must be high enough to be recovered economically, and
concentrate must be capable of being dissolved in sulfuric acid at a
tical temperature. The TiO_2 content ranges from about 45 percent
unaltered ilmenite concentrate to 70 to 72 percent for slag.

The raw material requirements for one Mg (ton) of pigment produced
e sulfate process are 1.5 to 2.4 Mg (1.6 to 2.6 tons) of ilmenite
tanium slag, 2.7 to 3.6 Mg (3 to 4 tons) of sulfuric acid, and 0.09
19 Mg (0.1 to 0.2 tons) of scrap iron.[116]

flow diagram of the sulfate process is shown in Figure 3-33.
ilmenite is dried in an ore dryer to drive off moisture. The
re is ground and then digested with concentrated sulfuric acid

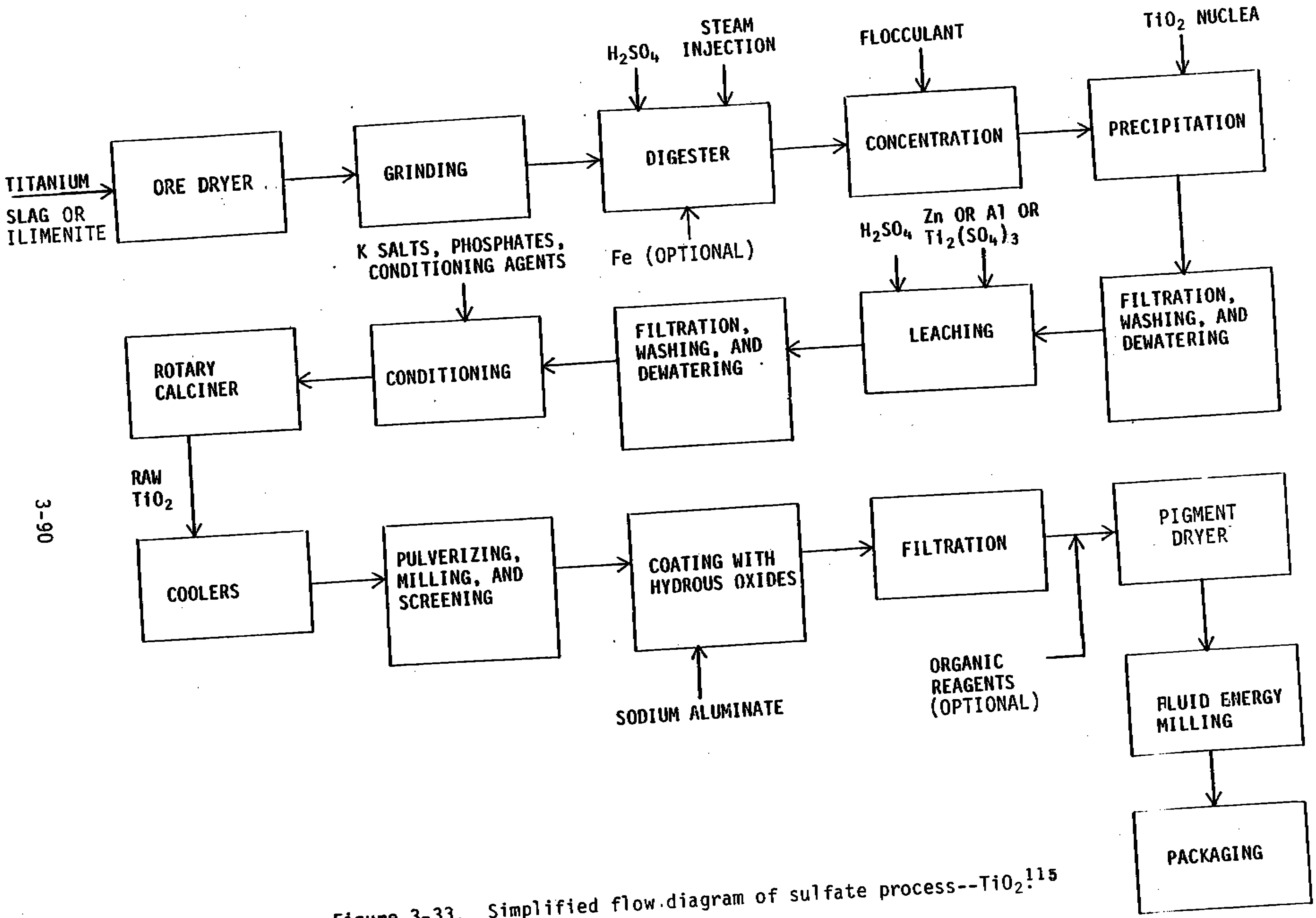


Figure 3-33. Simplified flow diagram of sulfate process--TiO_2.[115]

forming a solid, porous cake, which is then dissolved in dilute acid and water to yield a solution of titanyl sulfate ($TiOSO_4$) and iron sulfate ($FeSO_4$). The process occurs as a batch operation in large, conical concrete or steel tanks. The digestion process leaches sulfates of iron and titanium from the ore. Any iron present in the ferric state is reduced to the ferrous state by adding scrap iron. This is done to avoid precipitation of ferric iron late in the process and to facilitate washing the precipitated TiO_2. One company does not add scrap iron in the digestion step.

The solution resulting from the digestion process is clarified in thickeners, cooled, and sent to a vacuum crystallizer. Ferrous sulfate crystallizes as $FeSO_4 \cdot 7H_2O$ (copperas). These crystals are separated from the $TiOSO_4$ by centrifugation. The next step involves clarification of the $TiOSO_4$ by filtration and concentration by vacuum evaporation.[114] Depending on the form of the product desired, either anatase or rutile seed crystals are added to the concentrated liquor, and the mixture is steam heated or boiled for 6 or 3 hours, respectively. During the steam eating period, about 95 percent of the titanium is hydrolized to in- oluble titanium hydrate or metatitanic acid (H_2TiO_3). To remove residual on sulfate, the hydrate is vacuum filtered, washed by repulping, and ltered twice more, with repulping between filtrations. The first trate may be reworked to remove residual amounts of ferrous sulfate sulfuric acid. The other two filtrates are sent to settling tanks ecover the finely divided titanium hydrate that passed through the r media.

Following filtration, the titanium hydrate filter cake is repulped eated with various conditioning agents. The conditioning agents y include a potassium salt and phosphate and may also include ntimony, and aluminum compounds.[118] The nature of the various treatments determines the grade and type of finished pigment, whether it is anatase or rutile, chalking or nonchalking, oil- dispersable. For anatase production, 0.75 percent potassium is used as a conditioning agent and to develop the greatest trength and color quality.[114] For rutile production, rutile are added.

The titanium hydrate is then calcined to drive off water and residual sulfuric acid from the hydrate. The product from the calciners (raw TiO_2) is then finished by pulverizing, milling, screening, coating with hydrous oxides, filtering, and drying. Sometimes, organic reagents are added (to aid dispersion of pigments for customer's use) before the TiO_2 is dried. Drying is performed in a pigment dryer followed by final grinding by attrition in the fluid-energy mills.

3.2.16.2.3 Dryers/calciners in the chloride process. Dryers are used in the chloride process for ore drying and for pigment drying. Calciners are only used in the chloride-ilmenite process. Rotary dryers are used in the chloride process for drying of rutile ore. Operating temperatures range from 150° to 650°C (300° to 1200°F). Natural gas is the most common fuel used. The most commonly used pigment dryers are spray dryers, although flash dryers are also used. Operating temperatures for spray dryers range from 130° to 700°C (275° to 1300°F).

3.2.16.2.4 Dryers/calciners in the sulfate process. Dryers and calciners are used in the sulfate process for ore drying, ore calcining, and pigment drying. The most commonly used ore dryers are rotary indirect dryers, though rotary direct dryers are also used. Operating temperatures range from 120° to 130°C (250° to 275°F). Natural gas is the most commonly used fuel, although fuel oil is also used.

The TiO_2 hydrate (~65 percent water and some H_2SO_4) from the digester is calcined in direct-fired rotary calciners. As material passes through the calciner, it is first dried, then combined water and sulfate are driven off. The calciner temperature is carefully controlled according to the grade of pigment being made, that is, either anatase or rutile. An increase in temperature favors the formation of rutile. The calcining operation converts TiO_2 from an amorphous to a crystalline state thereby raising the refractive index.[113] Calcined material is approximately 99 percent TiO_2 and contains no moisture.[115]

3.2.17 Vermiculite

3.2.17.1 Background. Vermiculite is the geological name given to a group of hydrated laminar minerals that are aluminum-iron-magnesium silicates and that resemble mica in appearance. When subjected to heat, vermiculite has the unusual property of exfoliating, or expanding, due to the interlaminar generation of steam.[119]

The world's largest deposit of vermiculite is mined near Libby, Montana, with other major deposits located near Enoree, South Carolina, and in the Republic of South Africa. Vermiculite is also mined and beneficiated at a mine in Louisa County, Virginia. Deposits of economic significance contain 25 to 95 percent vermiculite.[120]

Estimated world production of crude vermiculite in 1981 was 522,000 Mg (576,000 tons), more than 80 percent of which came from five mines.[121] The United States and Republic of South Africa accounted for 92 percent of world production. Estimated U.S. production of crude vermiculite sold or used by producers in 1982 was 281,000 Mg (310,000 tons).[122]

Vermiculite ore is mined using open-pit methods. Beneficiation includes screening, flotation, drying in rotary or fluid bed dryers, and expansion by exposure to high heat. All mined vermiculite is dried and sized at the mine site prior to exfoliation. Approximately 84 percent of U.S. mined vermiculite is expanded. Uses of unexpanded vermiculite are minor and include muds for oil-well drilling and fillers in fire-resistant wallboard.[123]

Exfoliated vermiculite was produced at 48 plants in 31 States in 981. The principal producing States were, in order of decreasing foliated vermiculite output, Ohio, California, Texas, Florida, South rolina, New Jersey, and Illinois.[124] The main uses of exfoliated miculite in 1981 were: concrete aggregate (22 percent); premixes percent); fertilizer carriers (14 percent); block insulation percent); and loose fill insulation (12 percent). Other uses uded plaster aggregates (2 percent), horticultural uses (8 percent), oil conditioners (6 percent).[125]

Commercial exfoliation of vermiculite is achieved by heating the ized crude vermiculite in a furnace chamber. The bulk volume of cial grades increases 8- to 12-fold, but individual vermiculite les may expand as much as 30-fold compared to the raw ore.[126]

3.2.17.2 Process Description.

3.2.17.2.1 Crude ore processing. Figure 3-34 is a flow diagram of vermiculite ore processing. Crude ore from open-pit mines is brought to the mill by truck where it is stored in outdoor stockpiles. Primary processing consists of removing the plus 1.6 cm (5/8 in.) waste rock and returning the raw ore to stockpiles. Blending is accomplished as material is removed from stockpiles and conveyed to the mill feed bin. The blended ore is fed to the mill where it is separated into fractions by wet screening and concentrated by gravity. All concentrates are collected, dewatered, and dried in a fluid bed or rotary dryer. The dryer products are separated by standard screens and are stored in bins or silos for later shipment or exfoliation.[127]

The rotary dryer is the most common dryer type used in the industry, although one fluid bed dryer is used. Drying temperatures are 120° to 480°C (250° to 900°F), and fuel oil is the most common fuel. One plant has recently switched from No. 2 fuel oil to propane as the fuel for its rotary vermiculite dryer. Personnel at another plant indicated that the capacity for burning oil or wood may be added to their dryer or heat may be recovered from the dryer stack gases.

3.2.17.2.2 Exfoliation. Figure 3-35 depicts a typical vermiculite expanding process. Sized crude vermiculite is dropped continuously through a gas- or oil-fired vertical furnace. Exfoliation occurs after a residence time of less than 8 seconds in the furnace, and immediate removal of the expanded material from the furnace prevents damage to the structure of the vermiculite particle. Flame temperatures of more than 540°C (1000°F) are used for exfoliation. Proper exfoliation requires a high rate of heat transfer and rapid generation of steam within the vermiculite particles.[128] The expanded product falls through the furnace and is air conveyed to a classifier system, which collects the vermiculite product and removes excessive fines. Most units operate at production rates of approximately 0.9 Mg/h (1 ton/h).

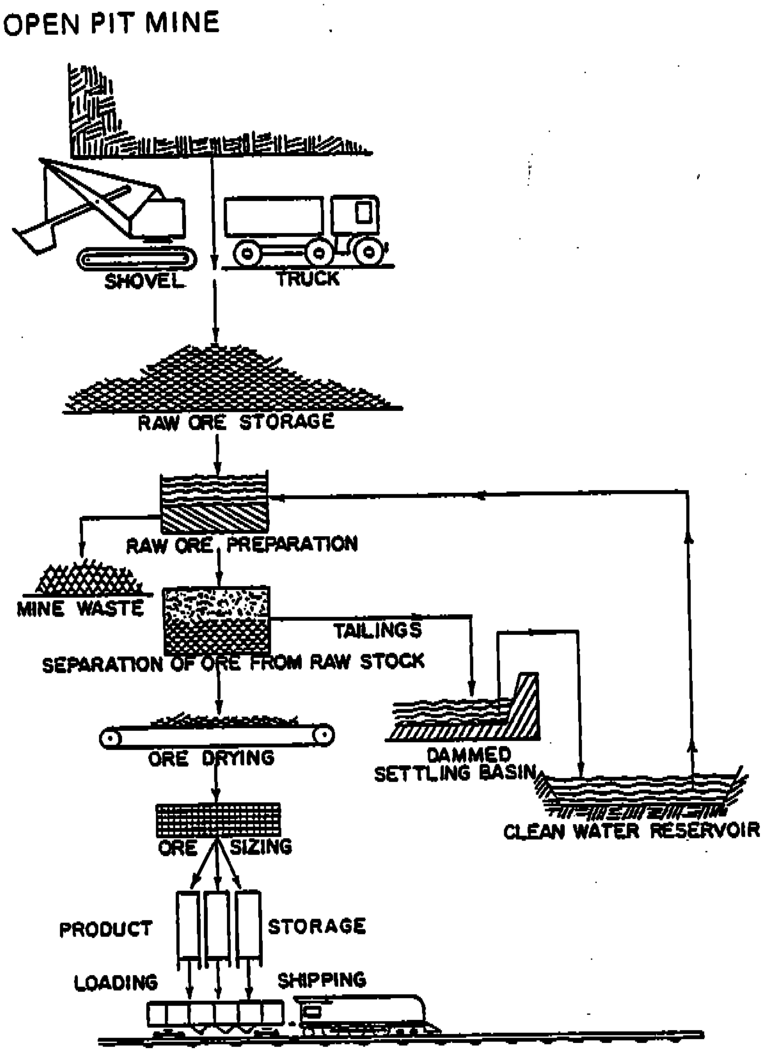


Figure 3-34. Flow diagram of vermiculite ore processing.[129]

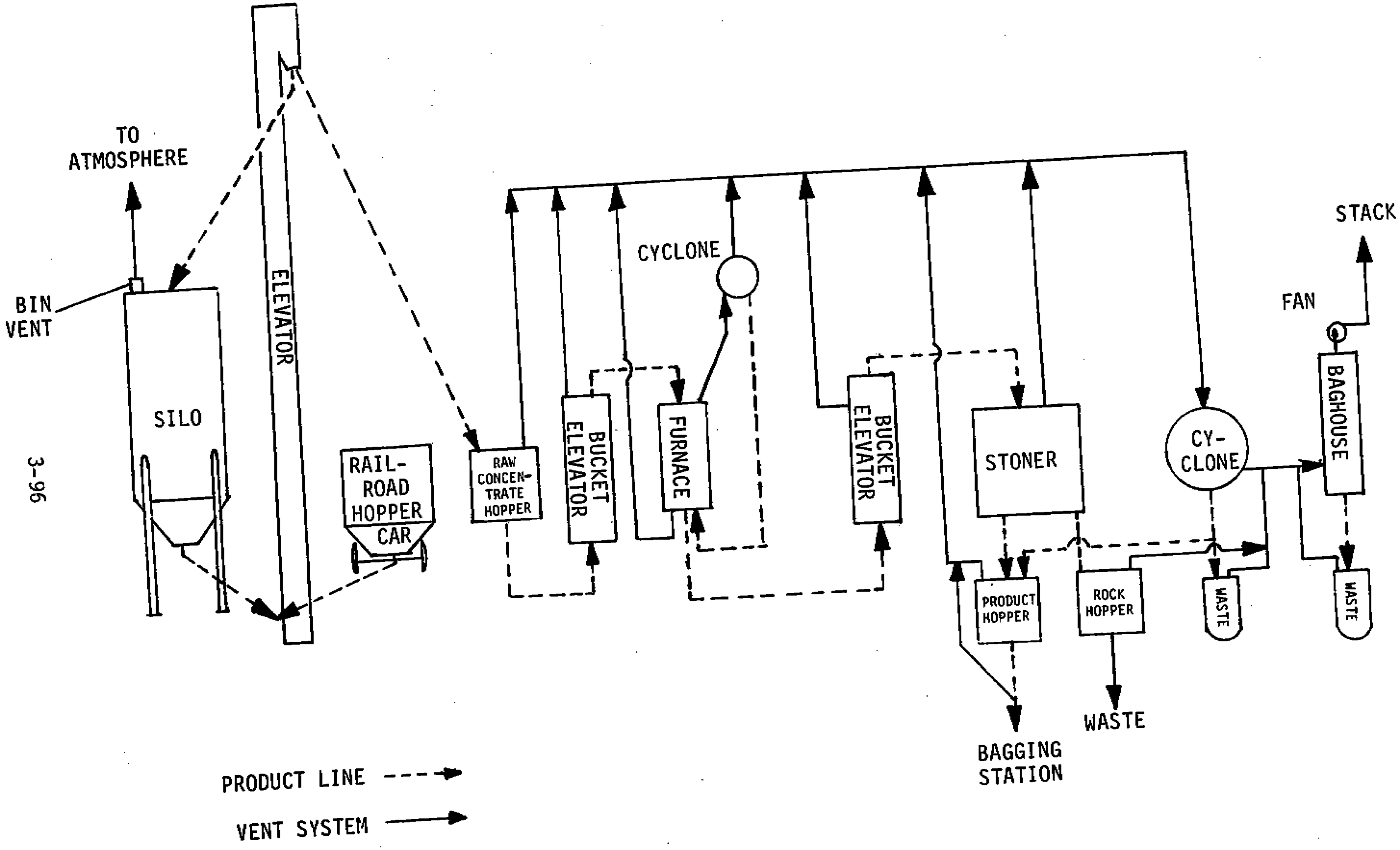


Figure 3-35. Vermiculite expansion system.[130]

3.3 VARIABLES AFFECTING EMISSIONS/UNCONTROLLED EMISSION DATA

3.3.1 Dryers

3.3.1.1 Variables Affecting Emissions. Particulate matter emissions from dryers result from entrainment of dust and fly ash particles in the gas stream through the dryer with subsequent carryover to the exhaust system. Conditions necessary for the entrainment of particulates in a dryer include: (1) a moving gas stream of sufficient velocity, (2) available particles for entrainment, and (3) sufficient mixing or contact between the gas stream and the particles. While there are many process and design variables and factors that affect emissions from dryers, each can be considered in terms of its effect on one or more of the conditions noted above.

3.3.1.1.1 Rotary dryers.

Gas velocity. The gas velocity in a rotary dryer is a function of the volumetric gas flow rate and the dryer diameter. Gas velocity has a significant effect on the amount of dust entrained in a rotary dryer. In 1960, the Barber-Greene Company performed a study on rotary dryers used in the asphalt concrete industry.[131] For a given drum, it was ound that the increase in dust carryout was proportional to the square f the exhaust gas volumetric flow rate, with all other factors held nstant. As shown in Figure 3-36, an increase of 50 percent in asphalt gregate rotary dryer gas velocity from 180 to 275 m/min (600 to 0 ft/min) increased dust carryout by 125 percent.[131]

To ensure low material loss, a low gas velocity or a large diameter r should be used.[132] Within a given industry, similar dryer types variations in the volumetric flow rate per unit of product because ifferent moisture contents in the raw material processed. In direct ry dryers, the gas stream must supply the heat necessary to remove ure from the raw material and must remove the evaporated moisture the dryer. For minimum particle entrainment and minimum energy ption, gas volumes, and consequently gas velocities, should be zed.[133]

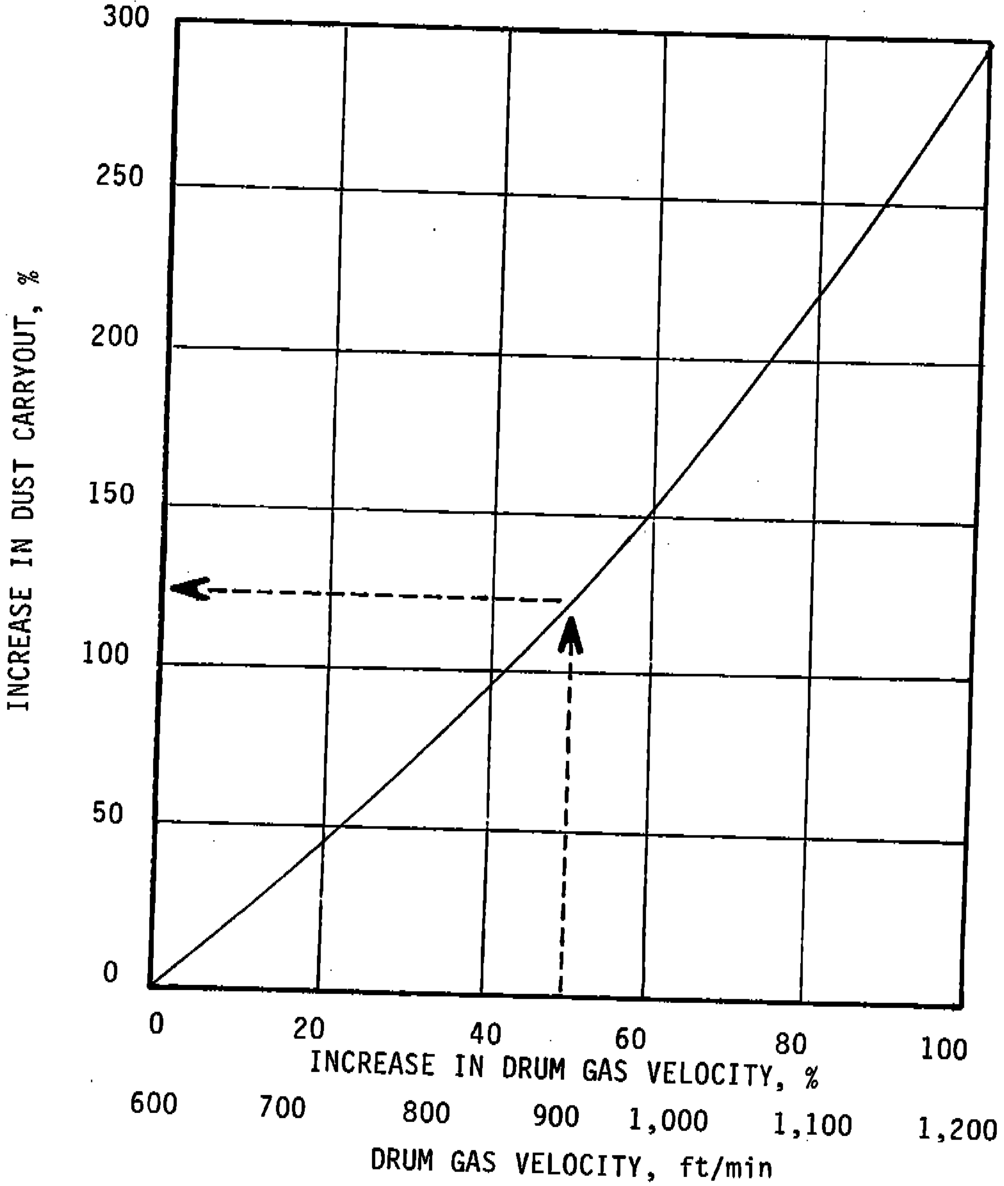


Figure 3-36. Dust carryout versus drum gas velocity.[131]

Indirect rotary dryers require only enough gas flow through the cylinder to remove evaporated moisture.[131] Material is dried by contact with the indirectly heated inner shell. When used in simple drying operations, as in the mineral industries, a damper-equipped dryer admits only sufficient outside air to sweep moisture from the cylinder. In this way, gas velocities and dust entrainment are minimized.[134] Steam-tube dryers are, therefore, especially suited for fine, dusty particles because of the low internal gas velocities required for their operation.[134]

Available particles for entrainment. The amount of readily entrainable fines has a direct impact on the amount of emissions from a rotary dryer. There are three sources of fines, namely, the fines generated by attrition during drying due to the friability of the material, the existing fines in the feed material, and the fly ash generated from burning fuel oil or pulverized coal.

For fine materials and materials that have a tendency to fractionate, a dryer should have a low gas velocity to minimize the amount of particle entrainment. Coarse-grained materials, such as industrial sand, can be processed in small diameter dryers with high gas velocities because these materials contain a limited amount of fines and the coarse material does not become entrained easily.

Rotary dryers in the mineral industries are fired with natural gas, fuel oil, and coal. Of the three fuel types, pulverized coal has the greatest impact on the uncontrolled emissions from a rotary drying unit because of the generation of fly ash particles during combustion.

For a typical pulverized coal-fired rotary dryer processing 27 Mg/h (30 tons/h) of raw material and having an air flow of 12 m^3/s (25,000 acfm), the additional emissions due to coal firing can be estimated as follows:

Assume--500,000 Btu/ton of product
--11,500 Btu/lb coal
--10 percent ash content
--100 percent of fly ash generated is carried out in the exhaust gas stream

$$\frac{500{,}000\ \text{Btu}}{\text{ton}} \times \frac{30\ \text{tons}}{\text{h}} \times \frac{\text{lb coal}}{11{,}500\ \text{Btu}} \times \frac{0.10\ \text{lb ash}}{\text{lb coal}} = \frac{130.4\ \text{lb ash}}{\text{h}}$$

$$\frac{130.4\ \text{lb ash}}{\text{h}} \times \frac{7{,}000\ \text{gr}}{\text{lb}} \times \frac{\text{h}}{60\ \text{min}} \times \frac{\text{min}}{25{,}000\ \text{acf}} = 0.6\ \text{gr/acf}$$

A similar analysis for fuel oil, assuming
--500,000 Btu/ton of product
--150,000 Btu/gal
--0.10 percent ash content
--100 percent of fly ash is carried out in gas stream

predicts additional particulate emissions of 6 $\times 10^{-5}$ gr/acf from fuel oil firing. Firing natural gas would not contribute particulate emissions to the dryer exhaust gas stream.

Gas/solids mixing. The direct-heat rotary dryer is usually equipped with flights on the interior of the shell for lifting and showering of solids through the gas stream as material passes through the cylinder.[135] Figure 3-37 is a schematic of flights used in rotary dryers. The efficiency of a direct rotary dryer is affected by the ability of the flights to produce a uniform curtain of material across the full area of the dryer and along its entire effective length. For this reason, the shape of the flights is an important dryer design factor.[136] While lifting flights improve heat transfer within the dryer, they also increase the amount of particle attrition due to increased material agitation. With low-density materials and materials that are dusty or become dusty by attrition through the cascading effect of the flights, air velocities must be kept at levels where carry-over is minimized.[137]

3.3.1.1.2 Fluid bed dryers. In fluid bed dryers, the gas velocity in the disengaging space is influenced by the dimensions of the disengaging space (height and cross-sectional area), the volume of gas flow through the dryer, and the size of the particles being dried. As a bubble of gas reaches the upper surface of a fluidized bed, the gas breaks through the thin upper layer of solid particles. Some of these particles become entrained by this action and are carried upward by the gas flow. The downward force of gravity and the upward force of the gas stream act on the particles simultaneously.[139] The large, dense particles generally fall back to the top of the bed due to the reduced gas velocity in the free space above the bed and are eventually discharged with the dryer product.[140] The finer and lighter particles are carried further upward until at some height, known as the transport disengaging height (TDH), a constant loading and size distribution are reached. The amount of material entrained at this point is a function of the viscosity of the

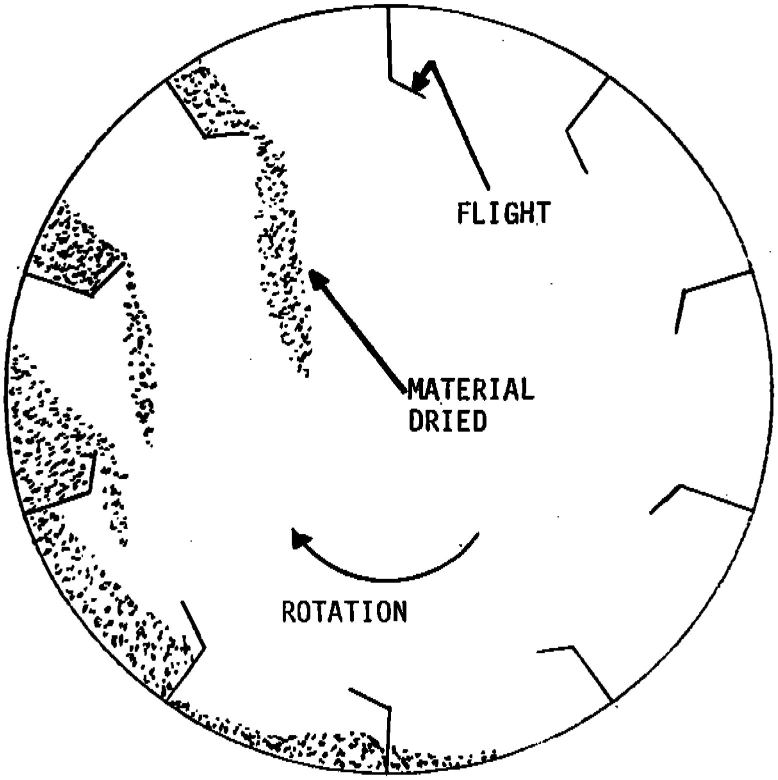


Figure 3-37. Typical flights used in rotary dryers.[138]

gas in the dryer, the gas velocity, the disengaging height, and the particle size of the material being dried.

3.3.1.1.3 Flash dryers. The variables that affect emissions from flash dryers used in the mineral industries include the production rate, the gas volume, and the characteristics of the material being dried. In a flash dryer, 100 percent of the process material is pneumatically conveyed to a cyclone for product collection. Therefore, uncontrolled mass loadings to a baghouse, wet scrubber, or electrostatic precipitator following the cyclone can be calculated directly from the production rate if the cyclone efficiency is known. Variations in the particle size distribution of the product material will affect the efficiency of the product collection equipment. Larger particles will be removed more effectively from the gas stream by a cyclone than will finer-sized particles.

3.3.1.1.4 Spray dryers. The variables that affect emissions from spray dryers in the mineral industries are the characteristics of the feed material, the type and operation of the atomizer device, and the spray chamber configuration.

Spray dried particles are usually spherical.[141] The particles of dried product may be solid or hollow, depending on the drying conditions and nature of the feed.[141] Particle size will usually depend on the type and operation of the atomizer device, the spray chamber configuration, and the relative movement of product and drying medium.[141]

3.3.1.1.5 Vibrating-grate dryers. Vibrating-grate dryers are used exclusively in the clay industries. The variables that affect emissions from vibrating-grate dryers are the feed particle size, the gas velocity through the dryer, and the amount of turbulence in the dryer. The feed particle size affects the emissions from a vibrating-grate dryer because smaller particles have a greater tendency to become entrained than do larger feed materials. The velocity of the gas through the dryer directly affects the degree of turbulence and the extent to which particles are entrained in the gas stream. As the velocity of the gas increases, the uncontrolled emission rate also increases. The mechanical agitation produced in a vibrating-grate dryer directly affects the quantity of dust available for entrainment. An increase in the degree of agitation will increase the turbulence in the dryer and may (to a limited degree) increase the uncontrolled particulate emission rate.

3.3.1.2 Uncontrolled Emission Data. Table 3-3 presents uncontrolled particulate matter emission data for dryers in five different mineral industries. These data were collected from EPA-conducted tests of representative facilities.

Fire clay is a generic term that encompasses 40 to 50 different materials, all of which may be processed in the same dryer or calciner. Because of the extreme variability in the physical properties of these materials, feedstock composition is the most important variable that affects mass loadings and particle size distributions from fire clay calciners and dryers. The discrete particle size distributions for various fire clay raw materials as reported by an industry representative are presented in Figure 3-38. Flint clay raw materials are much "harder" than plastic clays and tend to fracture or break apart, thus creating fine (entrainable), discrete dust particles. Conversely, plastic clays tend to agglomerate and not fracture as easily when dried or calcined. One industry representative indicated that emissions from processing of flint clays are more difficult to control during drying/calcining than are those from plastic clays.[142] Another industry representative indicated that plastic clays tend to be dustier once they are dried, making them more difficult to work with in subsequent processing.[143] The particle size distribution data given in Table 3-4 shows that 38 percent of the plastic clay particles suspended in a fire clay dryer outlet gas stream were smaller than 10 μm (4×10^{-4} in.) in diameter. As expected, the particle size distribution for the flint clay was smaller than that for the plastic clay. Table 3-4 shows that 54 percent of the entrained flint clay particles were smaller than 10 μm in diameter.

Particle size data from gypsum ore dryers indicate approximately 50 percent of the particles in the gas stream following dryer process cyclones were below 10 μm in diameter.

In addition to the data presented in Tables 3-3 and 3-4, the EPA conducted a test on a bentonite rotary dryer controlled by a baghouse (Plant C1). Because testing was not feasible at the baghouse inlet, particulate and particle size samples were collected upstream of a

TABLE 3-3. UNCONTROLLED PARTICULATE EMISSION DATA--DRYERS[144,145,147,149,151]

Industry/ raw material	Plant code	Process unit	Fuel type	Process rate % of capacity	Air flows		Gas velocity in dryer		Particulate emissions				Location of test
					m^3/s	acfm	m/s	ft/s	g/dsm^3	gr/dscf	kg/h	lb/h	
Bentonite	C1	Rotary dryer	Coal	87	7.0	14,800	1.5	4.9	259	113	3,510	7,732	Cylone inlet
Fire clay/ plastic	F1	Rotary dryer	Natural gas	100	4.7	9,950	0.7	2.3	11.5	5.03	141	310	Scrubber inlet[a]
Fire clay/ flint	F1	Rotary dryer	Natural gas	100	4.6	9,690	0.7	2.3	9.11	3.98	106	234	Scrubber inlet[a]
Gypsum	H1	Rotary dryer	Natural gas	92	4.6	9,700	1.3	4.2	8.81	3.85	107	239	Baghouse inlet[a]
Industrial sand	I1	Fluid bed dryer	Propane	97	31	65,700	0.4	1.4	22.1	9.65	1,570	3,460	Scrubber inlet
Industrial sand/float sand	I1	Rotary dryer	Propane	100	5.3	11,300	1.5	4.9	0.111	0.048	1.65	3.63	Scrubber inlet
TiO_2	P1	Spray dryer No. 1	Natural gas	80	7.3	15,400	N/A[b]		58.5	25.6	827	1,824	Baghouse inlet
TiO_2	P1	Spray dryer Nos. 1 and 2	Natural gas	80	12.2	25,850	N/A		4.8	2.1	210	463	Scrubber inlet[c]

[a] Outlet of product recovery cyclone.
[b] N/A = Not available.
[c] Two baghouses in parallel, followed by a common scrubber, control two spray dryers.

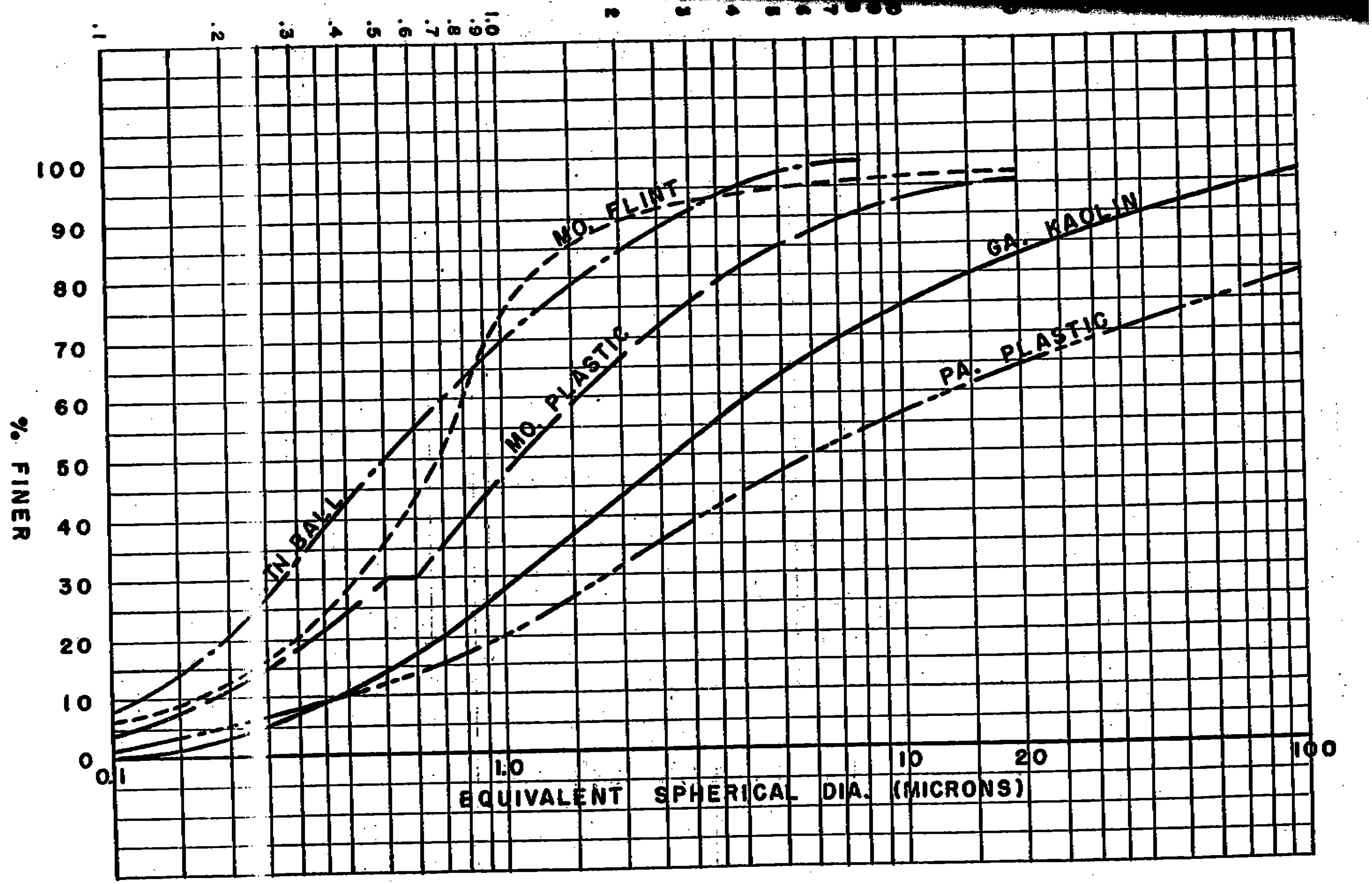


Figure 3-38. Discrete particle size distribution for various clay raw materials.[150]

TABLE 3-4. SUMMARY OF INLET PARTICLE SIZE DISTRIBUTION TESTS--DRYERS[144,145,147,149,151]

Industry/raw material	Plant code	Process unit	Location of test	Percent less than stated diameter		
				1 μm	2.5 μm	10 μm
Bentonite	C1	Rotary dryer	Cyclone inlet	0.2	0.95	6.0
Fire clay/plastic	F1	Rotary dryer	Scrubber inlet	6.0	13.6	38.2[a]
Fire clay/flint	F1	Rotary dryer	Scrubber inlet	4.8	12.3	54.4[a]
Gypsum	H1	Rotary dryer	Baghouse inlet	15.4	21.3	50.0[a]
Industrial sand	I1	Fluid bed dryer	Scrubber inlet	0.3	0.7	2.9
Industrial sand/float sand	I1	Rotary dryer	Scrubber inlet	5.5	8.8	14.9
TiO_2	P1	Spray dryer No. 1	Baghouse inlet	4.0	6.5	25.0
TiO_2	P1	Spray dryer Nos. 1 and 2	Scrubber inlet[b]	30.5	57.5	84.3

[a] Outlet of product recovery cyclone.

[b] Two baghouses in parallel, followed by a common scrubber, control two spray dryers.

product recovery cyclone. Particulate matter emissions from the dryer were 258.8 g/dscm (113.1 gr/dscf) and 6 percent of the suspended particles were less than 10 µm in diameter.

Process fugitive emissions were monitored during all testing where they were likely to occur. Table 3-5 presents a summary of these fugitive emission measurements. Actual measurements are presented in Appendix C.

3.3.2 Calciners

3.3.2.1 Variables Affecting Emissions. The variables that affect emissions from calciners include the gas velocity through the unit, the characteristics of the feed material, and the fuel type.

3.3.2.1.1 Rotary calciners. The calciner should be designed for adequate calcination without significant entrainment of solids. As the percentage of fines in the feed material increases, the gas velocity within the drum must decrease to prevent excessive material losses in the exit gas stream. Because rotary calciners do not usually use flights to shower the material through the gas stream, the attrition rates for friable materials tend to be lower in rotary calciners than the attrition rates of materials in rotary dryers. Gas velocities in rotary calciners used in the mineral industries range from 1.0 to 5.1 m/s (3.3 to 16.5 ft/s).

Pulverized coal is the fuel that has the greatest influence on uncontrolled emissions from rotary calciners because of the fly ash generated during its combustion. However, natural gas is the fuel most commonly used to fire rotary calciners in the mineral industries. Therefore, few particulate emissions can be attributed to fuel combustion.

3.3.2.1.2 Flash calciners. In a flash calciner, 100 percent of the process material is pneumatically conveyed to a cyclone for product collection. Therefore, the mass loading of uncontrolled emissions to a control device (baghouse, scrubber, ESP) from this unit is directly related to the production rate and the efficiency of the product recovery cyclone. The efficiency of the product collection equipment decreases as the particle size of the product material decreases.

3.3.2.1.3 Multiple hearth furnaces. The variables that affect emissions from multiple hearth furnaces include the exit gas velocity from the unit and the particle size of the feed material. The exit gas velocity from a multiple hearth furnace is usually designed to be

TABLE 3-5. PROCESS FUGITIVE EMISSION MEASUREMENTS--DRYERS[144,145,149]

Industry/ raw material	Plant code	Process unit	Process fugitive emission measurement location	Method 9 6 min. averages Range	Method 9 6 min. averages Average
Bentonite	C1	Rotary dryer	Feed belt discharge point	All 0%	0
Fire clay/flint and plastic	F1	Rotary dryer	Feed belt discharge point	All 0%	0
Industrial sand/ float sand	I1	Rotary dryer	Rotary dryer inlet	0-3.3	0.2
Industrial sand	I1	Fluid bed dryer	Fluid bed dryer inlet	All 0%	0
			Fluid bed dryer outlet	All 0%	0

approximately 1.5 to 3.1 m/s (5 to 10 ft/s).[152] The actual velocity will vary depending on the gas volume and the particle size of the material to be calcined. In most clay calcining applications, less than 3 to 4 percent of the product is lost by entrainment.[152]

3.3.2.1.4 Kettle calciners. The variables that influence emissions from batch and continuous kettle calciners include the degree of mechanical agitation, the velocity of the gas through the unit, the particle size of the feed material, and the production rate. The degree of mechanical agitation directly affects the quantity of dust available to be entrained in the air passing through the inside of the kettle.

Gas velocity through the kettle directly affects the degree of turbulence and the extent to which particles are entrained. As gas velocity increases, the uncontrolled emission rate should increase.

Increases in production rate will also increase uncontrolled emissions from continuous kettle calciners. The rate at which material is fed to the kettle affects the quantity of dust available to be entrained in the exit gases.

Emissions from batch calcining operations will vary widely with the phase of the cycle. Dust concentration in the air stream exiting the kettle is highest during charging, immediately after charging, and during discharging operations.[153]

3.3.2.1.5 Expansion furnaces.

Perlite. The variables that affect emissions from perlite expansion furnaces include the particle size of the ore being expanded and the temperature at which the ore is expanded. The perlite ore is injected into the furnace above the combustion burner. Preheating the ore prior to injection into the flame reduces the amount of fractionation that occurs and thereby reduces the amount of fines generated during expansion. Ores having a small particle size (<200 mesh) are not preheated because the distance between the combined water inside the ore particle and the particle surface is so short that preheating causes the water to be lost before particle expansion can take place in the furnace.[154] As in flash drying units, 100 percent of the product material is pneumatically conveyed to product collection equipment. The efficiency of these collection units is directly related to the particle size distribution of the expanded product, i.e., the smaller the product, the less efficient the collector.

The ore must be expanded at the proper temperature to ensure uniform product quality. If the temperature is too high, the expansion process occurs too quickly, fracturing the ore particles and generating fines. The temperature range for perlite expansion is 760° to 980°C (1400° to 1800°F). Most perlite ore is expanded at temperature of 980°C (1800°F).

Vermiculite. The factors that influence emissions from vermiculite expansion furnaces are the characteristics of the feed material and the gas velocity through the furnace. The feed material contains a percentage of unexpandable rock that is removed by a "stoner" following the expansion process. The presence of these rock impurities reduces the amount of vermiculite expanded. As the vermiculite expands it assumes an "accordian-like" shape instead of popping like popcorn as perlite does. The less violent expansion of the vermiculite ore at a lower temperature (583°C [1000°F]) results in a smaller amount of fines than are generated during perlite expansion.

The gas velocity through the furnace directly affects the amount of entrained particles that are carried to the control equipment. The expanded vermiculite is not pneumatically conveyed to collection equipment as in a perlite system. The mass loading of a vermiculite furnace to a product recovery device has been estimated by industry personnel to be approximately 45 kg/h (100 lb/h) compared to 900 kg/h (2,000 lb/h) for pneumatically conveyed perlite.[155]

3.3.2.2 Uncontrolled Emission Data. Table 3-6 presents uncontrolled particulate emission data for calciners in five mineral industries. These data were collected from EPA-conducted and State-conducted tests of representative facilities. The highest calciner emissions were generated by a natural gas-fired gypsum kettle calciner. Table 3-7 presents uncontrolled particle size distribution data for mineral calciners.

The rotary calciner system tested at Plant P1 has two parallel control systems. The exhaust gas stream from the rotary calciner splits into an east and a west system, each consisting of a conditioning tower and a wet ESP. The parallel lines then come together and enter a common

TABLE 3-6. UNCONTROLLED PARTICULATE EMISSION DATA--CALCINERS[146-148,151,156-162]

Industry/ raw material	Plant code	Process unit	Fuel type	Process rate % of capacity	Air flows		Particulate emissions				Location of test
					m^3/s	acfm	g/dsm^3	gr/dscf	kg/h	lb/h	
Fire clay/ flint	F2	Rotary calciner	Natural gas	100	20	41,300	20.8	9.10	452	997	Multiclone inlet
Fire clay/ kaolin	F3	Rotary calciner	Pulverized coal	98	36	76,800	17.5	7.64	1,000	2,200	Multiclone inlet
Fire clay/ kaolin	F3	Rotary calciner	Pulverized coal	98	16 16	34,000 33,000	9.86[a] 8.50[b]	4.31[a] 3.71[b]	250[a] 210[b]	560[a] 470[b]	Scrubber inlet
Gypsum	H1	Kettle calciner	Natural gas	100	1.2	2,600	251	110	225	496	Baghouse inlet
Gypsum	H2	Flash calciner	No. 6 oil	95	1.9	4,040	49.4	21.6	127	280	Baghouse inlet
Gypsum	H3	Kettle calciner[c] Kettle calciner[d]	Natural gas Natural gas	100 100	1.4 1.4	3,070 2,960	125 59.8	54.4 26.2	194 172	428 379	Baghouse inlet Baghouse inlet
Gypsum	H4	Flash calciner	Natural gas	95	1.8	3,720	49.9	21.8	110	244	Baghouse inlet
Kaolin	J1	Herreshoff furnace	Natural gas	115	5.1	10,900	8.58	3.75	68	149	Scrubber inlet
Kaolin	J1	Flash calciner	Natural gas	86	e	e	49.2	21.5	e	e	Baghouse inlet
LWA/shale	K1	Rotary calciner	Pulverized coal	83	50	106,000	59.7	26.1	4,261	9,129	Scrubber inlet
LWA/slate	K2	Rotary calciner	Pulverized coal	83	32	68,300	39.8	17.4	1,676	3,695	Scrubber inlet
LWA/slate	K5	Rotary calciner	Pulverized coal	100	8.3	17,600	18.4	8.01	329	725	Baghouse inlet
TiO_2	P1	Rotary calciner (sulfate process)	Natural gas	90	14 10	30,700 20,200	6.05[a] 4.14[b]	2.65[a] 1.81[b]	111[a] 54[b]	245[a] 119[b]	Conditioning tower inlet

[a] East side.
[b] West side.
[c] Continuous operation.
[d] Batch operation.
[e] Confidential data.

TABLE 3-7. SUMMARY OF INLET PARTICLE SIZE DISTRIBUTION TESTS--CALCINERS[146-148,151,156-161]

Industry/ raw material	Plant code	Process unit	Location of test	Percent less than stated diameter		
				1 μm	2.5 μm	10 μm
Fire clay/flint	F2	Rotary calciner	Multiclone inlet	0.8	2.7	26.0
Fire clay/kaolin	F3	Rotary calciner	Multiclone inlet	5.6	11.5	44.7
Fire clay/kaolin	F3	Rotary calciner	Scrubber inlet	4.0 7.0	15.0 25.0	50.0[a] 74.0[b]
Gypsum	H1	Kettle calciner	Baghouse inlet	4.7	25.3	54.2
Gypsum	H2	Flash calciner	Baghouse inlet	1.3	4.2	12.5
Gypsum	H3	Kettle calciner	Baghouse inlet	5.0	20.1	60.9
Gypsum	H4	Flash calciner	Baghouse inlet	6.6	24.1	60.0
Kaolin	J1	Herreshoff furnace	Scrubber inlet	5.7	23.0	47.2
Kaolin	J1	Flash calciner	Baghouse inlet	11.1	25.3	50.8
LWA/shale	K1	Rotary calciner	Scrubber inlet	0.0	0.7	22.3
LWA/slate	K2	Rotary calciner	Scrubber inlet	2.1	6.3	15.4
TiO_2	P1	Rotary calciner	Conditioning tower inlet	16.5 13.9	26.3 28.9	62.4[a] 65.5[b]

[a] East side.
[b] West side.

scrubber. Tests were performed at the inlets to the two conditioning towers and the two ducts leading to the common scrubber.

Particle size data obtained on a gypsum flash calciner at Plant H4 indicate 50 percent of the particles to be less than 7 µm (2.8×10^{-4} in.) in diameter upstream of a baghouse that is the only control device.

Process fugitive emission rates were monitored using EPA Method 9 where they were likely to occur. A summary of these fugitive emission measurements is presented in Table 3-8. Actual measurements are presented in Appendix C. Sulfur dioxide (SO_2), nitrogen oxides (as NO_2), and hydrocarbon (as methane) emission data from mineral calciners are presented in Table 3-9.

3.4 EMISSIONS ALLOWED UNDER CURRENT STATE REGULATIONS

Individual States currently use a variety of regulations and formulas to determine allowable particulate matter emissions under SIP's. Only three States (Georgia, New York, and New Mexico) have promulgated emission limitations for specific mineral industries. Process equipment in the kaolin and fuller's earth industries have a specific regulation in Georgia, the lightweight aggregate and gypsum industries in New York, and the perlite industry in New Mexico. Table 3-10 presents these industry-specific regulations. In most cases, calciners and dryers in the mineral industries are regulated as miscellaneous industrial processes. Regulations limiting particulate matter emissions from process sources are based on general process rate equations, concentration, and/or visible emission regulations. Tables 3-11 and 3-12 present these miscellaneous industrial process particulate mass emission regulations and visible emission limitations, respectively.

In addition to the miscellaneous industrial process regulations, two States (Arkansas and Indiana) have specific emission limits for some plants in this source category within their jurisdiction. Table 3-13 presents these plant-specific regulations. It should be noted that the miscellaneous industrial process emission limitations are not specific for each of the mineral industry sources and, therefore, do not represent a definite level of control based upon the performance of certain control devices at these sources. As a result, many existing plants are currently controlling some

TABLE 3-8. PROCESS FUGITIVE EMISSION MEASUREMENTS--CALCINERS[146,159,160]

Industry/ raw material	Plant code	Process unit	Process fugitive emission measurement location	Method 9 6 min. averages	
				Range	Average
Fire clay/flint	F2	Rotary calciner	Calciner inlet	All 0%	0
Kaolin	J1	Herreshoff furnace	Furnace outlet	All 0%	0
Kaolin	J1	Flash calciner	Calciner outlet	0-12.5	0.5
LWA/shale	K1	Rotary calciner	Calciner seals	All 0%	0

TABLE 3-9. SULFUR DIOXIDE, NITROGEN OXIDES (AS NO_2), AND HYDROCARBON EMISSIONS FROM MINERAL CALCINERS[148, 151, 160, 161, 163, 164]

Industry/ raw material	Plant code	Process unit	Location of test	Air flow rate, dscm/min (dscf/min)	SO_2[a] Emission rate, kg/h (lb/h)	SO_2[a] Concentration, mg/dscm (ppm by vol., dry)	NO_2[b] Emission rate, kg/h (lb/h)	NO_2[b] Concentration, mg/dscm, (ppm by vol., dry)	Hydrocarbon emission rate expressed as methane[c] kg/h (lb/h)
Fire clay/ kaolin	F3	Rotary calciner	Scrubber stack	844 (29,800)	56.9 (125.5)	1,124 (422)	28.9 (63.9)	571.7 (299.3)	--
LWA/shale	K1	Rotary calciner	Scrubber inlet	1,154 (40,755)	107.8 (237.6)	1,576 (592)	--	--	--
			Scrubber outlet	1,183 (41,788)	26.7 (58.8)	381 (143)	25.3 (55.7)	356 (186)	10.3 (22.7)
LWA/slate	K2	Rotary calciner	Scrubber inlet	698 (24,660)	228.4 (503.7)	5,515 (2,074)	--	--	--
			Scrubber outlet	1,400 (49,414)	--	--	34.7 (73.7)	398.3 (208.3)	5.4 (11.1)
LWA/clay-shale	K3	Rotary calciner	Scrubber outlet	1,850[d] (65,300)[d]	182.6 (403)	82 (31)	--	--	--
LWA/clay	K6	Rotary calciner	Scrubber inlet	--	20.7 (45.6)	713 (271)	--	--	--
			Scrubber outlet	602 (21,266)	18.5 (40.7)	511 (195)	10.4 (22.9)	287.3 (150)	4.2 (9.3)
TiO_2	P1	Rotary calciner	Scrubber stack	1,243 (43,900)	--	--	0.5 (1.2)	4.4 (2.3)	

[a] EPA Method 6.
[b] EPA Method 7.
[c] EPA Method 25.
[d] acm/min (acfm).

TABLE 3-10. SPECIFIC PROCESSES ADDRESSED UNDER STATE REGULATIONS

<table>
<tr><th rowspan="2">Process</th><th rowspan="2">State</th><th colspan="3">Allowable Emissions (AE)</th></tr>
<tr><th>Regulation[a]</th><th>Dryer</th><th>Calciner</th></tr>
<tr><td>Kaolin and fuller's earth</td><td>Georgia</td><td>$AE = 17.31\ p^{0.16}$
$p > 30$ tons/h</td><td></td><td></td></tr>
<tr><td>Perlite</td><td>New Mexico</td><td><table><tr><th>Process rate (lb/h)</th><th>Max. emission rate (AE)[b] (lb/h)</th></tr><tr><td>50,000</td><td>31</td></tr><tr><td>200,000</td><td>37</td></tr><tr><td>>600,000</td><td>50</td></tr></table></td><td></td><td></td></tr>
<tr><td>Gypsum</td><td>New York</td><td></td><td>0.15 gr/dscf</td><td></td></tr>
<tr><td>Lightweight aggregate</td><td>New York</td><td></td><td></td><td>0.15 gr/dscf</td></tr>
</table>

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[a] General regulation for all process sources in source category.

[b] Allowable emissions are for the total for the entire plant (all stacks), not just dryer emissions.

TABLE 3-11. SIP ALLOWABLE EMISSIONS

Maximum allowable emissions (E)		States
Allowable emissions in lb/h		
$E = 4.1 p^{0.67}$	$p \leq 30$ tons/h (p = tons of material processed)	Alabama,[a] Arizona,[b] Georgia, Iowa, Kansas, Louisiana, Michigan, Mississippi,[c] Missouri, Montana, Nevada, New Hampshire, North Dakota, Oklahoma, Oregon, South Carolina, South Dakota, Viginia, Wyoming
$E = 55 p^{0.11}-40$	$p > 30$ tons/h	
$E = 0.045 p^{0.60}$	$p < 9,250$ lb/h	Idaho
$E = 1.10 p^{0.25}$	$P \geq 9,250$ lb/h	
$E = 3.59 p^{0.62}$	$p \leq 30$ tons/h	Alabama,[d] Arizona,[e] Arkansas, Colorado, Connecticut, Florida, Kentucky, Minnesota, Tennessee, Wisconsin
$E = 17.31 p^{0.16}$	$p > 30$ tons/h	
$E = 2.54 p^{0.534}$	$p < 450$ tons/h	Illinois
$E = 24.8 p^{0.16}$	$p \geq 450$ tons/h	
E = Linear interpolation from table; ≤ 0.05 gr/dscf; or $E = 55p^{0.11}-40$ for $p > 30$ tons/h		Maryland
$E = \frac{1}{2}[55 p^{0.11}-40]$		Massachusetts
$E = 0.024 p^{0.665}$	$p < 100,000$ tons/h	New York[f]
$E = 0.05$ gr/dscf	$p > 100,000$ tons/h	
For emission rate (E), in lb/h, and production rate (R), in tons/h:		North Carolina[g]
$R = 1-30$	$E = 4p^{0.677}$; except when $R = 10$ $E = 19$	
$R = 30-100$	$E = 20.421 p^{0.1997}$; except when $R = 100$ $E = 50$	
$R = 1,000-3,000$	$E = 38,147 p^{0.1072}$	
$E = 0.551$	$p \leq 0.05$ ton/h	Ohio
$E = 4.1 p^{0.67}$	0.05 tons/h > $p \geq 30$ tons/h	
$E = 55 p^{0.11}-40$	$p > 30$ tons/h	

(continued)

TABLE 3-11. (continued)

Maximum allowable emissions (E)		States
$E = 0.04$	EG <150,000 dscf/min	Pennsylvania
$E = 6.000EG^{-1}$	$150,000 \leq EG \leq 300,000$ dscf/min	
$E = 0.02$	EG >300,000 dscf/min (EG = effluent gas volume	
$E = 0.048q^{0.62}$	(q = acfm)	Texas
E = 0.50 for calcining processes E = 0.21 for all other processes		West Virginia
Allowable emissions in gr/dscf		
E = 0.02 or 99% collection efficiency (whichever is more stringent)		New Jersey
E = 0.03		Indiana, Maryland[i]
E = 0.05		Maryland[h]
E = 0.06 or linear interpolation from table (whichever is more stringent)		Vermont
E = 0.10		Washington
E = 0.20		Delaware
E = 0.30		New Mexico

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[a] For Alabama, a Class I source is located in a county with 50 percent or more of its population in urban areas, and where secondary national ambient air quality standards are exceeded.

[b] For Arizona, if located outside Gila, Maricopa, Pima, Paral, or Santa Cruz Counties.

[c] For Mississippi, Equation Set 1 except 1B for p = 30 tons/h.

[d] For Alabama, a Class II source is in a county not satisfying Class I conditions.

[e] For Arizona, if located in Arizona counties listed in b above.

[f] For sources with New York State environmental rating of B or C.

[g] For North Carolina, 95 percent collection efficiency, by weight of particulate matter, for lightweight aggregate.

[h] For Maryland new sources in Areas III and IV.

[i] For Maryland, new sources in Areas I, II, V, VI.

TABLE 3-12. STATE VISIBLE EMISSIONS STANDARDS[a]

Visible emissions (percent)	States
10	Illinois,[b] Missouri, Montana,[c] New York,[d] West Virginia
20	Alabama, Arizona, Colorado, Connecticut, Delaware, Florida, Idaho, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Minnesota, Montana, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina,[e] North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Vermont, Virginia, Virgin Islands, Washington, Wisconsin, Wyoming
30	Illinois
40	Arizona, Georgia, Indiana,[f] Iowa, Mississippi, Utah,[f] North Carolina

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[a] General long term standards are included for new sources where applicable. Exceptions to individual State regulations due to manfulctions, start-ups, and shutdowns have been excluded.

[b] For Illinois, perlite--10 percent opacity; gypsum and industrial sand--30 percent opacity.

[c] For Montana, vermiculite--10 percent opacity; bentonite and gypsum--20 percent opacity.

[d] For New York, industrial sand, lightweight aggregate, and talc--10 percent opacity; gypsum--20 percent opacity.

[e] For North Carolina, feldspar, gypsum, lightweight aggregate, and perlite--20 percent opacity; industrial sand--40 percent opacity.

[f] For Indiana and Utah, attainment areas--40 percent opacity, nonattainment areas--30 percent opacity.

TABLE 3-13. SPECIFIC PLANTS ADDRESSED UNDER STATE REGULATIONS

Industry Plant/location	Allowable emissions, lb/h	Process unit(s)
Alumina		
ALCOA Bauxite, Ark.	5	13 dryers
	20	1 calciner
	25	6 calciners
	30	3 calciners
	35	2 calciners
	55	1 calciner
	75	1 calciner
	80	1 calciner
	100	1 calciner
Reynolds Aluminum Co. Bauxite, Ark.	60	9 rotary kilns
Clays		
Porocel Chemical Little Rock, Ark.	95	1 dryer
	32	2 calciners
Fire clay		
A. P. Green Little Rock, Ark.	130	1 calciner
Gypsum		
Temple Gypsum West Memphis, Ark.	120	1 dryer
LWA		
Arkansas LWA Corp. England, Ark.	140	2 calciners
Arkansas LWA Corp. West Memphis, Ark.	140	Old calciner
	40	New calciner
Perlite		
U.S. Gypsum Co. Shoals, Ind.	0.278[a]	1 dryer
	0.299[a]	1 expansion furnace
Roofing granules		
3M Company Little Rock, Ark.	50	1 dryer
	25	1 calciner
	200	2 calciners
Silica, glass, blasting sand		
Silica Products Guion, Ark.	32	1 dryer
	72	1 calciner

[a] lb/ton of material produced.

sources to a more stringent level than required by the SIP limitations. The mass emission limitations may also vary with the capacity of the individual process unit.

The rationale used to determine RA I (baseline) emission limits for each of the 17 industries is described below. Initially, the number and type of control devices used in each industry were tabulated, and representative (typical) units were selected for use as baseline control devices.[165] To determine the range of emissions allowed by States for a particular industry, equivalent concentration emission limits for each size and type of model process unit were calculated from State regulations. Typical-size process units were then used to develop a single, nationwide average SIP limit, using a weighted average based on total production by State.[166] If the calculated baseline emission limit was greater than 0.20 gr/dscf and the industry typically uses baghouses for control, it was assumed that the State opacity limits of 20 percent are more stringent than the corresponding SIP mass emission limits. Therefore, the baseline emission limit selected for evaluation was the emission grain loading estimated to result in an exhaust gas opacity of 20 percent, i.e., 0.15 gr/dscf.

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4. EMISSION CONTROL TECHNIQUES

This chapter presents the particulate matter emission control techniques used for dryers and calciners in 17 mineral processing industries. Significant design variables and factors that affect the performance of applicable control devices are discussed in Section 4.1. The applications and performance of the various techniques for controlling dryer and calciner emissions are discussed in Sections 4.2 and 4.3, respectively.

4.1 DESCRIPTION OF CONTROL TECHNIQUES

The primary control systems used to reduce particulate matter emissions from dryer and calciner systems are fabric filters, wet scrubbers, and electrostatic precipitators (ESP's). Single and multiple cyclone (centrifugal) separators are also used for emission control in a few cases. However, in the majority of dryer and calciner systems, cyclones are primarily used to recover product material from the exhaust gas stream before the gas is ducted to the primary control device. Table 4-1 summarizes the use of emission control techniques on dryers and calciners in mineral industries.

4.1.1 Centrifugal Separators

4.1.1.1 General Description. Centrifugal separators, or cyclones, rely on centrifugal force to separate particles from a gas stream. Figure 4-1 is a schematic of a typical cyclone. A circular flow pattern is induced in the carrier gas by a tangential inlet or by inlet vanes.[1] As a result, particles of sufficient mass impinge on the cyclone wall and fall into a hopper.

Single cyclones of medium efficiency design are capable of handling high gas volumes at a pressure drop of 1.0 to 1.5 kilopascals (kPa)

TABLE 4-1. EMISSION CONTROL TECHNIQUES FOR DRYERS AND CALCINERS IN THE MINERAL INDUSTRIES

	Control device(s) used		
Industry/Process unit	Fabric filter	Wet scrubber	Electrostatic precipitator
Alumina			
Flash calciner			x
Rotary calciner			x
Ball Clay			
Rotary dryer (indirect)	x		
Vibrating-grate dryer (indirect)	x		
Bentonite			
Fluid bed dryer	x		x
Rotary dryer	x		x
Diatomite			
Flash dryer	x	x	
Rotary dryer	x	x	
Rotary calciner	x	x	
Feldspar			
Fluid bed dryer	x	x	
Rotary dryer	x	x	
Fire Clay			
Rotary dryer	x	x	
Vibrating-grate dryer		x	
Rotary calciner		x	x
Fuller's Earth			
Fluid bed dryer	x		
Rotary dryer	x	x	
Rotary calciner	x	x	
Gypsum			
Rotary dryer	x		x
Flash calciner	x		
Kettle calciner	x		x
Industrial Sand			
Fluid bed dryer	x	x	
Rotary dryer		x	

(continued)

TABLE 4-1. (continued)

Industry/Process unit	Control device(s) used		
	Fabric filter	Wet scrubber	Electrostatic precipitator
Kaolin			
Rotary dryer	x	x	
Spray dryer	x		
Flash calciner	x		
Multiple hearth furnace		x	
Rotary calciner	x	x	
Lightweight Aggregate			
Rotary calciner	x	x	x
Magnesium Compounds			
Multiple hearth furnace	x		x
Rotary calciner	x	x	x
Perlite			
Rotary dryer	x	x	
Expansion furnace	x	x	
Roofing Granules			
Fluid bed dryer		x	
Rotary dryer	x	x	
Talc			
Flash dryer	x		
Rotary dryer	x		
Rotary calciner	x		
Titanium Dioxide			
Flash dryer		x	
Fluid bed dryer		x	
Rotary dryer (direct)	x	x	
Rotary dryer (indirect)		x	
Spray dryer	x	x	
Rotary calciner		x	
Vermiculite			
Fluid bed dryer	x		
Rotary dryer		x	
Expansion furnace	x	x	

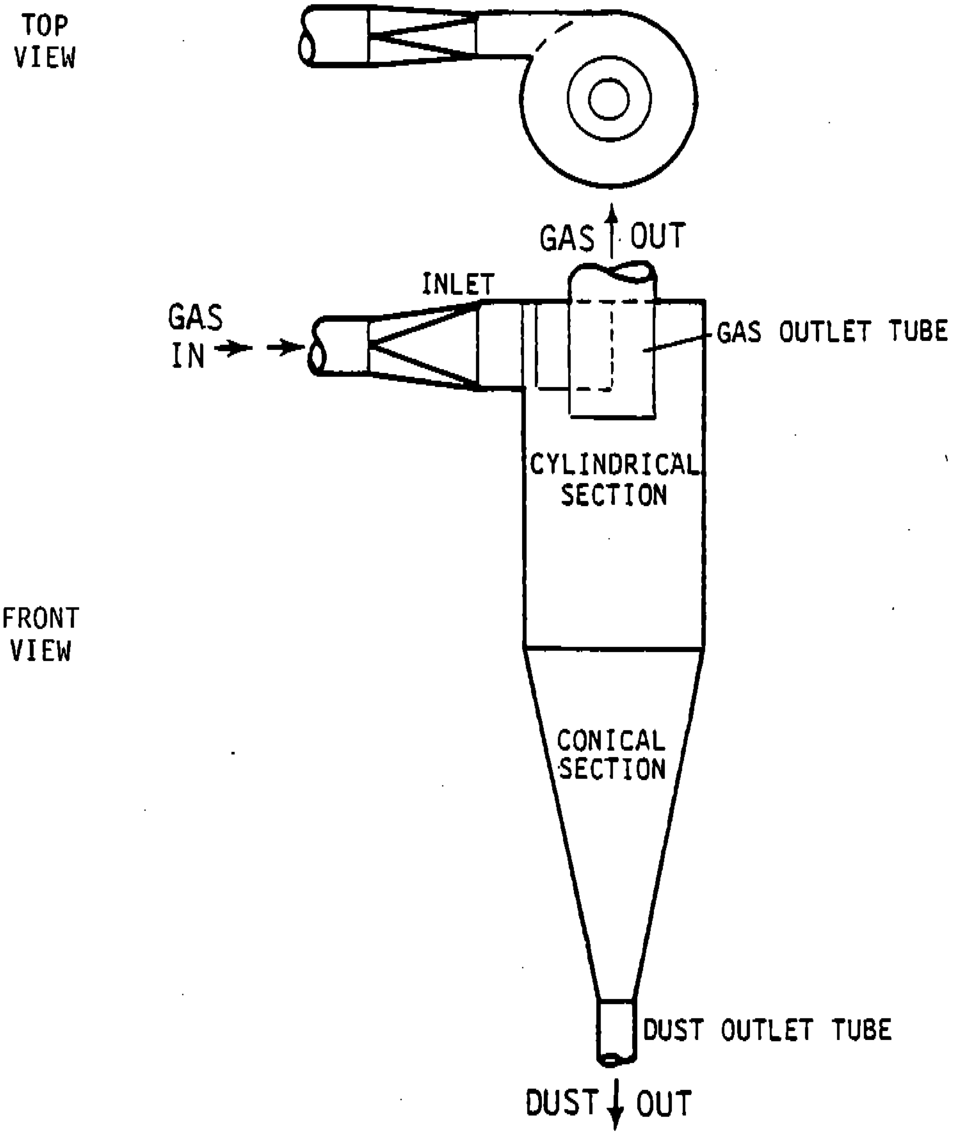


Figure 4-1. Typical simple cyclone collector.[4]

(4 to 6 inches of water column [in. w.c.]).[2] High efficiency cyclones are generally less than 1 m (3.3 ft) in diameter and operate at a pressure drop of 2.0 to 2.5 kPa (8 to 10 in. w.c.).[2]

A multiple cyclone separator consists of a number of cyclones that operate in parallel.[3] The individual cyclones are typically from 15 to 60 cm (6 to 24 in.) in diameter and operate at pressure drops from 0.5 to 1.5 kPa (2 to 6 in. w.c.). The number of cyclones used in a multiple cyclone separator is limited by the amount of space available and the system pressure drop.

Centrifugal separators are typically used upstream of a fabric filter, wet scrubber, or an ESP for product recovery or to reduce the dust loading to the primary control device.

4.1.1.2 Factors Affecting Performance. The efficiency of a single cyclone separator increases with an increase in any of the following parameters: (1) density of the particulate matter, (2) gas velocity into the cyclone, (3) cyclone body length, (4) number of gas revolutions, (5) particle diameter, (6) amount of dust entrained in the gas stream, and (7) smoothness of the cyclone inner wall.[3]

Conventional cyclones seldom remove particles with an efficiency greater than 90 percent unless the particle size is 25 µm (1×10^{-3} in.) or larger.[1] For effective removal of particles down to 5 µm (2×10^{-4} in.) in diameter, small-diameter, high efficiency cyclones are available. They typically remove 95 to 99 percent of particles having diameters of 15 to 40 µm (6×10^{-4} to 1.6×10^{-3} in.), 80 to 95 percent of particles from 5 to 20 µm (2×10^{-4} to 8×10^{-4} in.), and 50 to 80 percent of particles with diameters less than 5 µm (2×10^{-4} in.).[1] Overall cyclone efficiency ranges from about 50 to 95 percent.[1]

Other factors affecting performance for a given cyclone are the volumetric flow rate and reentrainment of particulate matter. If the actual volumetric flow rate is lower than the design flow rate, then the actual collection efficiency will be lower than the design collection efficiency. As the gas temperature rises, the gas viscosity increases, which causes a reduction in the cyclone's efficiency. Ambient air leaking into the cyclone impairs the gas flow within the cyclone. Once the flow becomes irregular, the cyclone is susceptible to both abrasion of the internal surfaces and reentrainment of particles in the cleaned gas stream.

4.1.2 Fabric Filters

4.1.2.1 General Description. A fabric filter system (baghouse) consists of a number of filtering elements (bags), a bag cleaning system, a main shell structure (that is usually divided into compartments and equipped with dust hoppers), a dust removal system, and a fan. Particulate matter is filtered from the gas stream as the gas passes through the bag fabric. Accumulated dust on the bags is periodically removed using mechanical or pneumatic mechanisms. Typical design and operation information for fabric filters used to control particulate matter emissions from mineral dryers and calciners is presented in Section 4.2.2.

As particle-laden gas passes through the porous bag fabric, dust particles are deposited on individual fiber surfaces and within the interstices of the fiber matrix. Continued particle deposition on the fabric creates a uniform dust cake that functions as a porous filter medium. Because the pores of the fabric matrix are large relative to the diameter of most of the incoming particles, some particles at the dust cake/fabric interface will migrate through the fabric and escape into the effluent gas stream. The outlet dust concentration is relatively constant over time and substantially independent of the dust concentration entering the fabric filter.[5-7]

Figure 4-2 depicts the mechanisms of fabric filtration. The most important particle collection mechanisms of fabric filtration are inertial impaction, Brownian diffusion, and interception. Filtration theory predicts that particle size will have a limited effect on the efficiency of particle capture. For particles less than approximately 1 μm (4×10^{-5} in.) in diameter, diffusion is the primary capture mechanism; for particles greater than approximately 2 μm (8×10^{-5} in.), impaction is the primary capture mechanism.[9,10]

The superficial (face) velocity through a fabric filter is calculated by dividing the total gas flow rate (at operating temperature and pressure) by the total cloth area available for filtration. This parameter is referred to as the air-to-cloth (A/C) ratio. Baghouse operation at A/C ratios higher than those recommended by the manufacturer may lead to

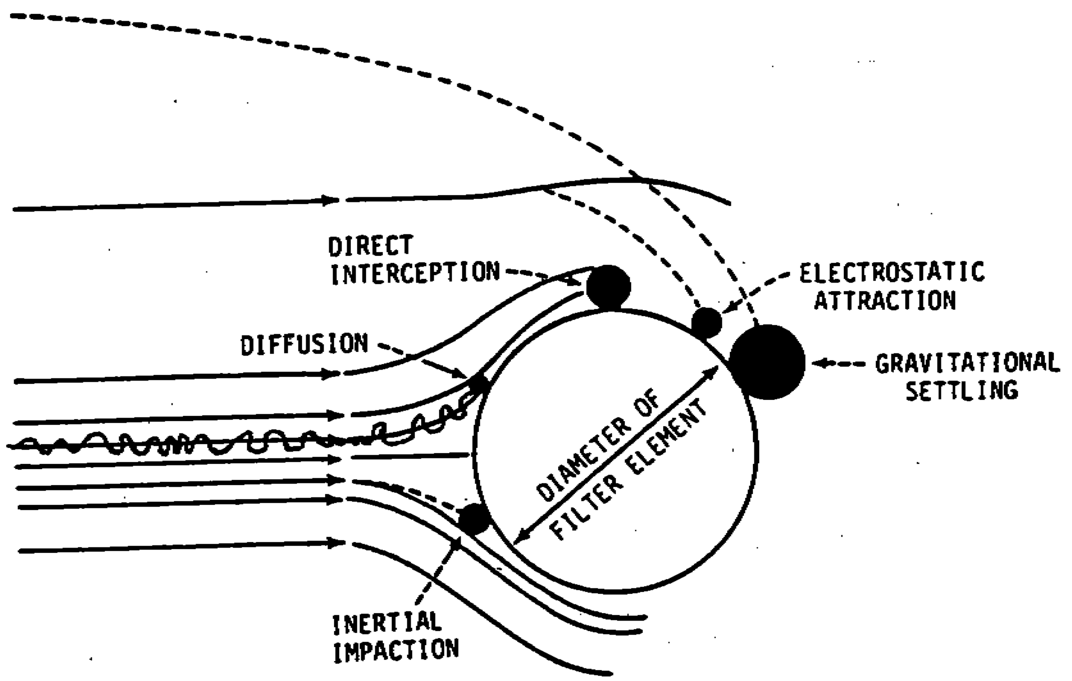


Figure 4-2. Mechanisms of fabric filtration.[8]

excessive particle penetration or blinding of the fabric, which results in reduced collection efficiency and reduced fabric life.[11]

The static pressure drop is an indicator of the resistance to gas flow through the filter fabric and the dust cake. Pressure drop is controlled by the cleaning cycle. At regular intervals, the dust cake that accumulates on the fabric must be removed to reduce the resistance to gas flow. Cleaning systems are designed to allow the isolation and cleaning of one compartment at a time while the remaining compartments continue to filter "dirty" gas. The cleaning frequency of baghouses can be controlled by a timer, or sensors can be installed that start the cleaning cycle when a specified pressure drop occurs across the system. The primary fabric cleaning mechanisms are mechanical shaking, reverse air cleaning, and pulse jet cleaning. Pulse jet cleaning is the method selected for most baghouse applications on calciners and dryers in mineral industries.

A conventional shaker-type fabric filter is shown in Figure 4-3. Mechanical shaking is normally accomplished by a rapid horizontal motion of the filter bag, induced by a mechanical shaker bar. The shaking causes flexing of the fabric and the release of the dust cake from the fabric surface. In shaker-type fabric filters the A/C ratio is normally less than 1 cubic meter of gas per minute per square meter of cloth area ($m^3/min-m^2$) (3.3 cubic feet per minute per square foot [$ft^3/min-ft^2$]).

A reverse air baghouse is shown in Figure 4-4. Reverse air cleaning is accomplished by reversal of the gas flow through the filter fabric to release the dust cake from the bag. The reverse air flow may be supplied by cleaned exhaust gases or by a secondary high pressure fan supplying ambient air.[14] Typical A/C ratios for reverse air baghouses in mineral industries range from 0.32 to 2.2 $m^3/min-m^2$ (1 to 7 $ft^3/min-ft^2$).

A pulse jet baghouse is shown in Figure 4-5. In pulse jet cleaning, a sudden pulse of compressed air is injected into the top of the bag. This pulse creates a traveling wave in the fabric that separates the cake from the surface of the fabric. The cleaning normally proceeds by rows, all bags in the row being cleaned simultaneously. The compressed air pulse, delivered at 550 to 800 kPa (80 to 116 lb/in^2 [psi]) results in local reversal of the gas flow. The cleaning intensity is a function

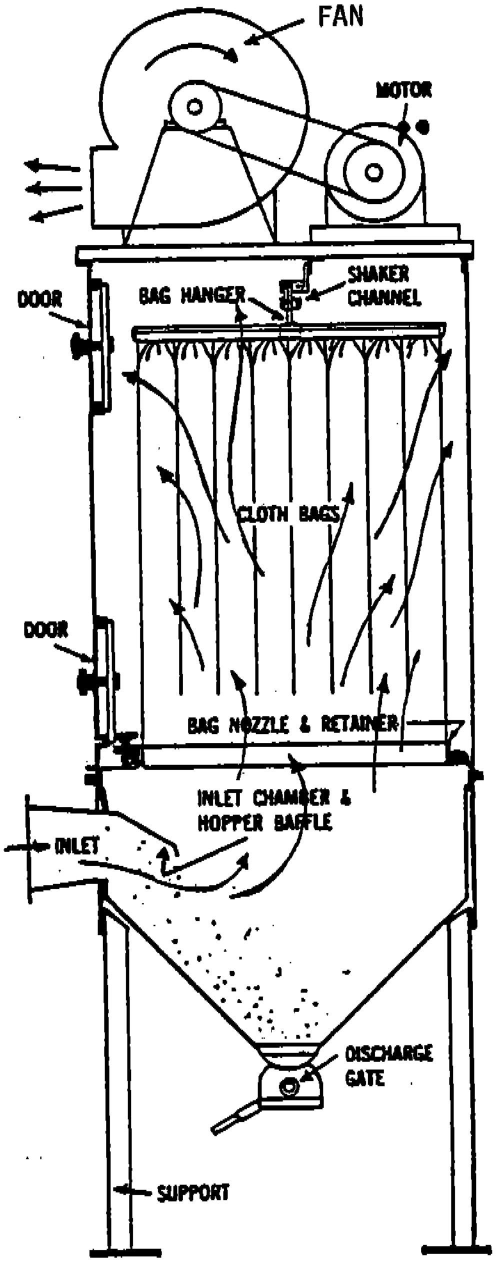


Figure 4-3. Shaker-type baghouse.[12]

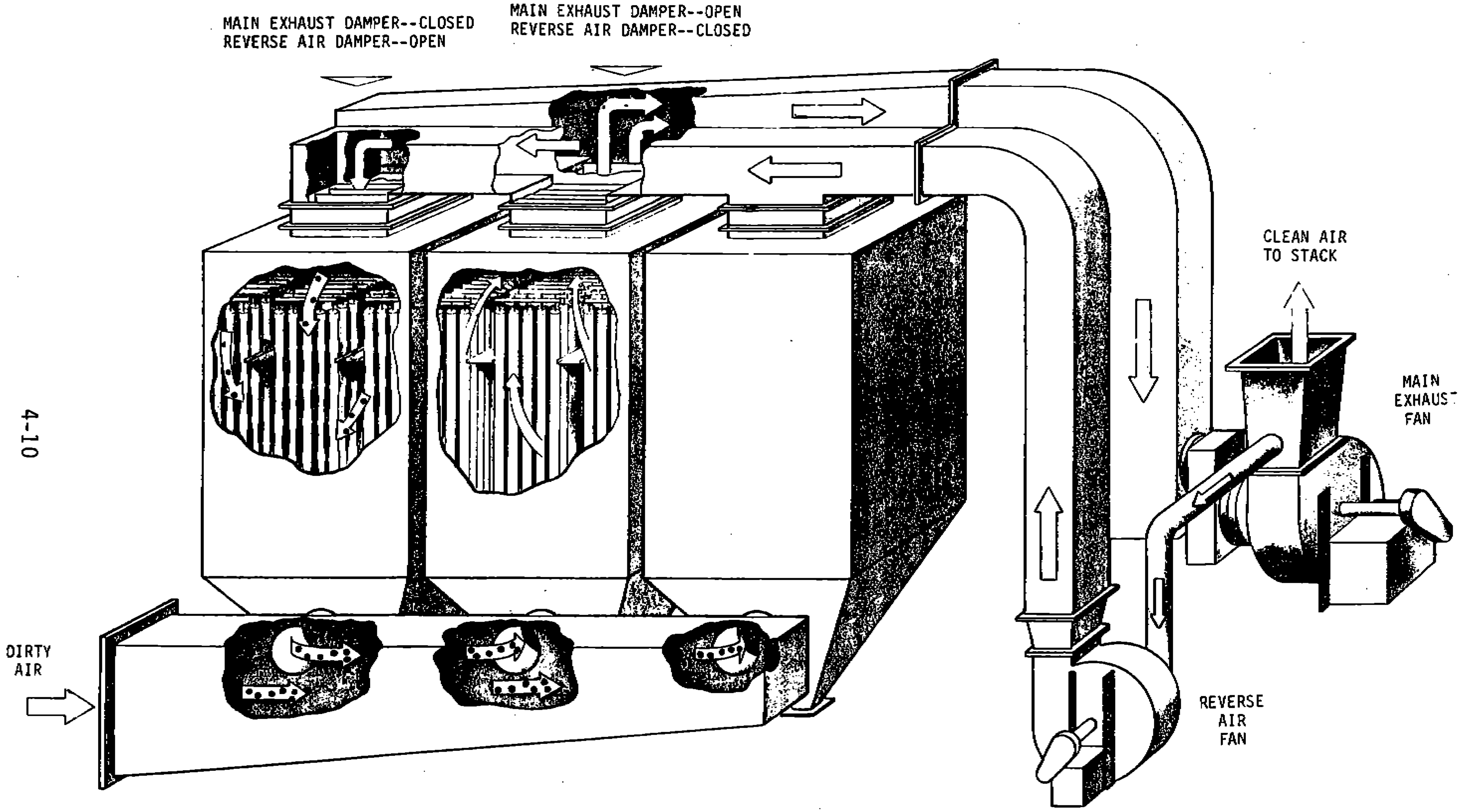


Figure 4-4. Reverse air baghouse.[13]

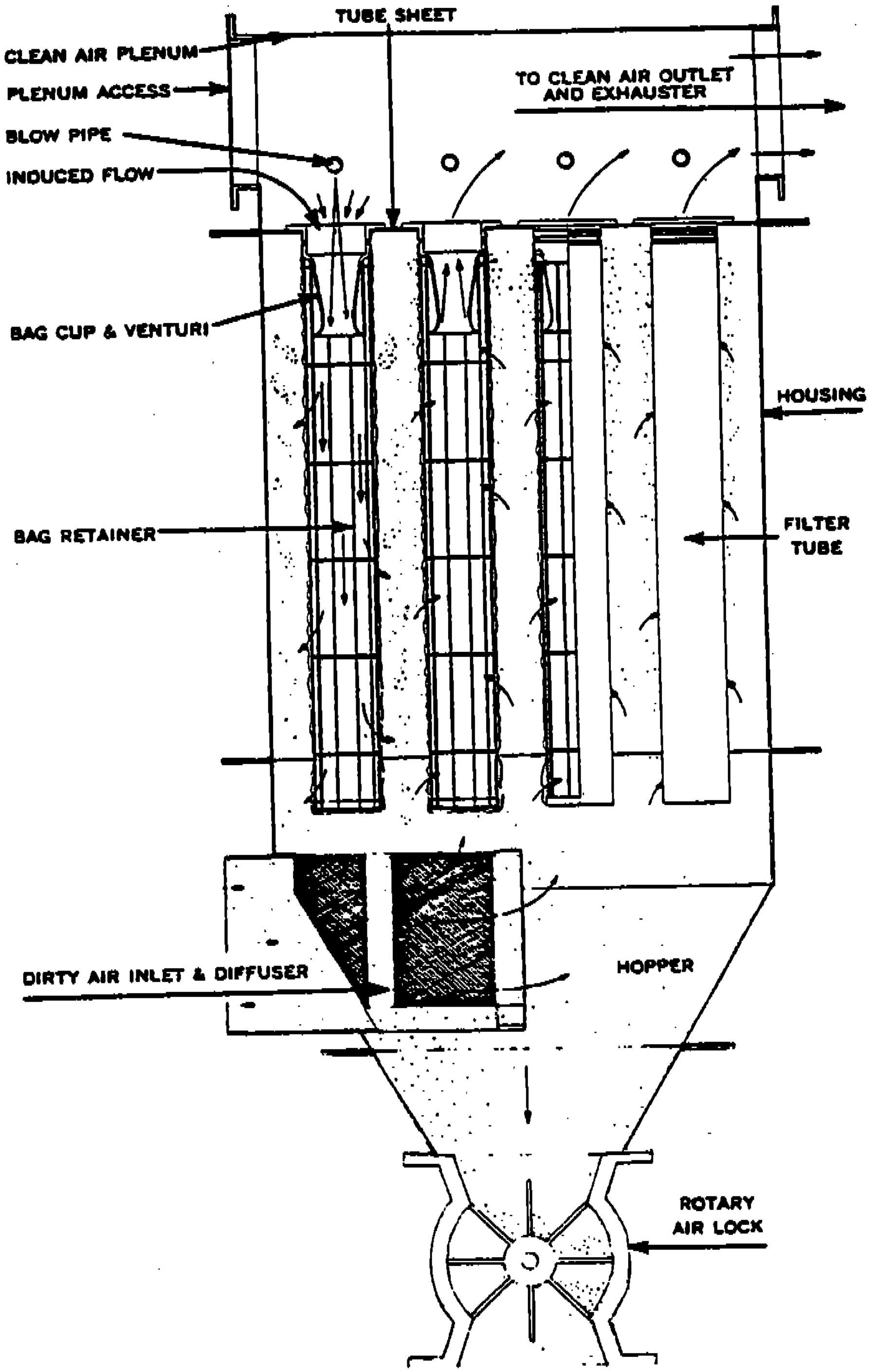


Figure 4-5. Pulse jet baghouse.[15]

of the compressed air pressure, the pulse duration, and the pulse frequency.[14] Typical A/C ratios for pulse jet baghouses in mineral processing industries range from 0.95 to 2.5 m^3/min-m^2 (3 to 8 ft^3/min-ft^2).

Fabric filters are characterized as positive pressure or negative pressure depending on the location of the fan. In positive pressure systems, the effluent gas is forced through the fabric filter by a fan on the inlet side of the filter. In negative pressure fabric filters, the effluent gas is drawn through the bag fabric by a fan on the outlet side of the filter. Negative pressure filters require less fan maintenance (because of less abrasion) and less operating horsepower than the positive pressure type.[16] Negative pressure baghouses are the most common design used in the mineral processing industries.

4.1.2.2 Factors Affecting Performance. The physical characteristics of the gas stream to be cleaned are the predominant factors affecting the design of a fabric filter. Important parameters include gas temperature and particle size.[17] In many calciner systems and in high temperature dryer systems, the exit gas temperature must be reduced before the gas enters the baghouse. The most common methods of cooling the gas stream from dryers and calciners are dilution and radiant cooling (heat exchangers). The use of dilution air to lower gas temperature is the simplest approach, but it increases the operating cost because the volume of ambient air required necessitates a larger baghouse and fan. The use of radiant cooling reduces collector size, but it requires an initial investment in additional ductwork.[18]

The particle size distribution of the particulate matter in the gas stream affects both dust cake porosity and abrasion of the fabric.[19] A smaller overall particle size distribution will result in greater penetration into the fabric. Although greater penetration causes more abrasion to the fabric strands, the small particles create a more uniform dust cake than larger particles, thus reducing porosity and improving filtration. Because larger particles are more easily filtered out and smaller particles create a more efficient filter cake, fabric filters are relatively insensitive to inlet particle size variations. The outlet dust concentration is however, relatively constant over time and substantially independent of the dust concentration entering the fabric filter.[5,6]

Fabric selection is usually based on the experience of the manufacturer with similar baghouse applications. Important factors to consider in the selection of a fabric are: (a) dust penetration, (b) continuous and maximum operating temperatures, (c) chemical degradation, (d) abrasion resistance, (e) cake release, (f) pressure drop, (g) cost, (h) cleaning method, and (i) fabric construction.[20]

Woven and felted materials are used to make bag filters. Woven filters are made of yarn with a definite repeated pattern and felted filters are composed of randomly placed fibers compressed into a mat and attached to a loosly woven backing material. Woven filters are used with low energy cleaning methods such as shaking and reverse air. Felted fabrics are used with pulse jet cleaning.[21] A tightly woven fabric has a low permeability and is better for the capture of small particles, at the cost of increased pressure drop. Felted filters are generally 2 to 3 times thicker than woven filters and each fiber acts as a target for particle capture by impaction and interception. Felted bags should not be used in high humidity situations, especially if the particles are hygroscopic, because clogging and blinding could occur.[21]

Table 4-2 shows the continuous maximum operating temperatures recommended by fabric manufacturers and the chemical and abrasion resistance of common commercial fabrics. Some filters are made from natural fibers such as cotton or wool. These fibers are relatively inexpensive but have temperature limitations (<100°C [212°F]) and only average abrasion resistance. Synthetic fibers such as nylon, Orlon®, and polyester have slightly higher temperature limitations and chemical resistance. Synthetic fibers are more expensive than natural fibers. Nomex® is a registered trademark of fibers made by DuPont. DuPont makes the fibers, not filter fabrics or bags. Nomex® is widely used due to its relatively high temperature resistance and its resistance to abrasion. Other fibers such as Teflon® and Fiberglas® can be used in very high temperature situations (230° to 260°C [446° to 500°F]). Both materials have good resistance to acid attack, but are generally more expensive

TABLE 4-2. MAXIMUM RECOMMENDED OPERATING TEMPERATURES, AND CHEMICAL AND ABRASION RESISTANCE OF COMMON COMMERCIAL FABRICS[23]

Fabric	Generic name	Type yarn	Maximum operating temp. °C (°F) long periods	Maximum operating temp. °C (°F) short periods	Acid resistance	Alkali resistance	Flex and abrasion resistance
Cotton	Natural fiber cellulose	Staple	77 (171)	107 (225)	Poor	Fair-good	Fair-good
Wool	Natural fiber protein	Staple	97 (207)	127 (261)	Very good	Poor-fair	Fair
Nylon	Nylon polyamide	Filament spun	97 (207)	127 (261)	Fair	Very good-excellent	Very good-excellent
Dynel®	Modacrylic	Filament spun	77 (171)	177 (243)	Good-very good	Good-very good	Fair-good
Polypropylene	Polyolefin	Filament spun	97 (207)	127 (261)	Excellent	Excellent	Very good-excellent
Orlon®	Acrylic	Spun	117 (243)	137 (279)	Good-excellent	Fair	Fair
Dacron®	Polyester	Filament spun	137 (279)	167 (333)	Good	Fair-good	Very good
Nomex®	Nylon aromatic	Filament spun	217 (423)	257 (495)	Fair	Excellent	Very good-excellent
Teflon®	Fluorocarbon	Filament spun	227 (441)	257 (495)	Excellent	Excellent	Fair
Fiberglas®	Glass	Filament spun bulked	257 (495)	317 (603)	Fair-good	Fair	Poor
Polyethylene	Polyolefin	Filament spun	97 (207)	N/A[a]	Very good-excellent	Very good-excellent	Good excellent

[a] N/A = Not available.

than other fibers.[21] The most common bag materials for dryer and calciner baghouses are Nomex®, Dacron®, Fiberglas®, and polyester.

4.1.3 Wet Scrubbers

4.1.3.1 General Description. The types of wet scrubbers used to control particulate matter emissions from dryers and calciners in the mineral industries are spray towers, venturi scrubbers, packed bed scrubbers, cyclonic scrubbers, impingement plate scrubbers, and dynamic scrubbers. Specific details about wet scrubbers used to control particulate matter emissions from mineral dryers and calciners are presented in Section 4.2.3.

The most important mechanism by which all scrubbers remove particulates from gas streams is the inertial impaction of the particulate onto the water droplet.[22] Removal of particles from the collecting surfaces is accomplished by flushing with a liquid. Particles can be wetted by the following mechanisms:

1. Impingement by spray droplets. Liquid droplets in a spray directed across the path of the dust particles impinge upon the dust particles with an efficiency proportional to the number of droplets in the spray and to the force imparted to the droplets.

2. Diffusion. When liquid droplets are dispersed among dust particles, the dust particles are deposited on the droplets by Brownian movement or diffusion. This is the principal mechanism in the collection of submicron particles. Diffusion as the result of fluid turbulence may also be a significant mechanism in the deposition of dust particles on spray droplets.

3. Condensation. When a gas is cooled below its dew point in passing through a wet collector, condensation of moisture occurs, because the dust particles act as condensation nuclei. Condensation is an important mechanism only for gases that are initially hot.

To be wetted, particulate matter must either make contact with a spray droplet or impinge upon a wetted surface. Particles that have been wetted increase in mass and are more easily removed from the gas stream than are dry particles. Wetted particles may be separated from the gas stream by impingment against surfaces placed in the path of the gas flow (mist eliminator); centrifugal action may be used to throw them to the outer walls of the collector; or simple gravity settling may be employed.

The difficulty of removing particulate material from a gas stream by impingement on water droplets increases with a decrease in particle size. Higher relative velocities (between particles in the gas stream and the water droplets) and more acute changes in direction are required to remove small particles from the gas stream by impingement than are required to remove large particles.[24]

4.1.3.1.1 Spray towers. One of the simplest types of wet scrubber is the spray tower. Liquid droplets, produced by either spray nozzles or atomizers, fall through a rising gas stream containing dust particles. The terminal settling velocity of the spray droplets must be greater than the velocity of the rising gas stream to prevent spray droplet entrainment and carryover. In most applications, this gas velocity ranges from 0.6 to 1.5 m/s (2 to 5 ft/s).[25] For higher velocities (over 1.8 m/s [6 ft/s]), a mist eliminator must be used in the top of the tower to capture spray droplets that become entrained in the gas stream.[23] Figure 4-6 is a schematic of a spray tower.

Operating characteristics of spray towers include a low pressure drop (≦0.75 kPa [3 in. w.c.]), liquid requirements ranging from 0.4 to 2.7 liters per 1,000 cubic meters (ℓ/1,000 m^3) (3 to 20 gallons per 1,000 cubic feet [gal/1,000 ft^3]) of gas treated, and typical gas retention times within the tower of 20 to 30 seconds. An advantage of spray towers is their ability to handle large gas volumes. The chief disadvantage of spray towers is their relatively low scrubbing efficiency for particles less than 5 µm (2 $\times 10^{-4}$ in.) in diameter.[25]

4.1.3.1.2 Venturi scrubbers. Figure 4-7 shows a cross-section of a venturi scrubber. As water is introduced into the throat, the gas is forced to move at a higher velocity and the water will shear into droplets. Particles in the gas stream then impact onto the water droplets produced. Moving a large volume of gas through a small constriction gives a high gas velocity and a high pressure drop across the system. Collection efficiency for small particles increases with increased velocities (and corresponding increased pressure drops) since the water is sheared into more and smaller droplets than at lower velocities. The large number of

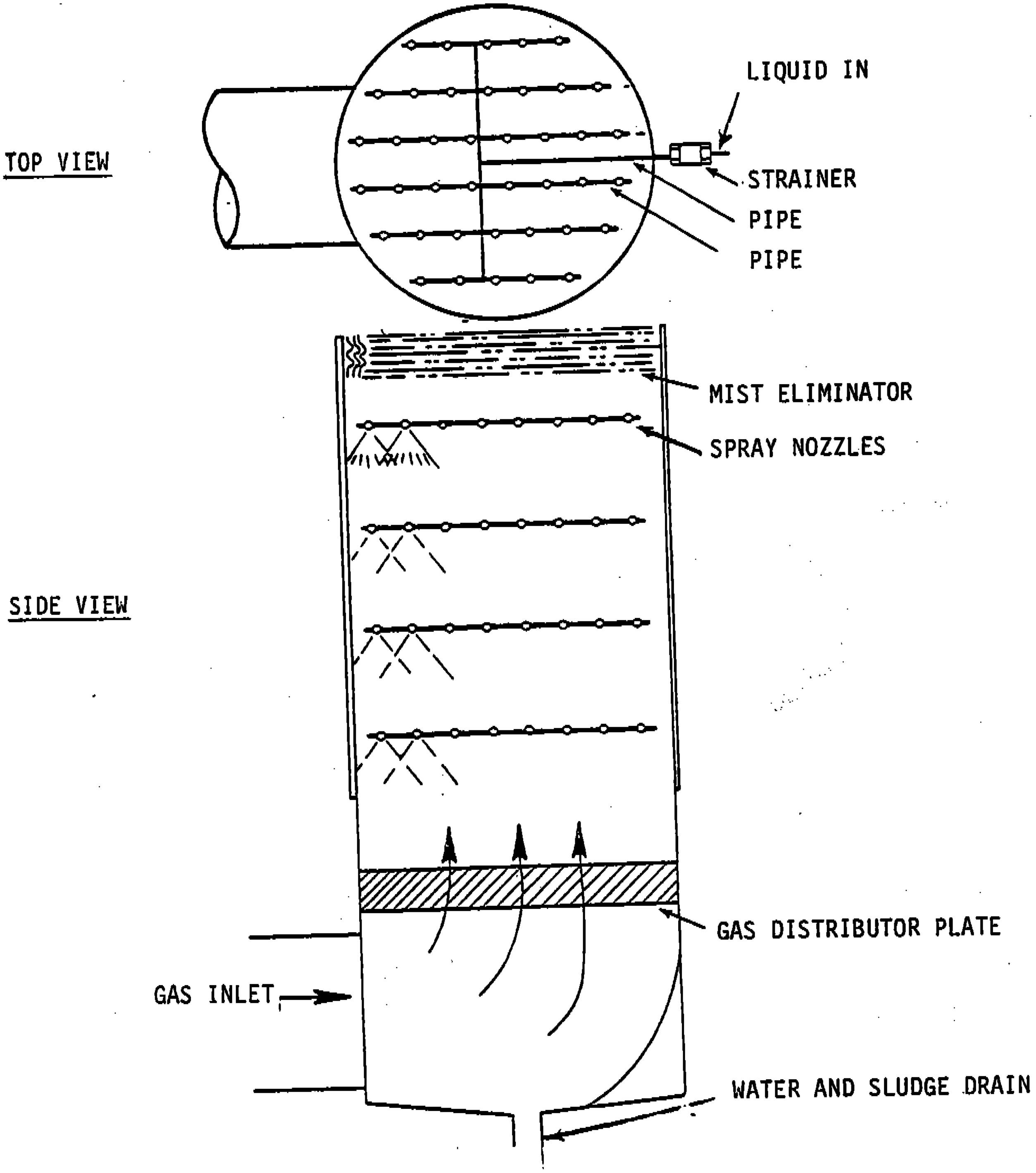


Figure 4-6. Gravity spray tower.[26]

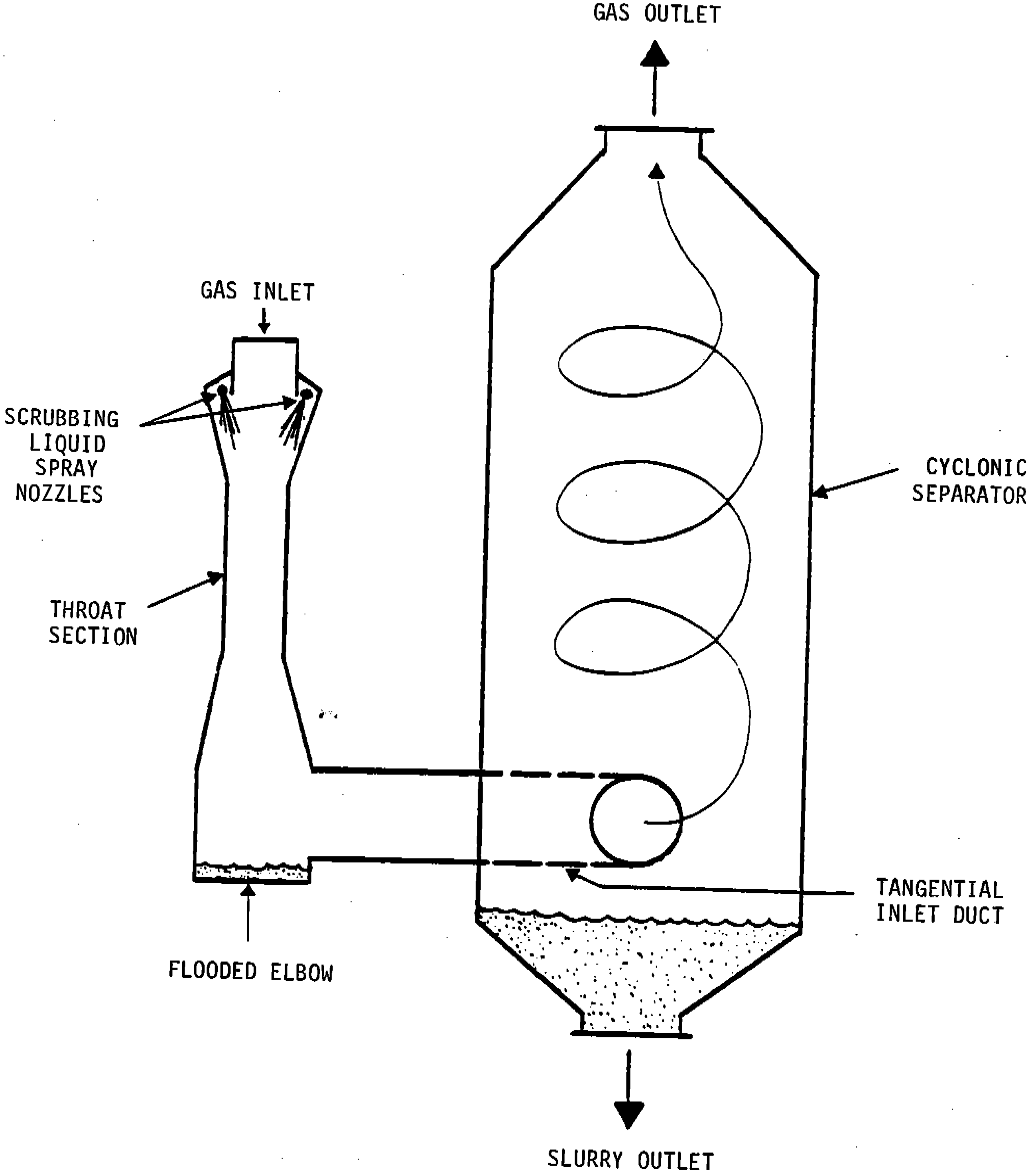


Figure 4-7. Cross sectional view of a typical venturi scrubber.[27]

small droplets combined with the turbulence in the throat section provides numerous impaction targets for particle collection.[28]

The venturi is a gas conditioner and must be followed by a device for the elimination of entrained droplets. The entrained droplets are removed from the gas stream in a cyclone separator that may be followed by other mechanical means of mist elimination.[29]

Figure 4-8 shows the relationship among pressure drop, particle size, and removal efficiency for a typical venturi scrubber. As shown in this figure, collection efficiency increases with increasing pressure drop for a given particle size. The pressure drop of a scrubber is an indicator of the efficiency that can be achieved and the energy required for its operation.

Collection efficiency increases as the gas velocity in the throat increases.[31] Theoretical efficiency curves showing the effect of variable throat velocity for a typical venturi are presented in Figure 4-9. Collection efficiency increases as the liquid-to-gas (L/G) ratio and the pressure drop increase.[33-35] At very high L/G ratios, however, liquid may flood the system and cause efficiency to decrease. The effect of different L/G ratios on the operation of a typical venturi scrubber is shown in Figure 4-10. As particles become smaller, the relative difference in velocity between the particles and the water droplets must be increased to achieve collision. (Small particles tend to follow gas flow streams around water droplets rather than collide with the droplets.) A typical L/G ratio for dryer and calciner venturi scrubbers is 30 ℓ/1,000 m^3 (8 gal/1,000 ft^3).

4.1.3.1.3 Packed bed scrubbers. A typical packed bed scrubber is shown in Figure 4-11. Packed bed scrubbers are vertical columns that have been filled with material that has a high surface area to volume ratio. Water is distributed over, and trickles down through, the packed bed, exposing the gas to a large, wetted surface area.

The modes of gas-liquid contact in packed bed scrubbers may be cocurrent, countercurrent, or crossflow. The packed towers most commonly used for dryer and calciner emission control are countercurrent scrubbers. Gas velocities in countercurrent scrubbers range from 0.9 to 1.8 m/s (3 to 6 ft/s). Bed depth in packed countercurrent scrubbers is typically

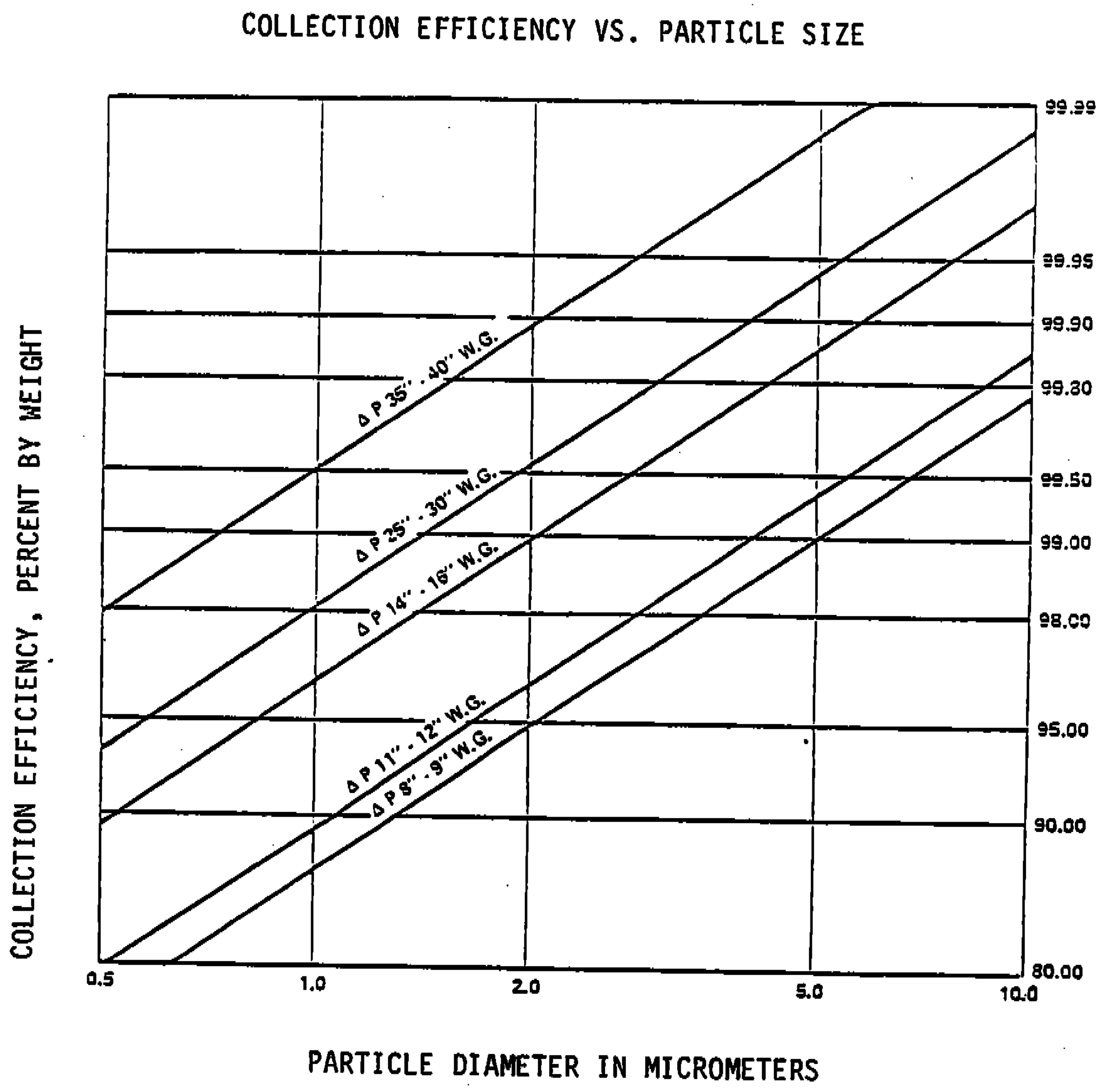
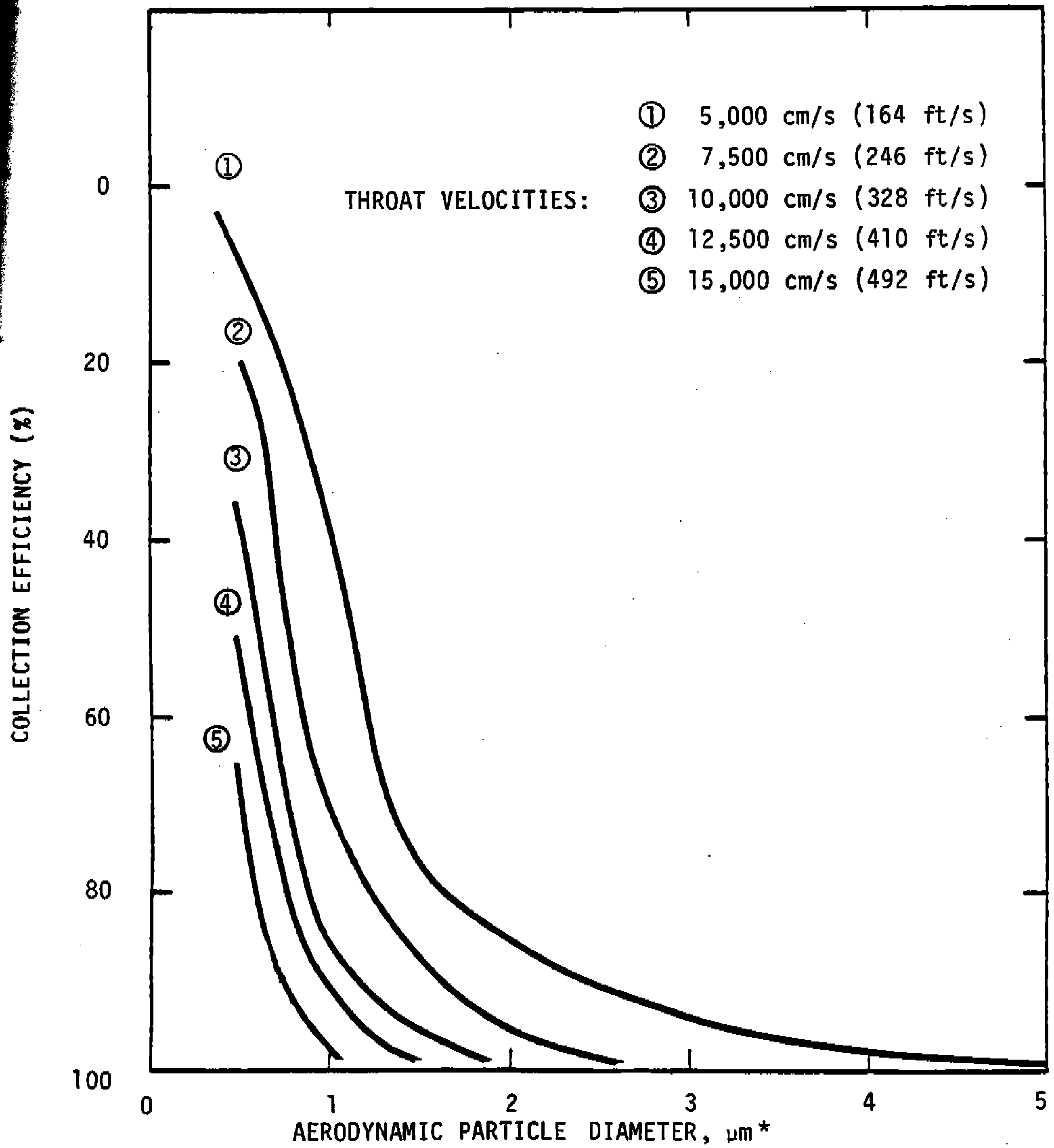


Figure 4-8. Venturi scrubber comparative fractional efficiency curves.[30]



*The aerodynamic particle diameter is the diameter of a unit density sphere having the same aerodynamic characteristics as the actual particle.

Figure 4-9. Theoretical efficiency curve for a venturi scrubber illustrating effect of throat velocity.[32]

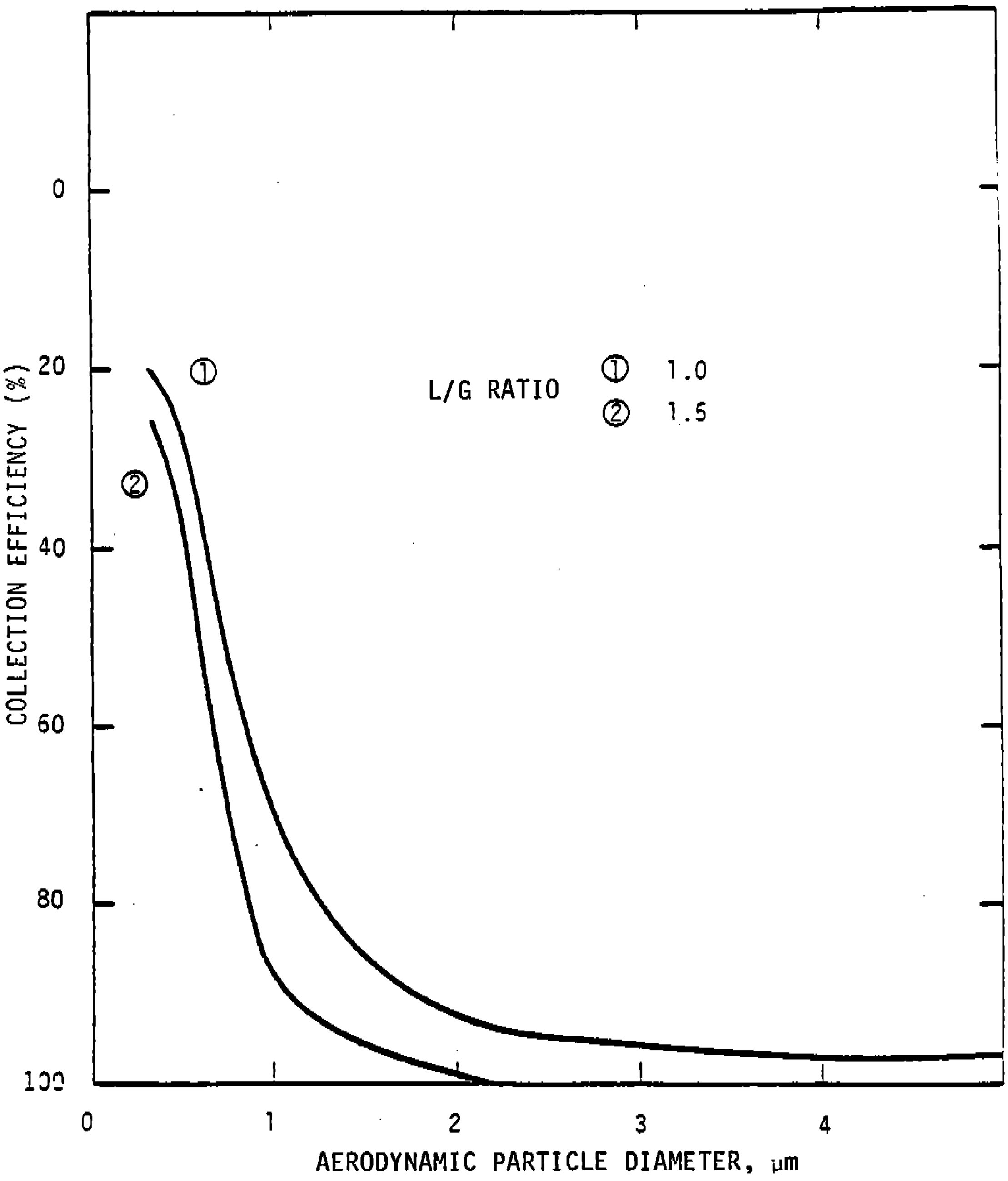


Figure 4-10. Theoretical efficiency curve for venturi scrubber illustrating effect of liquid to gas ratio.[36]

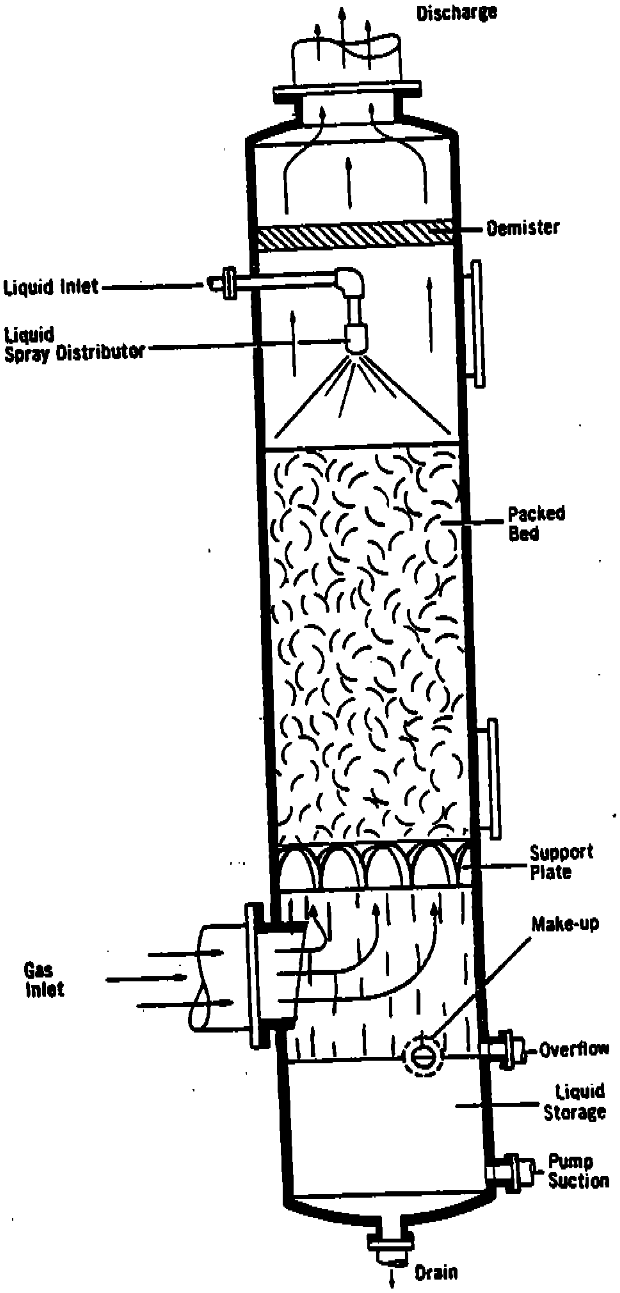


Figure 4-11. Typical packed bed scrubber.[37]

0.9 to 3.1 m (3 to 10 ft). Countercurrent scrubbers are also the most efficient of the three packed bed scrubber types for the collection of particulates as small as 3 to 5 μm (1 x10^{-4} to 2 x10^{-4} in.).

Coarsely packed beds are used for removing coarse dusts with particle diameters greater than 10 μm (4 x10^{-4} in.) and with velocities through the bed of approximately 2 m/s (6.7 ft/s). Finely packed beds may be used for removing smaller particulates, but the velocity through the bed must be kept below 0.3 m/s (0.8 ft/s) to achieve particulate removal. Finely packed beds have a tendency to plug, and their applications are generally limited to gas streams with low grain loadings.

4.1.3.1.4 Cyclonic scrubbers. Figure 4-12 shows a standard type of cyclonic scrubber. The gas enters tangentially at the bottom of the scrubber and follows a spiral path upwards. Liquid spray is introduced into the gas stream from an axially located manifold in the lower part of the unit. The atomized fine-spray droplets are caught in the gas stream and are swept to the walls of the cylinder by centrifugal force, colliding with, absorbing, and collecting particulate matter en route. The scrubbing liquid and collected particles run down the walls and out of the bottom of the unit; the clean gas leaves through the top.

Because impaction is the principal collecting mechanism, collection efficiency is by enhanced comparatively high gas velocities. Pressure drops vary from 0.5 to 2 kPa (2 to 8 in. w.c.), and L/G ratios vary from 0.6 to 1.3 ℓ/1,000 m^3 (4 to 10 gal/1,000 ft^3). The particulate collection efficiency of cyclonic scrubbers is low compared to venturi scrubbers but superior to spray towers and packed bed scrubbers.[39]

4.1.3.1.5 Impingement plate scrubbers. Figure 4-13 shows an impingement plate scrubber. This scrubber is a tower consisting of a vertical shell in which a large number of equally spaced, circular, perforated (orifice) plates are mounted. Downstream of each orifice plate is a target plate for impingement of the gas stream. At one side of each orifice plate, a conduit (downspout) is provided to pass the liquid to the plate below. At the opposite side of the orifice plate, a similar conduit feeds liquid from the plate above.

Gas flowing upward is divided into thousands of jets by the orifices. Each jet aspirates liquid and creates a wetted surface on the target

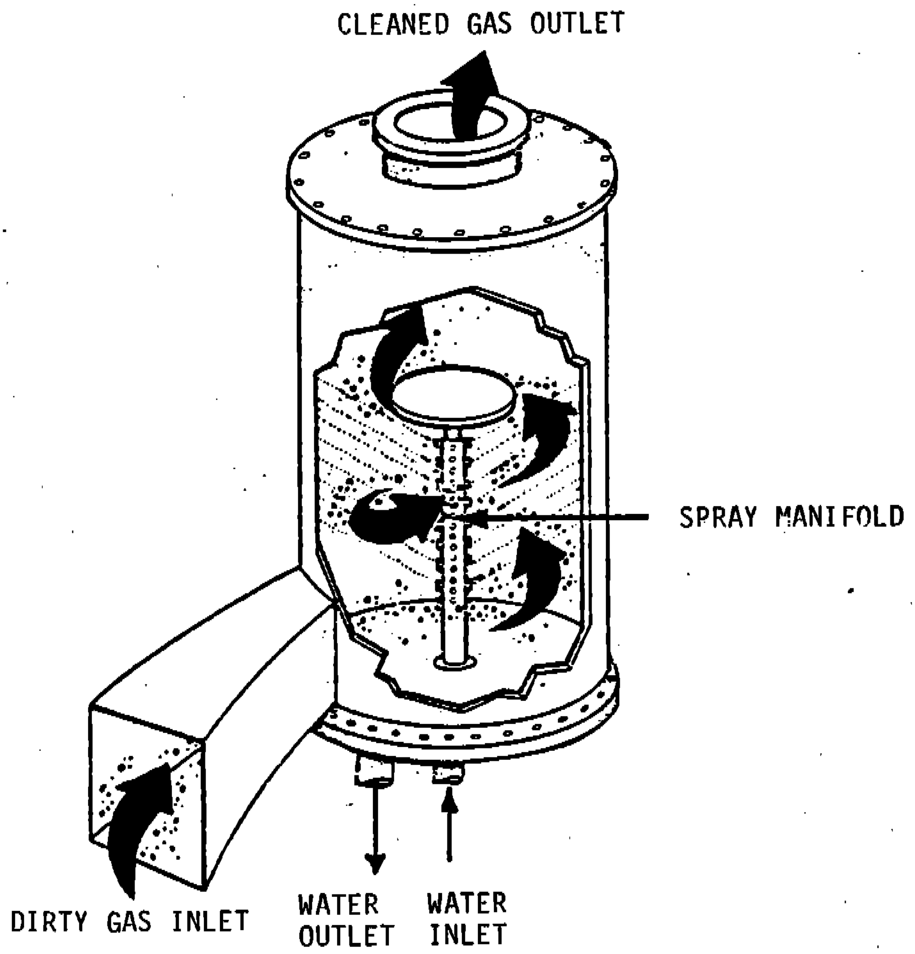
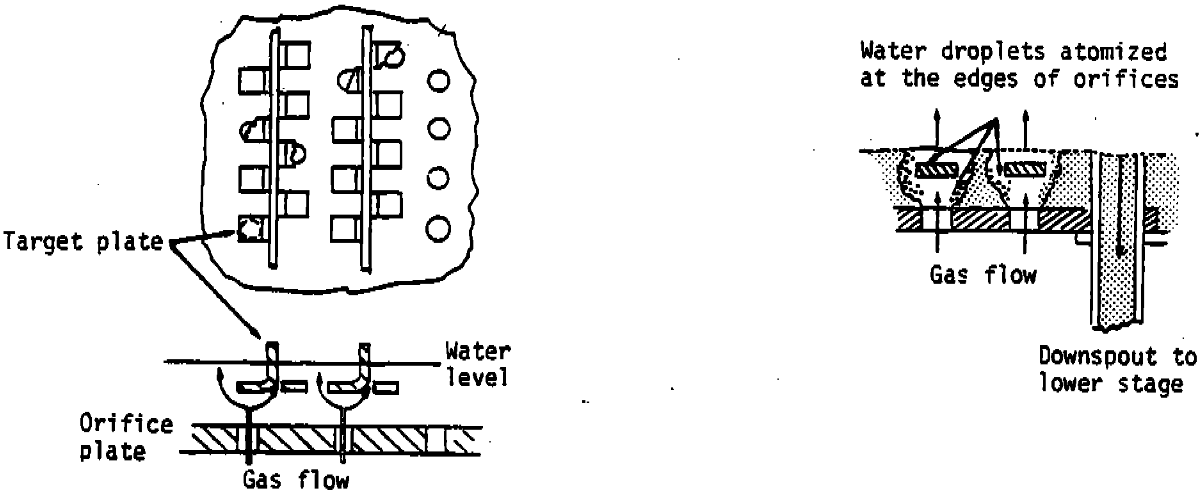


Figure 4-12. Cyclonic scrubber.[38]



ARRANGEMENT OF "TARGET PLATES" IN IMPINGEMENT SCRUBBER

MECHANISM OF IMPINGEMENT SCRUBBER

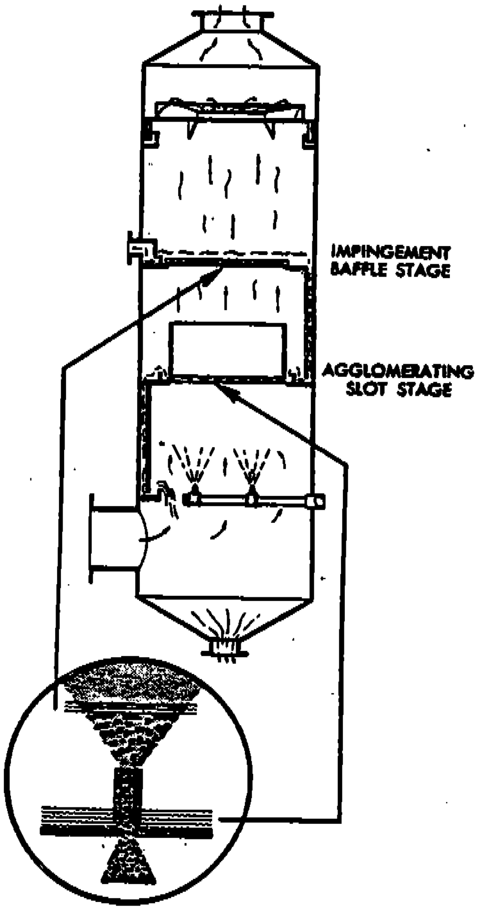


Figure 4-13. Impingement plate scrubber.[40]

plate at the point of maximum jet velocity. As the jet impinges on a wetted target, particles are entrapped in the scrubbing liquid. On impingement, each jet forms minute gas bubbles that rise through, and create turbulence in, the liquid blanket. This provides close gas-liquid contact for maximum cleaning. Continuous violent agitation of the blanket by the bubbles prevents settling of entrapped particles and flushes them away in the scrubbing liquid.

Gas velocities of 4.6 to 6 m/s (15 to 20 ft/s) through the orifices are common.[40] Overall collection efficiencies for a single plate may range from 90 to 98 percent for 1 μm (4 x 10^{-5} in.) particles, and pressure drops from 0.3 to 2 kPa (1 to 8 in. w.c.) are typical. Water requirements usually range from 0.4 to 0.7 ℓ/1,000 m^3 (3 to 5 gal/ 1,000 ft^3) of gas.[40]

4.1.3.1.6 Dynamic scrubbers. Figure 4-14 is a generalized depiction of a dynamic scrubber. In this type of collector, the scrubber liquid is introduced just prior to the fan. The fan acts as a propeller of the gas stream, a mixer for the gas and liquid streams, and an impingment surface for particles and contaminated liquid. Water is typically added at a rate of 75 to 150 ℓ/1,000 m^3 (0.5 to 1 gal/1,000 ft^3) of gas. Several manufacturers offer improvements on the dynamic scrubber design by adding preconditioning sections to the scrubber. These preconditioning sections utilize cyclonic flows and liquid additions to provide an initial mixing of the scrubber liquid and the gas stream.

4.1.3.2 Factors Affecting Performance. The most important parameters to be considered in analyzing the performance of wet scrubbers include the energy imparted in the liquid-gas mixing process (measured as pressure drop), the amount of scrubber water used per volume of gas (L/G ratio), and the inlet particle size and concentration. High pressure drops across a wet scrubber increase the likelihood of contact between the scrubbing liquid and individual particles. High particle removal efficiencies thus require high energy input if the inlet particle size is small.

The difficulty of removing particulate matter with scrubbers increases markedly with decreased particle size. As particle diameter decreases, higher velocities and more acute changes in direction are

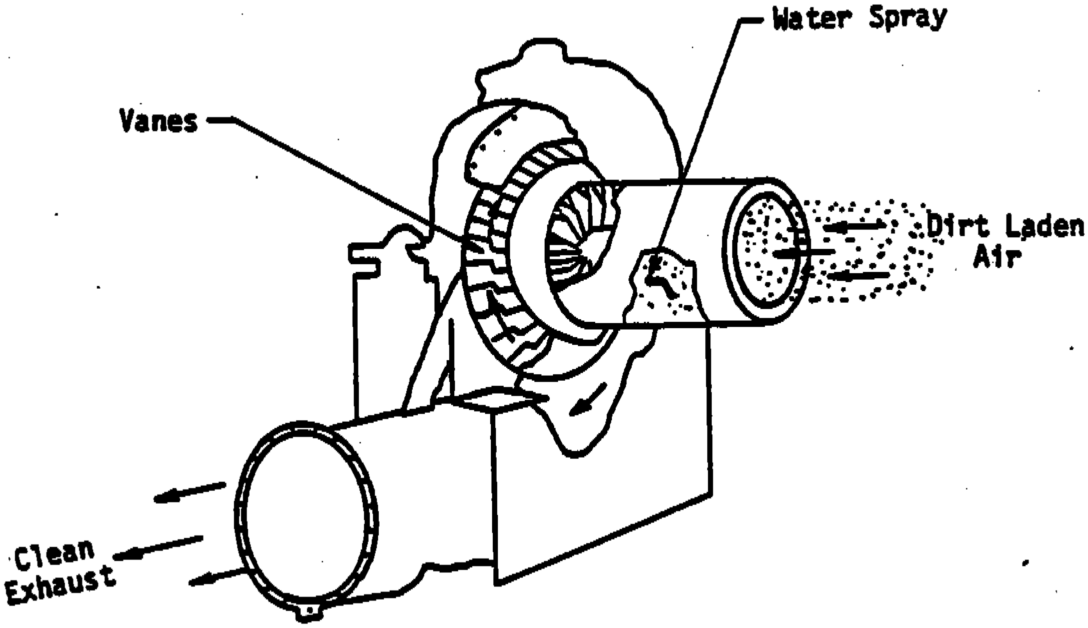


Figure 4-14. Generalized depiction of a dynamic wet scrubber.[41]

required to separate particles from the gas stream. A typical 2.5 kPa (10 in. w.c.) pressure drop venturi scrubber can remove particles of approximately 2 μm (8 x10^{-5} in.) with almost 100 percent efficiency, while a 15 kPa (60 in. w.c.) pressure drop venturi may be required to remove 100 percent of the particles as small as 0.4 μm (1.6 x10^{-5} in.).[42]

4.1.4 Electrostatic Precipitators

4.1.4.1 General Description. Electrostatic precipitators are used to remove particulate matter from an exhaust gas stream based on the attraction between particles of one electrical charge and a collection electrode of opposite charge. Specific details about ESP's used to control particulate matter emissions from mineral dryers and calciners are presented in Section 4.2.4.

Figure 4-15 presents a diagram of a typical ESP that is used to control particulate matter emissions from mineral dryers and calciners. Particulate matter collection in an ESP involves three steps: the electrical charging of particles in the gas stream, the collection of the particles on the collection plates or electrodes, and the removal of the collected particulate matter. Electric fields are established by applying a direct-current voltage across a pair of electrodes: a discharge electrode (a negatively charged metal rod or plate) and a collection electrode (a metal plate). Particles in the inlet gas stream acquire a negative electrical charge as they pass through the electric fields around the discharge electrodes. The negatively charged particles then migrate toward the positively charged collection electrodes. The particulate matter is separated from the gas stream by retention on the collection electrode. Figure 4-16 presents the basic processes involved in electrostatic precipitation.

Once collected, the particulate matter must be removed from the collection electrode. This removal is generally accomplished by rapping the electrodes to dislodge the accumulated dust layer, which falls into a hopper for subsequent removal. Rapping of collection electrodes is done at regular, predetermined intervals. Successful rapping depends upon accumulation of sufficient material on the electrodes such that the dust layer falls in large chunks into the hopper, thus reducing the possibility of particle reentrainment in the gas stream. The depth

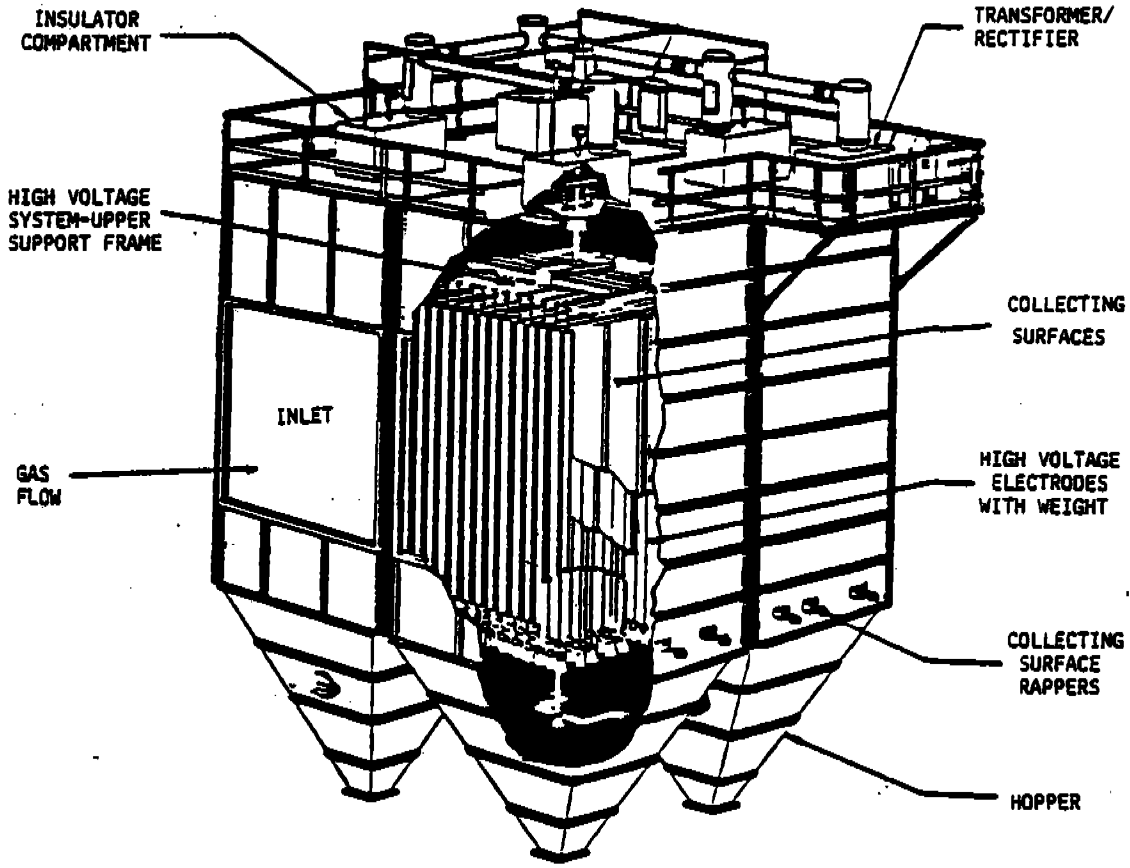


Figure 4-15. Typical ESP with insulator compartment.[43]

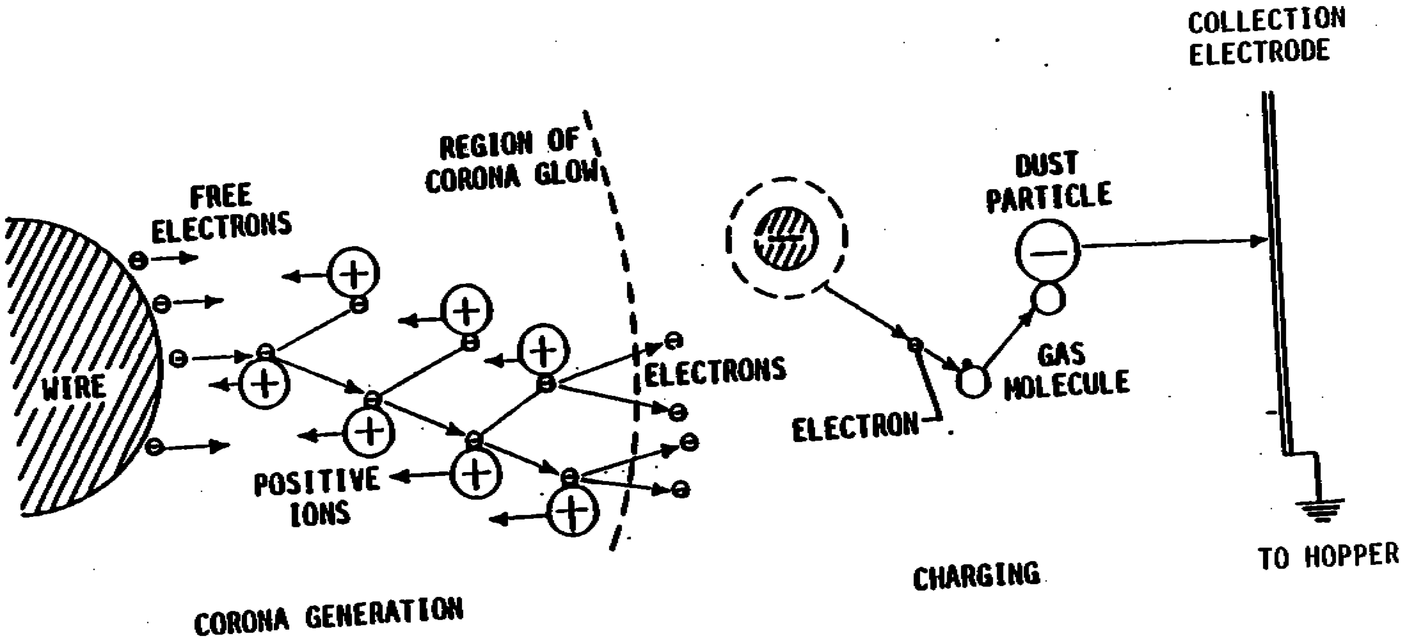


Figure 4-16. Basic processes involved in electrostatic precipitation.[44]

of the ESP is significant in determining the extent of particle reentrainment.

4.1.4.2 Factors Affecting Performance. An ESP must be designed for specific process conditions. The process variables that affect ESP performance include:

1. Gas flow rate and moisture content;
2. Particle size distribution; and
3. Particle resistivity.

The ESP design parameters that affect ESP performance are:

1. Plate area (of the collecting electrodes);
2. Electrode spacing and configuration;
3. Voltage; and
4. Uniform flow distribution.

The gas flow rate is critical in determining the ESP collection plate area. Proper design of the ESP (e.g., size of each compartment and the number of compartments) ensures adequate time for the particles to be electrically charged and to migrate to a collection electrode. Operation at flow rates in excess of the design flow rate will reduce the residence time for charging and collecting the particles and may cause an increase in outlet emissions.[45] In contrast, operation at reduced air flows will result in increased particulate matter removal efficiency. Therefore, ESP's should be designed to accommodate the maximum air flow expected from the production process.

In sizing an ESP, the total collection area of the plates must be increased as the fraction of small particles increases. To account for particle size in new installations, vendors must utilize particle size data for the specific industry or base the design on their experience within industries having similar emission characteristics.[46]

The most effective operation of an ESP is obtained when the particle resistivity falls between 10^4 and 10^{10} ohm-cm.[47] If the resistivity is too low, particles rapidly lose their charge upon reaching the collection electrode and can become reentrained in the gas stream. If the resistivity is too high, charged particles reaching the collection electrode cannot lose their charge because of the low conductivity of the material deposited earlier; hence, it is difficult to clean the plates.

The specific collection area (SCA) is defined as the ratio of the total plate area to the gas flow rate. For a given ESP application, collection efficiency improves as SCA increases. However, the ESP also becomes larger, and consequently more expensive, as the SCA is increased.

The collection plate area and gas flow rate have been specifically related to the overall collection efficiency through the Deutsch-Anderson equation, which is used to estimate plate area:[48]

$$\eta = 1 - \exp(-wA/Q)$$

where: η = collection efficiency
w = precipitation rate parameter
A = plate area
Q = volumetric gas flow rate

The precipitation rate parameter is a performance parameter that relates gas flow rate, collection plate area, and particle capture efficiency. This parameter is a function of the physical properties of the emissions (e.g., particle size distribution and resistivity) and is determined by tests on pilot units and/or by operation of an ESP on similar emission sources. This equation shows that ESP collection efficiency increases with increasing plate area and with increasing (absolute) values of the precipitation rate parameter. The electrode type, and plate spacing, height, and length influence the electrostatic forces exerted on the particles and, thus, affect the collection efficiency. The voltage applied to the ESP electrodes must be sufficient to ensure an adequate electric field strength for charging the particles while minimizing problems of sparking (i.e., arcing or short circuiting between electrodes).

Inlet dust concentration determines both the frequency of rapping (cleaning) and the size of the dust removal system. Increased inlet dust concentration reduces ESP performance and requires a higher power input so that all particles are charged. Alternatively, a larger collection plate area can compensate for increased dust concentration.[49,50]

4.2 APPLICATION OF CONTROL TECHNIQUES TO CALCINERS AND DRYERS IN THE MINERAL INDUSTRIES

The application of various control techniques to dryer and calciner systems is discussed in this section. The use of centrifugal separators is limited mainly to product collection. Fabric filters are used for particulate matter emission control in over 90 percent of the mineral industries included in this study. They are also used for product collection in some cases. A variety of wet scrubbers are used to control calciner and dryer emissions in more than 75 percent of the 17 industries. Electrostatic precipitators are used in 5 of the 17 mineral industries.

4.2.1 Centrifugal Separators

Single and multiple cyclone collectors are used primarily for product recovery from dryer and calciner systems. In most cases, the material recovered by these devices is recycled into the process. In one case, a multiple cyclone collector is used for air pollution control before a venturi scrubber on a fire clay rotary calciner.[51] The material collected by this device is landfilled. Particulate matter emission levels measured in the gas stream following centrifugal separators on dryers and calciners are presented in Chapter 3.

4.2.2 Fabric Filters

Fabric filters (baghouses) are used to control particulate matter emissions from dryers and/or calciners in 16 of the 17 mineral industries being considered in this study. They are also used for product recovery in the case of flash drying/calcining units. Table 4-3 presents the range of operating parameters for baghouses used on process units within each industry.

Baghouses are currently not being used to control particulate matter emissions from calciners in the alumina industry. However, baghouses are the predominant control device used on calciners and dryers in the ball clay, gypsum, kaolin, perlite, talc, and vermiculite industries.

Pulse jet is the most frequently used cleaning mechanism. Typical A/C ratios for dryer and calciner pulse jet baghouses range from 0.9 to

TABLE 4-3. TYPICAL OPERATING PARAMETER RANGES FOR DRYER AND CALCINER BAGHOUSES

Industry	Process unit	Cleaning mechanism(s)	A/C ratio, acfm/ft^2	No. of compartments	Frequency of cleaning/min	Pressure drop, in. w.c.	Bag material
1. Alumina	No baghouses used.						
2. Ball clay	Vibrating-grate dryer[52-53] (Indirect)	Pulse jet	4.6-5:1 5-5.7:1	1	1	4, 4.2	Polyester
3. Bentonite	Rotary dryer[54-56]	Reverse air	1.5:1	1	>1	N/A[a]	Polyester
		Pulse jet	6.6:1	1-2	4-10, continuous	1.5-3	Nomex
4. Diatomite	Flash dryer[57]	Pulse jet	0.5:1	1	1-2, intermittent	2-4	Nomex
	Rotary dryer[58]	Pulse jet	4:1	1	9[b]	2.5	Polyester
	Rotary calciner[59]	Pulse jet	3.6:1	1		4	Polyester
5. Feldspar	Fluid bed dryer[60]	Pulse jet	5.5:1	1	4	2	Dacron
	Rotary dryer[61]	Pulse jet	5.4:1	4	20[b]	N/A	Nomex
6. Fire clay	Rotary dryer[62-64]	Pulse jet	1.9-7.5:1	1-5	2-3, continuous	1-7	Nomex, Dacron, Polyester, acrylic
7. Fuller's earth	Fluid bed dryer[65]	Pulse jet	4.5:1	1	>5	1-2.5	Huglas
	Rotary dryer[66,67]	Pulse jet	4:1	1	3		Acrylic, Nomex
	Rotary calciner[68]	Pulse jet	4.5:1	1	<1	0.25-0.5	Nomex, Teflon
8. Gypsum	Rotary dryer[69]	Pulse jet	4-6:1	N/A	N/A	3-3.5	Nomex, Dacron
		Reverse air	2.5-3:1	N/A	N/A	N/A	Orlon
	Flash calciner[70]	Pulse jet	4.2:1	N/A	N/A	3-3.5	Nomex
	Kettle calciner[71]	Pulse jet	2.3-5.5:1	N/A	N/A	2.5-3.5	Nomex
9. Industrial sand	Fluid bed dryer[72]	Pulse jet	7:1	1	1	1.5	Polypropylene felt
10. Kaolin	Flash dryer[73]	Pulse jet	N/A	1	N/A	6	Polyester
	Rotary dryer[74]	Pulse jet	3.9:1		N/A		Dacron
	Spray dryer[75-77]	Shaker	2.0-3.8:1	4-8	N/A	4	Acrylic, Dacron
		Pulse jet	5.0:1				
	Rotary calciner[78]	Pulse jet	3.3-5.3:1	1	N/A	9.0	Dacron, Nomex
	Flash calciner[79]	Reverse air	1-1.2:1	6-14	N/A	3	Polyester
		Pulse jet			N/A	6	Polyester

(continued)

TABLE 4-3. (continued)

Industry	Process unit	Cleaning mechanism(s)	A/C ratio, acfm/ft^2	No. of compart-ments	Frequency of cleaning/min	Pressure drop, in. w.c.	Bag material
11. Lightweight aggregate	Rotary calciner^{80}	Pulse jet	5:1	7	8^b	5-8	Teflon
12. Magnesium compounds	Multiple hearth furnace^{81}	Reverse air	1.4:1	6	N/A	4-6	Fiberglass
	Rotary calciner^{81}	Reverse air	1.7:1	10	N/A	4-6	Fiberglass
13. Perlite	Rotary dryer$^{82-85}$	Pulse jet	4.5:1	N/A	5	5	Nomex
		Reverse air	2.8:1	4	10^b	2-3	Dacron
		Shaker	2:1	5-6		2-4	Acrylic, cotton
	Expansion furnace$^{86-89}$	Pulse jet	2.6:1	1-4	$4-10^b$	3-4	Nomex, fiberglass
		Reverse air	2-4.7:1	2-8	$8-12^b$	3-4	Nomex, fiberglass, Dacron
14. Roofing granules	Rotary dryer^{90}	Pulse jet	4.6:1	1	6^b	18	Polyester
15. Talc	Flash dryer^{91}	Reverse air	2.0:1	1	25^b	2	Polyester
	Rotary dryer^{92,93}	Shaker jet	2.3:1	6	2^b	12	Dacron
		Pulse jet	8.5:1	1	Continuous	3	Nomex
	Rotary calciner^{94}	Pulse jet	N/A	N/A	1	4	Dacron
16. Titanium dioxide	Rotary dryer^{95,96}	Pulse jet	2.8-5.1:1	1-3	4-10	4	Dacron, Orlon
	Spray dryer^{97}	Pulse jet	3.5:1	4, 6	N/A	5	Nomex
17. Vermiculite	Fluid bed dryer^{98}	Pulse jet	6:1	8	0.5	10	Nomex
	Expansion furnace$^{99-101}$	Pulse jet	5.2:1	1	Variable	2-6	Nomex
		Reverse air	6.8:1	N/A	N/A	5	Nomex
		Shaker	2.8:1	3	1/day	N/A	Dralon

[a] N/A = Not available.
[b] No. of pulses per hour.

1.8 $m^3/min-m^2$ (3 to 8 $ft^3/min-ft^2$). Pressure drops range from 0.5 to 1.2 kPa (2 to 5 in. w.c.).

Baghouses used to control particulate matter emissions from mineral dryers must either be well insulated or the gas stream must be heated to prevent moisture condensation that would lead to caking and blinding of the bags. Maximum baghouse inlet gas temperatures for dryers and calciners are about 150°C (300°F) and 260°C (500°F), respectively. Consequently, high-temperature-resistant filter fabrics are required. Nomex® and glass fabrics are the most common types used for high temperature applications.

4.2.3 Wet Scrubbers

Table 4-4 presents typical operating data for wet scrubbers on dryers and calciners. Wet scrubbers are used to control particulate emissions from dryers and/or calciners in 12 of the 17 mineral industries being considered in this study. Venturi scrubbers are the most common type, used by 10 of the 12 industries. Pressure drops range from 0.5 to 15 kPa (2 to 60 in. w.c.). Wet scrubbers are currently not used in the alumina, bentonite, and talc industries. Wet scrubbers are not being used to control particulate emissions from gypsum plants built in the last 13 years. However, in a few older installations, low energy wet scrubbers are used to control gypsum dryer and calciner emissions. Scrubbers are not used in newer installations primarily because particulate matter collected using wet scrubbers cannot be recycled into the process.

4.2.4 Electrostatic Precipitators

Table 4-5 contains operating information regarding temperature, pressure drop, and specific collection area (SCA) for existing ESP-controlled dryer and calciner facilities. Electrostatic precipitators are used to control particulate emissions from dryers and/or calciners in 5 of the 17 mineral industries. They are used to control emissions from two dryer types and four types of calciners, as shown in Tables 4-1 and 4-5. The ranges of operating temperatures for ESP's on dryers and calciners are 80° to 130°C (175° to 270°F) and 120° to 430°C (250° to 800°F), respectively. The pressure drop across these units ranges from

TABLE 4-4. TYPICAL OPERATING PARAMETER RANGES FOR DRYER AND CALCINER WET SCRUBBERS

Industry	Process equipment	Scrubber type	Inlet temp. °C (°F)	Pressure drop System -- kPa (in. w.c.) ---	Pressure drop Throat -- kPa (in. w.c.) ---	Liquid-to-gas ratio ℓ/1,000 m^3 (gal/1,000 ft^3)
1. Alumina	No scrubbers used.					
2. Ball clay	No scrubbers used.					
3. Bentonite	No scrubbers used.					
4. Diatomite	Flash dryer[102]	Venturi	66-80 (158-174)	7.0-7.5 (28-30)	3.7-7.0 (15-28)	2.95-9.27 (0.78-2.45)
	Rotary dryer[58,103]	N/A[a]	55-82 (130-180)	1.5 (6)	--	40.5-91.6 (10.7-24.2)
5. Feldspar	Fluid bed dryer[104]	Packed bed	93 (200)	2.5 (10)	--	89.1 (23.53)
	Rotary dryer[104,105]	Packed bed	52-93 (125-200)	2.5 (10)	--	47.3 (12.5)
		Cyclonic	80 (175)	0.7 (3)	--	19.1 (5.05)
		Venturi	37 (99)	2.0 (8.1)	1.4 (5.5)	63.0 (16.6)
6. Fire clay	Rotary dryer[106]	Cyclonic	93 (200)	2.7-3.2 (11-13)	--	6.9 (1.82)
	Vibrating-grate dryer[107]	Impinjet	70 (160)	3.0 (12)	--	5.5-7.34 (1.45-1.94)
	Rotary calciner[107-109]	Cyclonic	315 (600)	3.7 (15)	--	N/A
		Venturi	50-70 (120-160)	7.5-8.2 (30-33)	6-6.7 (24-27)	36.8-43.9 (9.7-11.6)
		Packed bed	225 (440)	1.4 (5.5)	--	2.08 (0.55)
7. Fuller's earth	Rotary dryer[65,110]	N/A	113 (235)	2.4-2.5 (9.5-10)	--	N/A
		Venturi	N/A	N/A	3.7-5.0 (15-20)	N/A
8. Gypsum	No scrubbers used.[b]					
9. Industrial sand	Fluid bed dryer[72,111,112]	Impinjet	70-150 (160-300)	0.8-1.6 (3.4-6.5)	--	7.68-8.29 (2.03-2.19)
		Venturi	79-93 (175-200)	4.4 (17.5)	0.1-2.0 (0.5-8.0)	17.64-38.2 (4.66-10.1)
	Rotary dryer[113]	Impinjet	93 (200)	1.5-1.7 (6-7)	--	42.13 (11.13)

(continued)

TABLE 4-4. (continued)

Industry	Process equipment	Scrubber type	Inlet temp. °C (°F)	Pressure drop System -- kPa (in. w.c.) ---	Pressure drop Throat	Liquid-to-gas ratio ℓ/1,000 m³ (gal/1,000 ft³)
10. Kaolin	Multiple hearth furnace[75,79]	Venturi	60-454 (140-850)	3.0-5.2 (12-21)	4.2 (17)	42.2 (11.2)
	Rotary calciner[114]	Venturi	70 (160)	N/A	5.0 (20)	38.2 (10.1)
11. Lightweight aggregate	Rotary calciner[115,116]	Venturi	220-230 (426-443)	2.4-3.5 (9.5-14)	N/A	22.4-29.0 (5.9-7.7)
		Impinjet	N/A	2.5 (10)	--	N/A
12. Magnesium compounds	Multiple hearth furnace[81]	Venturi	149 (300)	N/A	4.0 (16)	60.6 (16.0)
	Rotary calciner[117]	Venturi	260-482 (500-900)	10.0 (40)	8.0 (32)	7.2-9.8 (1.9-2.6)
13. Perlite	Expansion furnace[118]	N/A	190 (375)	1.0 (4)	--	1.1 (0.29)
14. Roofing granules	Fluid bed dryer[90]	Impinjet	80 (175)	1.1 (4.3)	--	7.5 (2.0)
	Rotary dryer[119]	Impinget	38 (100)	3.0 (12)	--	4.0 (1.06)
15. Talc	No scrubbers used.					
16. Titanium dioxide	Flash dryer[120]	Venturi	135 (275)	N/A	10 (40)	82.9 (22)
	Rotary dryer[120-122]	Spray tower	N/A	1.5 (6)	--	N/A
		Venturi	38-316 (100-600)	5.0-12.4 (20-50)	3.2-11.2 (13-45)	10.2 (2.7)
	Spray dryer[123]	Venturi	66 (150)	17.4 (70)	7.5 (30)	79.9 (21.13)
	Rotary calciner[95,121]	Venturi	70 (160)	5.5-7.5 (22-30)	N/A	N/A
		Venturi	66 (150)	1.5 (6)	0.5 (2)	86.8 (22.9)
17. Vermiculite	Rotary dryer[101,124]	Spray tower	93 (200)	<1.2 (<5)	--	N/A
		Venturi	N/A	2.0 (8.0)	N/A	23.5 (6.2)

[a] N/A = Not available.

[b] No scrubbers have been installed on gypsum calciners and dryers built in the last 13 years.

TABLE 4-5. TYPICAL OPERATING PARAMETER RANGES FOR DRYER AND CALCINER ELECTROSTATIC PRECIPITATORS

Industry	Process equipment	Inlet temp. °C (°F)	Pressure drop, kPa (in. w.c.)	Specific collector area $m^2/10^3\ m^3\ min^{-1}$ ($ft^2/10^3$ acfm)	Rapper type
Alumina	Flash calciners[125]	[a]	[a]	[a]	Impact
	Rotary calciners[126-128]	120-340 (250-650)	0.1-1.6 (0.5-6.3)	258-1,500 (79-457)	Vibration hammer
Bentonite	Fluid bed dryer[129]	90-110 (200-230)	0.1 (0.5)	682 (208)	Electromagnetic
	Rotary dryers[56,130]	90-130 (200-270)	0.1 (0.5)	782-857 (239-261)	Electromagnetic
Fire clay	Rotary calciner[131]	320-430 (600-800)	0.07 (0.3)	1,167 (360)	Electromechanical
Gypsum	Kettle calciners[132]	N/A	N/A	N/A	N/A
Lightweight aggregate	Rotary calciners[133]	250 (480)	N/A	N/A	N/A
Magnesium compounds	Multiple hearth furnaces[117,134]	320-385 (600-725)	0.07-0.1 (0.3-0.5)	1,453-1,565 (443-477)	Impact/vibration hammer
	Rotary calciners[134]	340-370 (640-700)	0.2 (1.0)	962-1,493 (293-455)	Electromechanical

[a] Confidential data.

4.3 PERFORMANCE OF EMISSION CONTROL SYSTEMS

The performance of various control systems used to collect particulate matter emissions from dryers and calciners is discussed in this section. The data base for this study was developed from EPA-conducted tests on selected systems and from EPA-approved compliance tests conducted by plant owners and State agencies.

Data obtained from the EPA testing program are summarized in Table 4-6. Four rotary dryers, one fluid bed dryer, and three spray dryers were tested. The air pollution control devices on these dryers include fabric filters and wet scrubbers. Seven rotary calciners, one kettle calciner, one Herreshoff furnace, three flash calciners, and one expansion furnace were also tested. The calciner control devices tested include a centrifugal separator, fabric filters, wet scrubbers, and a wet ESP. These data are presented graphically in Figures 4-17 and 4-18. The units tested are representative of the worst-case fuel and feed materials, as identified by industry representatives. The production rates of the systems tested range from 80 to 129 percent of design capacity. The unit tested at 129 percent of capacity was operating at a rate above normal; however, this high production level is representative of the worst case particulate loading to the control device. For the remaining tests, the operating conditions of the process and control devices are representative of normal plant operating conditions. Additional information about each test is presented in Appendix C. The testing and analysis methodologies are described in Appendix D.

Figures 4-19 and 4-20 graphically present emission data obtained from EPA-approved compliance tests performed by State agencies and plant owners. [EPA-conducted tests are also contained in these figures.] Figures 4-17 through 4-20 also show the predicted performance levels of selected wet scrubbers operating at pressure drops higher than the pressure drops recorded during emission tests. Tables 4-7 and 4-8 summarize the compliance test data presented in the two figures. Table 4-9 summarizes visible emission data obtained from the dryers and calciners tested. Table 4-10 presents the outlet particle size distribution data obtained for several of the dryer and calciner units.

TABLE 4-6. SUMMARY OF CONTROLLED EMISSION DATA FROM EPA TEST PROGRAM[135-148]

Industry/Raw material	Plant code	Process unit	Percent of design capacity	Fuel	Control device	Average particulate emissions g/dscm (gr/dscf)
<u>DRYERS</u>						
Bentonite	C1	Rotary dryer	87	Pulverized coal	Baghouse A/C = 1.45:1	0.047 (0.020)
Fire clay/plastic	F1	Rotary dryer	100	Natural gas	Wet scrubber ΔP = 12 in. w.c.	0.070 (0.031)
Fire clay/flint	F1	Rotary dryer	100	Natural gas	Wet scrubber ΔP = 12 in. w.c.	0.088 (0.038)
Gypsum	H1	Rotary dryer	92	Natural gas	Baghouse ΔP = 6.4:1	0.010 (0.004)
Industrial sand/float sand	I1	Rotary dryer	100	Propane	Wet scrubber ΔP = 3.0 in. w.c.	0.014 (0.006)
Industrial sand	I1	Fluid bed dryer	97	Propane	Wet scrubber ΔP = 3.0 in. w.c.	0.049 (0.021)
Titanium dioxide	P1	Spray dryer No. 1	80	Natural gas	Baghouse A/C = 3.5:1	0.012 (0.005)
	P1	Spray dryer Nos. 1 and 2	80	Natural gas	Wet scrubber ΔP = a	0.057 (0.025)[b]
Titanium dioxide	P2	Spray dryer	129	Natural gas	Baghouse A/C = 3:1	0.024 (0.010)
<u>CALCINERS</u>						
Fire clay/flint	F2	Rotary calciner	100	Natural gas	Wet scrubber ΔP = 24-27 in. w.c.	0.018 (0.008)
Fire clay/kaolin	F3	Rotary calciner	98	Pulverized coal	Multiple cyclone, wet scrubber ΔP = 18 in. w.c.	0.076 (0.033)
Gypsum	H1	Kettle calciner	100	Natural gas	Baghouse ΔP = 2.9:1	0.028 (0.012)
Gypsum	H2	Flash calciner	95	Natural gas	Baghouse A/C = 4.2:1	0.054 (0.024)
Gypsum	H4	Flash calciner	95	Natural gas	Baghouse A/C = 4.3:1	0.014 (0.006)

(continued)

TABLE 4-6. (continued)

Industry/Raw material	Plant code	Process unit	Percent of design capacity	Fuel	Control device	Average particulate emissions g/dscm (gr/dscf)
Kaolin	J1	Herreshoff furnace	115	Natural gas	Wet scrubber ΔP = 12 in. w.c.	0.047 (0.021)
	J1	Flash calciner	86	Natural gas	Baghouse A/C = 1.1 to 1.6:1	0.002 (0.001)
Lightweight aggregate/shale	K1	Rotary calciner	83	Pulverized coal	Wet scrubber ΔP = 6 in. w.c.	0.099 (0.043)
Lightweight aggregate/clay	K6	Rotary calciner	100	Pulverized coal	Wet scrubber ΔP = 10 in. w.c.	0.096 (0.042)
Perlite	M1	Expansion furnace	93	Natural gas	Baghouse A/C = 2.6:1	0.027 (0.012)[c] 0.045 (0.020)[d] 0.034 (0.015)[e]
Titanium dioxide	P1	Rotary calciner	90	Natural gas	Wet ESP, wet scrubber SCA = 228 $ft^2/10^3$ acfm ΔP = a	0.122 (0.053)[f] 0.096 (0.042)[g] 0.007 (0.003)[h]

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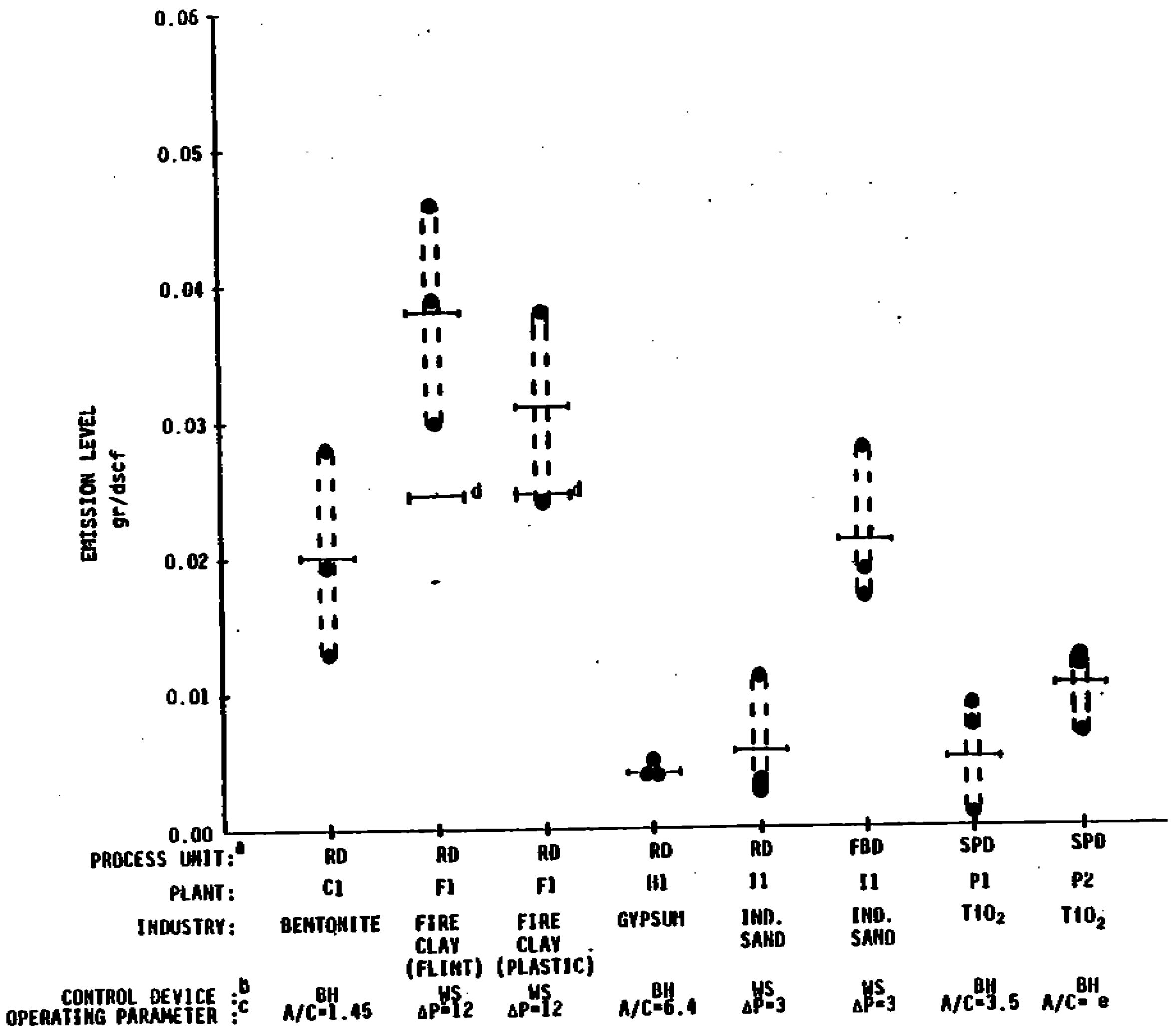
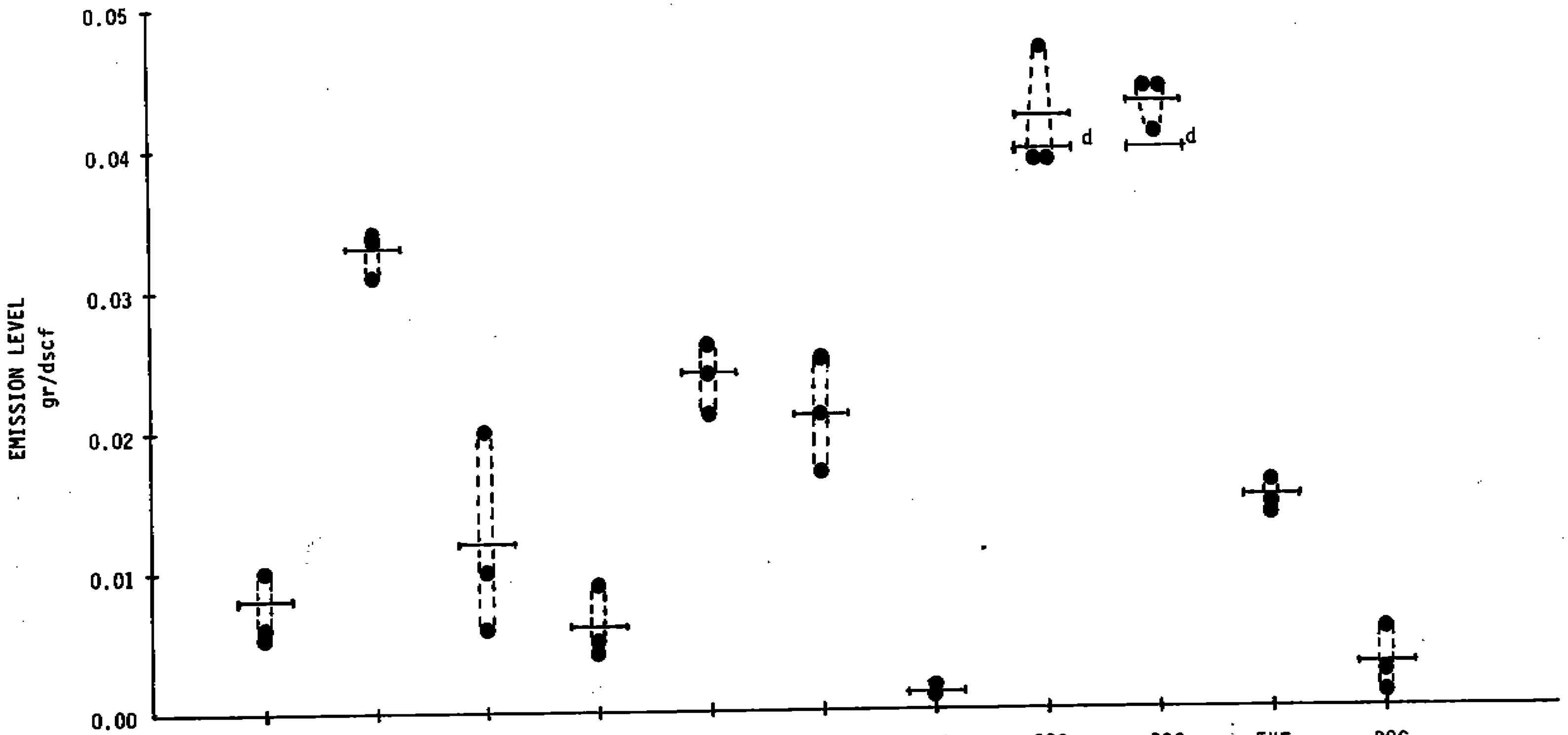
[a] Confidential data.
[b] Common scrubber for two spray dryers.
[c] West stack.
[d] East stack.
[e] Combined emissions of both stacks.
[f] ESP outlet--east.
[g] ESP outlet--west.
[h] Scrubber outlet.



[a] RD = Rotary dryer; FBD = Fluid bed dryer; SPD = Spray dryer.
[b] BH = Baghouse; WS = Wet scrubber.
[c] ΔP = in. w.c.; A/C = $ft^3/min\text{-}ft^2$.
[d] Achievable emission level at ΔP=14 in. w.c.
[e] Confidential data.

Figure 4-17. EPA-conducted project test data for dryers.[135-140]



PROCESS UNIT:[a]	ROC	ROC	KC	FLC	FLC	HF	FLC	ROC	ROC	EXF	ROC
PLANT:	F2	F3	H1	H4	H2	J1	J1	K6	K1	M1	P1
INDUSTRY:	FIRE CLAY	KAOLIN/ FIRE CLAY	GYPSUM	GYPSUM	GYPSUM	KAOLIN	KAOLIN	LWA	LWA	PERLITE	TiO_2
CONTROL DEVICE:[b]	WS	MC, WS	BH	BH	BH	WS	BH	WS	WS	BH	WESP,WS
OPERATING PARAMETER:[c]	ΔP=24-27	ΔP=18	A/C=2.9	A/C=4.3	A/C=4.2	ΔP=12	A/C=1.6	ΔP=10	ΔP=6	A/C=2.6	SCA=228;ΔP=e

[a] ROC = Rotary calciner; KC = Kettle calciner; FLC = Flash calciner; HF = Herreshoff furnace; EXF = Expansion furnace.

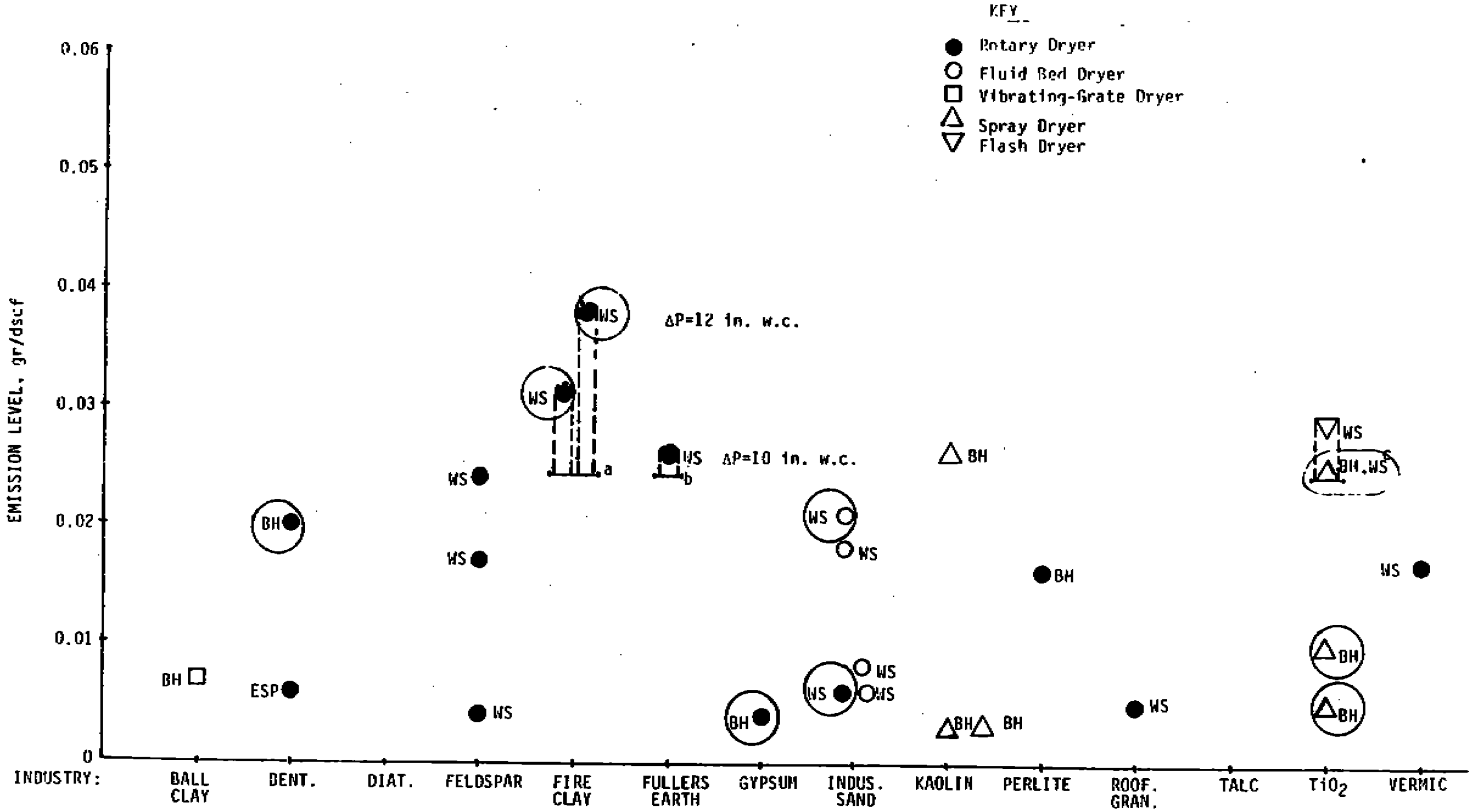
[b] WS = Wet scrubber; MC = Multiple cyclone; BH = Baghouse; WESP = Wet Electrostatic precipitator.

[c] ΔP = in. w.c.; A/C = $ft^3/min\text{-}ft^2$; SCA = $ft^2/1000$ acfm

[e] Confidential data.

[d] Achievable emission level at ΔP= 23 in. w.c.

Figure 4-18. EPA-conducted project test data for calciners.[137,139,141-148]



(EPA-conducted tests are circled. Operating parameters for control devices are presented in Table 4-6.)

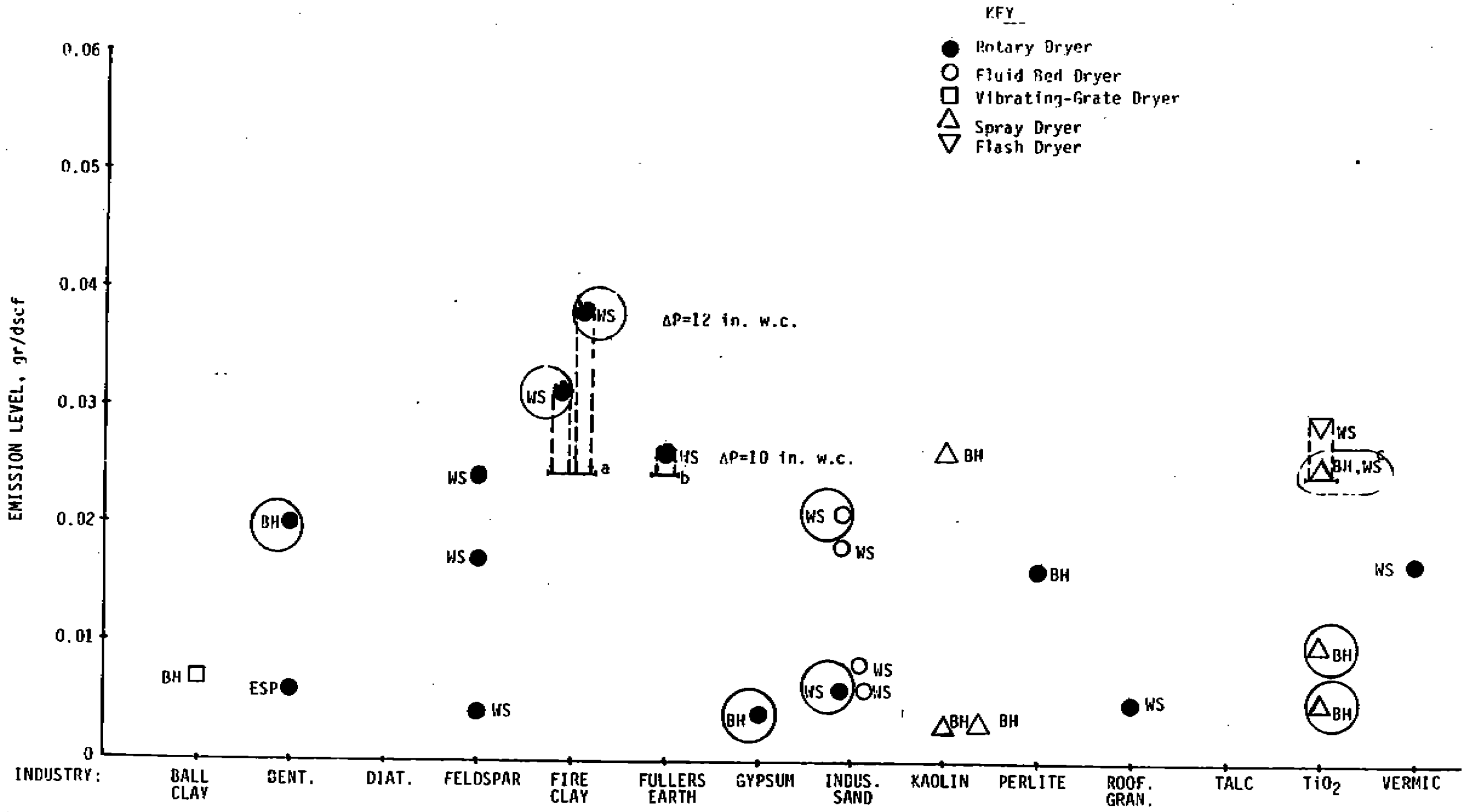
ESP = Electrostatic precipitator; WS = Wet scrubber; BH = Baghouse.

[a] Achievable emission level at ΔP= 14 in. w.c.

[b] Achievable emission level at ΔP= 11 in. w.c.

[c] Achievable emission level at ΔP = 43 in. w.c.

Figure 4-19. Controlled particulate emission data for dryers.[135,136,138-140,149-164]



(EPA-conducted tests are circled. Operating parameters for control devices are presented in Table 4-6.)

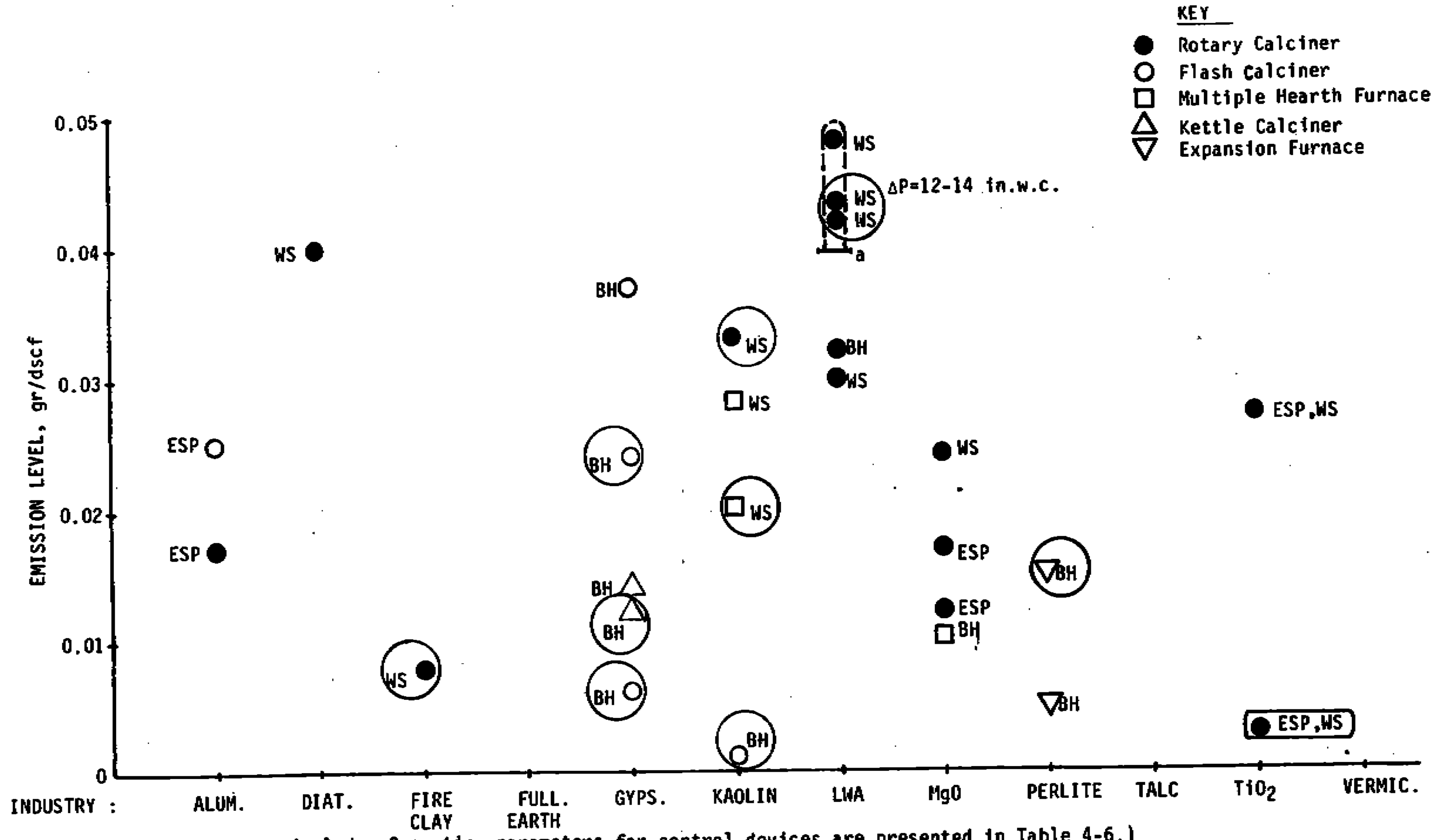
ESP = Electrostatic precipitator; WS = Wet scrubber; BH = Baghouse.

[a] Achievable emission level at ΔP= 14in. w.c.

[b] Achievable emission level at ΔP= 11in. w.c.

[c] Achievable emission level at ΔP = 43 in. w.c.

Figure 4-19. Controlled particulate emission data for dryers.[135,136,138-140,149-164]



(EPA-conducted tests are circled. Operating parameters for control devices are presented in Table 4-6.)
ESP = Electrostatic precipitator; WS = Wet scrubber; BH = Baghouse.

[a] Achievable emission level at ΔP=23 in. w.c.

Figure 4-20. Controlled particulate emission test data for calciners.[137,138,141-148,158,165-175]

TABLE 4-7. EPA-APPROVED COMPLIANCE TEST DATA FOR DRYERS[149-164]

Industry	Plant code	Process unit	Percent of design capacity	Fuel	Control device	Particulate emissions g/dscm (gr/dscf)
1. Alumina		No dryers used.				
2. Ball clay	B1	Vibrating-grate dryer	81	Natural gas	Baghouse A/C = 4.5:1[a]	0.016 (0.007)
3. Bentonite	C3	Rotary dryer	96	Pulverized coal	ESP SCA = 904[b]	0.014 (0.006)
4. Diatomite		No EPA-approved compliance data on dryers.				
5. Feldspar	E1	Rotary dryer	90	No. 2 oil	Wet scrubber ΔP = 10. in. w.c.	0.055 (0.024)
	E2	Rotary dryer	100	No. 2 oil	Wet scrubber ΔP = c	0.038 (0.017)
	E3	Rotary dryer	100	No. 2 oil	Wet scrubber ΔP = Not reported	0.010 (0.004)
6. Fire clay		No EPA-approved compliance data on dryers.				
7. Fuller's earth	G1	Rotary dryer	102	Natural gas	Wet scrubber ΔP = 10 in. w.c.	0.059 (0.026)
8. Gypsum		No EPA-approved compliance data on dryers.				
9. Industrial sand	I2	Fluid bed dryer	91	Propane	Wet scrubber ΔP = 3 in. w.c.	0.018 (0.008)
	I3	Fluid bed dryer	100	No. 2 oil	Wet scrubber ΔP = Not reported	0.013 (0.006)
	I4	Fluid bed dryer	103	Natural gas	Wet scrubber ΔP = Not reported	0.042 (0.018)
10. Kaolin	J2	Spray dryer	81	Natural gas	Baghouse A/C = 2.7:1	0.007 (0.003)
	J3	Spray dryer	83	Natural gas	Baghouse A/C = 3.8:1	0.060 (0.026)
	J4	Spray dryer	104	Natural gas	Baghouse A/C = 2.02:1	0.006 (0.003)
11. Lightweight aggregate		No dryers used.				
12. Magnesium compounds		No dryers used.				
13. Perlite	M2	Rotary dryers (2)	139	No. 2 oil/ reclaimed engine oil	Baghouse A/C = 2.0:1	0.037 (0.016)
14. Roofing granules	N1	Rotary dryer	100	No. 2 oil	Wet scrubber ΔP = 4.5 in. w.c.	0.012 (0.005)
15. Talc		No EPA-approved compliance data on dryers.				
16. Titanium dioxide	P3	Flash dryer	93	Natural gas	Wet scrubber ΔP = c	0.067 (0.029)
17. Vermiculite	Q1	Rotary dryer	86	No. 4 oil	Wet scrubber ΔP = 5 in. w.c.	0.038 (0.017)

[a] A/C units are ft^3/ft^2-min.
[b] SCA units are $ft^2/10^3$ ft^3-min.
[c] Confidential data.

TABLE 4-8. EPA-APPROVED COMPLIANCE TEST DATA FOR CALCINERS[137,139,165-177]

Industry	Plant code	Process unit	Percent of design capacity	Fuel	Control device	Particulate emissions g/dscm (gr/dscf)
1. Alumina	A1	Flash calciner	90	Natural gas	ESP SCA = a	0.056 (0.025)
	A2	Rotary calciner No. 1	105	No. 6 oil	ESP No. 1 SCA = 146[b]	0.078 (0.034)
		Rotary calciner No. 2	117	No. 6 oil	ESP No. 2 SCA = 147	0.036 (0.016)
		Rotary calciners Nos. 1 and 2	--	--	ESP Nos. 3 and 4 SCA = 344	0.038 (0.017)
2. Ball clay		No calciners used.				
3. Bentonite		No calciners used.				
4. Diatomite	D1	Rotary calciner/ flash dryer	89-104	Natural gas	Wet scrubber ΔP = Not reported	0.09 (0.04)
5. Feldspar		No calciners used.				
6. Fire clay		No EPA-approved compliance data on calciners.				
7. Fuller's earth		No EPA-approved compliance data on calciners.				
8. Gypsum	H1	Kettle calciner	100	Natural gas	Baghouse A/C = 2.3:1[c]	0.032 (0.014)
	H5	Flash calciner	100	No. 6 oil	Baghouse A/C = 3.2:1	0.085 (0.037)
9. Industrial sand		No calciners used.				
10. Kaolin	J2	Multiple hearth furnace	110	Natural gas	Wet scrubber ΔP = 18-21 in. w.c.	0.097 (0.028)
11. Lightweight aggregate	K3	Rotary calciner	100	Pulverized coal	Wet scrubber ΔP = 14 in. w.c.	0.172[d] (0.075)
	K3	Rotary calciner	109	Pulverized coal	Wet scrubber ΔP = 14 in. w.c.	0.109[e] (0.048)
	K4	Rotary calciner	92	No. 2 oil	Wet scrubber ΔP = Not reported	0.070 (0.031)
	K5	Rotary calciner	100	Pulverized coal	Baghouse A/C = 5:1	0.074 (0.032)
12. Magnesium compounds	L1	Multiple hearth furnace	85	No. 6 oil	Baghouse A/C = 1.38:1	0.022 (0.010)
	L2	Rotary calciner	92	Natural gas	ESP SCA = 550	0.037 (0.016)
	L3	Rotary calciner	95	No. 6 oil	Wet scrubber ΔP = 10 in. w.c.	0.050 (0.024)
	L4	Rotary calciner	101	Natural gas	ESP SCA = 1,458	0.042 (0.018)
13. Perlite	M3	Expansion furnace	100	Natural gas	Baghouse A/C = Not reported	0.012 (0.005)
14. Roofing granules		No calciners used.				
15. Talc		No EPA-approved compliance data on calciners.				
16. Titanium dioxide	P1	Rotary calciner	85	Natural gas	ESP, wet scrubber SCA = 228 ΔP = 22-30 in. w.c.	0.062 (0.027)
17. Vermiculite		No EPA-approved compliance data on calciners.				

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[a] Confidential data.
[b] SCA units are $ft^2/10^3$ acfm.
[c] A/C units are ft^3/ft^2-min.
[d] Multiclone that precedes wet scrubber was bypassed during test.
[e] Multiclone not bypassed.

TABLE 4-9. SUMMARY OF VISIBLE EMISSION DATA[135-148,168,178]

Industry	Plant code	Process unit	Control device[a]	No. of 6-min. avg.	Range of 6-min avg. opacities, %	No. of 6-min averages greater than stated, %					
						5	10	15	20	25	30
DRYERS											
Bentonite	C1	Rotary dryer	BH	86	0-8.3	7	0	0	0	0	0
Fire clay	F1	Rotary dryer	WS	100	0.4-3.5	0	0	0	0	0	0
Gypsum	H1	Rotary dryer	BH	40	0-0.4	0	0	0	0	0	0
Industrial sand	I1	Fluid bed dryer	WS	22	0-1.5	0	0	0	0	0	0
	I1	Rotary dryer	WS	89	0-0.6	0	0	0	0	0	0
Titanium dioxide	P1	Spray dryer	WS	60	1.5-19.4	37	20	8	0	0	0
	P2	Spray dryer	BH	64	0-0.8	0	0	0	0	0	0
CALCINERS											
Alumina	A1	Flash calciner	ESP	3	5.0-6.7	2	0	0	0	0	0
Fire clay	F2	Rotary calciner	WS	70	all 0%	0	0	0	0	0	0
	F3	Rotary calciner	WS	101	all 0%	0	0	0	0	0	0
Gypsum	H1	Kettle calciner	BH	40	0-0.6	0	0	0	0	0	0
	H2	Flash calciner	BH	70	0-2.3	0	0	0	0	0	0
	H4	Flash calciner	BH	83	all 0%	0	0	0	0	0	0
	H5	Flash calciner	BH	9	0-0.6	0	0	0	0	0	0
Kaolin	J1	Herreshoff furnace	WS	73	all 0%	0	0	0	0	0	0
	J1	Flash calciner	BH	61	0-0.6	0	0	0	0	0	0
Lightweight aggregate	K1	Rotary calciner	WS	41	0-3.8	0	0	0	0	0	0
	K6	Rotary calciner	WS	21	0-10.0	10	0	0	0	0	0
Perlite	M1	Expansion furnace	BH	60	0-0.8	0	0	0	0	0	0
Titanium dioxide	P1	Rotary calciner	WS	30	0-0.4	0	0	0	0	0	0

[a] BH = baghouse; WS = wet scrubber; ESP = electrostatic precipitator.

TABLE 4-10. SUMMARY OF PARTICLE SIZE DISTRIBUTION TESTS AT CONTROL DEVICE OUTLET[135,137-139,144-148]

Industry	Plant code	Process unit	Control device	Percent less than		
				1 μm	2.5 μm	10 μm
Dryers						
Bentonite	C1	Rotary dryer	Baghouse	2	12	74
Gypsum	H1	Rotary dryer[a]	Baghouse	43	47	N/A[b]
Industrial sand	I1	Rotary dryer	Wet scrubber	8	47	66
Titanium dioxide	P1	Spray dryer No. 1	Baghouse	38	57	89
Titanium dioxide	P2	Spray dryer	Baghouse	32	65	95
Calciners						
Fire clay	F2	Rotary calciner	Venturi scrubber	31	46	70
Gypsum	H4	Flash calciner	Baghouse	39	65	92
Kaolin	J1	Flash calciner	Baghouse	27	55	88
Lightweight aggregate[c]	K1	Rotary calciner	Wet scrubber	11	14	17
Lightweight aggregate[d]	K6	Rotary calciner	Wet scrubber	33	56	84
Perlite	M1	Expansion furnace	Baghouse	2	13	93[e]

[a] Processing ore that is 100 percent minus 5 cm (2 inches).
[b] N/A = Not available.
[c] Shale.
[d] Clay.
[e] Results of one run only.

tested. Particle sizing was not feasible at all of the outlet locations because of excessive moisture in the exhaust gas stream.

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5. MODIFICATION AND RECONSTRUCTION

Standards of performance apply to facilities for which construction, modification, or reconstruction commenced (as defined under 40 CFR 60.2) after the date of proposal of the standards. Such facilities are termed "affected facilities." Standards of performance are not applicable to facilities for which construction, modification, or reconstruction commenced on or before the date of proposal of the standards. An existing facility may become an affected facility and therefore be subject to the standards if the facility undergoes modification or reconstruction.

Modification and reconstruction are defined under 40 CFR 60.14 and 60.15, respectively. These general provisions are summarized in Sections 5.1 and 5.2. The applicability of these provisions to dryers and calciners in the mineral industries is also discussed. However, the enforcement division of the appropriate EPA regional office will make the final determination as to whether a source is modified or reconstructed and, as a result, becomes an affected facility.

5.1 MODIFICATION

5.1.1 Provisions for Modification

With certain exceptions, any physical or operational change to an existing facility that would increase the emission rate to the atmosphere from that facility of any pollutant covered by the standard would be considered a modification within the meaning of Section 111 of the Clean Air Act. The key to determining if a change is considered a modification is whether the total emission rate to the atmosphere from the facility increased as a result of the change. If an existing facility is determined to be modified, all of the emission sources of that facility are subject to the standards of performance applicable to the pollutant for which the emission rate increased. A modification to one existing facility at a plant will not cause other existing facilities at the same plant to become subject to the standards.

Under the regulations, certain physical or operational changes are not considered to be modifications even though emissions may increase as a result of the change (see 40 CFR 60.14(e)). For the most part, these exceptions are allowed because they account for fluctuations in emissions that do not cause a facility to become a significant new source of air pollution. The exceptions as allowed under 40 CFR 60.14(e) are as follows:

1. Routine maintenance, repair, and replacement (e.g., lubrication of mechanical equipment; replacement of pumps, motors, and piping; cleaning of pipes and ductwork; replacement or refurbishing of components subject to high abrasion and impact);
2. An increase in the production rate, if the increase can be accomplished without a capital expenditure (as defined in 40 CFR 60.2);
3. An increase in the hours of operation;
4. Use of an alternative fuel or raw material if, prior to proposal of the standard, the existing facility was designed to accommodate that alternate fuel or raw material;
5. The addition or use of any system or device whose primary function is to reduce air pollutants, except when an emission control system is replaced by a system determined by EPA to be less environmentally beneficial; and
6. Relocation or change in ownership of the existing facility.

An owner or operator of an existing facility who is planning a physical or operational change that may increase the emission rate of a pollutant to which a standard applies shall notify the appropriate EPA regional office 60 days prior to the change, as specified in 40 CFR 60.7(a)(4).

5.1.2 Applicability to Dryers and Calciners

The impact of the modification provision on existing dryer and calciner facilities at mineral processing plants should be minimal. Repairs to dryer and calciner components subject to high temperatures, abrasion, and impact (e.g., end seals, flights, refractory lining) are routinely performed and, thus, are not generally considered modifications.

Normal maintenance procedures are similar for most dryers. Typical maintenance includes replacing refractory brick or patching with castable refractory once every 2 to 4 years; repairing or replacing dryer lifters once a year; repairing trunnions and trunnion bearings once every 2 to 5 years; repairing or replacing the dryer liner once a year; rebricking the firebox once every 2 to 8 years; replacing the ring and pinion gears once every 2 to 5 years; replacing the insulation once every 4 years; and lubricating and greasing moving parts daily. Other maintenance performed as needed includes replacing belts, sheaves, bearings, and shafts; repairing or replacing the burner; and replacing gaskets and flexible connectors. For spray dryers, additional maintenance includes repairing the spray feeding system.

Normal maintenance procedures for most calciners include rebricking or replacing the castable refractory once every 2 to 10 years; repairing kiln trunnions and trunnion bearings every 5 to 10 years; replacing kiln seals once a year; repairing the shell once every 6 months; and lubricating and oiling moving parts daily. Maintenance performed as needed includes replacing kiln flights or spillers; repairing or replacing motor bearings; repairing kiln drives, feeders, conveyors, and discharge equipment; and replacing control valves. For flash calciners, additional maintenance includes repairing or replacing fluid bed gas distribution plates. Additional maintenance items for multiple hearth furnaces include replacing furnace arms and teeth once a year and repairing or replacing the upper and lower hearths once every 5 to 8 years. Additional maintenance for expansion furnaces includes repairing or replacing the expansion tube once every 3 years.

When expansions at existing plants take place, usually a completely new dryer or calciner is added. Such an increase in production would not be considered a modification but rather a new source. Drying and calcining operations usually operate below 100 percent of capacity and are capable of handling increased throughput without additional equipment. If a raw material or fuel change occurs for which the dryer or calciner was originally designed, the change is not considered a modification. However, if a conversion is made, allowing a unit to burn a fuel or to process a new material for which it was not originally designed, and an increase in emissions occurs because of this change, the change is considered to be a modification. Those changes that result in an increased production rate above the original design production rate are considered a modification.

Should an applicable enforcement agency determine that a modification has taken place, there are no known constraints that would preclude the use of any control devices presently used to control particulate emissions.

5.2 RECONSTRUCTION

5.2.1 Provisions for Reconstruction

An existing facility may become subject to an NSPS if it is reconstructed. Reconstruction is defined as the replacement of the components of an existing facility to the extent that (1) the fixed capital cost of the new components exceeds 50 percent of the fixed capital cost required to construct a comparable new facility and (2) it is technically and economically feasible for the facility to meet the applicable standards. Because EPA considers reconstructed facilities to constitute new construction rather than modification, reconstruction determinations are made irrespective of changes in emission rates.

The purpose of the reconstruction provisions is to discourage the perpetuation of an existing facility for the sole purpose of circumventing a standard that is applicable to new facilities. Without such a provision, all but certain components, such as frames, housings, and support structures, of the existing facility could be replaced without causing the facility to be considered a "new" facility subject to NSPS. If the facility is determined to be reconstructed, it must comply with all of the provisions of the standards of performance applicable to that facility.

If an owner or operator of an existing facility is planning to replace components and the fixed capital cost of the new components exceeds 50 percent of the fixed capital cost of a comparable new facility, the owner or operator must notify the appropriate EPA regional office 60 days before the construction of the replacement commences, as required under 40 CFR 60.15(d).

5.2.2 Applicability to Dryers and Calciners

Replacement or refurbishing of equipment parts subject to high abrasion and impact are performed on a regular basis and could be considered routine maintenance rather than reconstruction. However, the cumulative cost of these repairs to any one piece of equipment over a period of time could exceed 50 percent of the fixed capital cost of entirely new equipment. Final determination regarding reconstruction considerations would be made by the applicable enforcement agency on a case-by-case basis.

6. MODEL FACILITIES AND REGULATORY ALTERNATIVES

The regulatory alternatives discussed in this chapter are based on the particulate matter emission control technologies presented in Chapter 4. To evaluate the environmental, energy, and economic impacts of these regulatory alternatives, model facilities were developed for dryers and calciners in the 17 mineral industries.[1] Tables 6-1 and 6-2 present the various dryers and calciners, respectively, used in each industry. Table 6-3 presents the model facility sizes that have been developed for process units in each industry. Tables 6-4a and 6-4b summarize the levels of control in metric and English units, respectively, and recommended control devices for RA I, II, and III.

6.1 MODEL FACILITIES

As shown in Table 6-3, three model facility sizes (small, medium, and large) were developed, based on production capacity, for most of the dryer/calciner types. For some industries, however, only one model facility size was developed because the facilities are only built in one production capacity. In all cases, the typical-sized units have been identified for use in regulatory alternative development.

Tables 6-5 to 6-50 present the model facility parameters for each dryer/calciner type in each industry. These parameters are a composite of data from EPA source tests, industry responses to information requests, and plant visits. Therefore, model facilities do not represent any particular existing process unit. They represent typical facilities that may be constructed in the future.

The control device operating parameters shown in Tables 6-5 to 6-50 refer to RA II and RA III. Differences between the control device operating parameters shown for RA II and RA III occur for dryers controlled with wet scrubbers and ESP's.

6.2 REGULATORY ALTERNATIVES

The devices used to control particulate matter emissions from dryers and calciners in the mineral industries are baghouses, ESP's, and wet scrubbers (see Chapter 4). For each industry segment and dryer/calciner type, a control technology and an associated level of emission control were selected for each of two regulatory alternatives. In Table 6-4, the control levels presented under the baseline alternative (RA I) represent the weighted average emission limits determined from SIP's for typical-sized facilities in each industry.[2,3] The control devices listed in Table 6-4 under RA I are representative of the control technology necessary for plants in the mineral industries to comply with SIP requirements.

A control level of 90 mg/dscm (0.04 gr/dscf) is used for RA II for both dryers and calciners. For RA III, a control level of 57 mg/dscm (0.025 gr/dscf) is used for dryers and a control level of 90 mg/dscm (0.04 gr/dscf) is used for calciners. Control equipment parameters for each alternative have been selected based on data and information presented in Chapters 3 and 4 and from industry responses to information requests.

In many cases, the control devices used to achieve the baseline level of control for RA I could be used to achieve the RA II and RA III levels of control. In these instances, the differences among RA I, II, and III are the amount and frequency of routine maintenance performed on the control devices and, in some cases, the control equipment operating parameters (e.g., different pressure drops for wet scrubbers).

TABLE 6-1. AFFECTED FACILITIES--DRYERS USED IN EACH INDUSTRY[a]

Industry	Rotary (direct)	Rotary (indirect)	Fluid bed	Vibrating grate	Flash	Spray
Ball clay		x		x (indirect)		
Bentonite	x		x			
Diatomite	x				x	
Feldspar	x		x			
Fire clay	x			x		
Fuller's earth	x		x			
Gypsum	x					
Industrial sand	x		x			
Kaolin	x					x
Perlite	x					
Roofing granules	x		x			
Talc	x				x	
Titanium dioxide	x	x	x		x	x
Vermiculite	x		x			

[a] Dryers are not used in the alumina, lightweight aggregate, or magnesium compounds industries.

TABLE 6-2. AFFECTED FACILITIES--CALCINERS USED IN EACH INDUSTRY[a]

Industry	Rotary	Flash	Multiple hearth furnace	Kettle	Expansion furnace
Alumina	x	x			
Diatomite	x				
Fire clay	x				
Fuller's earth	x				
Gypsum		x		x	
Kaolin	x	x	x		
Lightweight aggregate	x				
Magnesium compounds	x		x		
Perlite					x
Talc	x				
Titanium dioxide	x				
Vermiculite					x

[a] Calciners are not used in the ball clay, bentonite, feldspar, industrial sand, or roofing granules industries.

TABLE 6-3. MODEL FACILITY SIZES FOR PROCESS UNITS IN THE MINERAL INDUSTRIES

Industry/facility	Production capacity, Mg/h (tons/h)		
	Small	Medium	Large
<u>Alumina</u>			
Flash calciner			a*
Rotary calciner	23 (25)*	32 (35)	45 (50)
<u>Ball Clay</u>			
Rotary dryer (indirect)		a*	
Vibrating-grate dryer (indirect)		11 (12)*	23 (25)
<u>Bentonite</u>			
Fluid bed dryer		40 (45)*	
Rotary dryer	18 (20)	32 (35)*	54 (60)
<u>Diatomite</u>			
Flash dryer	4 (5)*		11 (12)
Rotary dryer		9 (10)*	
Rotary calciner	4 (5)		11 (12)*
<u>Feldspar</u>			
Fluid bed dryer		a*	a*
Rotary dryer	a	18 (20)	27 (30)*
<u>Fire Clay</u>			
Rotary dryer	9 (10)	27 (30)*	45 (50)
Vibrating-grate dryer		23 (25)*	
Rotary calciner	9 (10)	18 (20)*	
<u>Fuller's Earth</u>			
Fluid bed dryer			a*
Rotary dryer	4 (5)*	14 (15)	27 (30)
Rotary calciner	4 (5)	23 (25)*	40 (45)
<u>Gypsum</u>			
Rotary dryer		45 (50)*	73 (80)
Flash calciner		9 (10)*	
Kettle calciner		11 (12)*	
<u>Industrial Sand</u>			
Fluid bed dryer	45 (50)	90 (100)*	180 (200)
Rotary dryer	45 (50)*	90 (100)	135 (150)
<u>Kaolin</u>			
Rotary dryer		18 (20)*	
Spray dryer		14 (15)*	27 (30)*
Flash calciner	a*		
Multiple hearth furnace	4 (5)*		
Rotary calciner	5 (6)*		

(continued)

TABLE 6-3. (continued)

Industry/facility	Production capacity, Mg/h (tons/h) Small	Medium	Large
Lightweight Aggregate			
Rotary calciner	18 (20)	27 (30)*	36 (40)
Magnesium Compounds			
Multiple hearth furnace			
$Mg(OH)_2$ feed	2 (2)	a	a*
Magnesite feed		a*	a
Rotary calciner			
$Mg(OH)_2$ feed	4 (5)*	9 (10)	
Magnesite feed			a*
Perlite			
Rotary dryer		23 (25)*	a
Expansion furnace	1 (1)*		
Roofing Granules			
Fluid bed dryer		36 (40)*	
Rotary dryer	14 (15)*	54 (60)*	200 (220)
Talc			
Flash dryer	a*		
Rotary dryer		9 (10)*	18 (20)
Rotary calciner	4 (5)*		
Titanium Dioxide			
Flash dryer			23 (25)*
Fluid bed dryer			a*
Rotary dryer (direct)	2 (2)	6 (7)	a*
Rotary dryer (indirect)		11 (12)*	
Spray dryer	a	a*	a
Rotary calciner	a*	a*	
Vermiculite			
Fluid bed dryer			54 (60)*
Rotary dryer		9 (10)*	18 (20)
Expansion furnace	1 (1)*		

[a] = Confidential information (see Reference 4).

* = Typical size facility.

TABLE 6-4a. CONTROL LEVELS AND ASSOCIATED CONTROL EQUIPMENT FOR REGULATORY ALTERNATIVES (METRIC UNITS)

	Alternative I (baseline)		Alternative II		Alternative III	
Industry/facility	mg/dscm^a	Control device^b	mg/dscm^a	Control device^b	mg/dscm^a	Control device^b
<u>Alumina</u>						
Flash calciner	340	ESP (SCA = 0.59)^c	90	ESP (SCA = Conf.)^d	90	ESP (SCA = Conf.)
Rotary calciner	440	ESP (SCA = 0.92)	90	ESP (SCA = 1.25)	90	ESP (SCA = 1.25)
<u>Ball Clay</u>						
Rotary dryer (indirect)	340^e	BH	90	BH^f	57	BH^f
Vibrating-grate dryer (indirect)	300	BH	90	BH	57	BH
<u>Bentonite</u>						
Fluid bed dryer	230	BH, ESP (SCA = 0.57)	90	BH, ESP (SCA = 1.0)	57	BH, ESP (SCA = 1.15)
Rotary dryer	210	BH	90	BH	57	BH
<u>Diatomite</u>						
Flash dryer	180	WS (ΔP = 1.5 kPa)^g	90	WS (ΔP = 3.5 kPa)	57	WS (ΔP = 6.2 kPa)
Rotary dryer	320	BH	90	BH	57	BH
Rotary calciner	230	BH, WS (ΔP = 2.0 kPa)	90	BH, WS (ΔP = 5.7 kPa)	90	BH, WS (ΔP = 5.7 kPa)
<u>Feldspar</u>						
Fluid bed dryer	340^e	BH, WS (ΔP = 2.5 kPa)	90	BH	57	BH
Rotary dryer	600	WS (ΔP = 0.8 kPa)	90	WS (ΔP = 1.0 kPa)	57	WS (ΔP = 2.5 kPa)
<u>Fire Clay</u>						
Rotary dryer	340^e	BH, WS (ΔP = 0.8 kPa)	90	BH, WS (ΔP = 2.5 kPa)	57	BH, WS (ΔP = 3.5 kPa)
Vibrating-grate dryer	160	WS (ΔP = 0.8 kPa)	90	WS (ΔP = 0.8 kPa)	57	WS (ΔP = 0.8 kPa)
Rotary calciner	390	WS (ΔP = 1.5 kPa)	90	WS (ΔP = 4.7 kPa)	90	WS (ΔP = 4.7 kPa)
<u>Fuller's Earth</u>						
Fluid bed dryer	160	BH	90	BH	57	BH
Rotary dryer	230	BH, WS (ΔP = 1.2 kPa)	90	BH, WS (ΔP = 2.0 kPa)	57	BH, WS (ΔP = 2.7 kPa)
Rotary calciner	340^e	BH, WS (ΔP = 2.5 kPa)	90	BH	90	BH

(continued)

TABLE 6-4a. (continued)

Industry/facility	Alternative I (baseline)		Alternative II		Alternative III	
	mg/dscm[a]	Control device[b]	mg/dscm[a]	Control device[b]	mg/dscm[a]	Control device[b]
Gypsum						
Rotary dryer	340[e]	BH	90	BH	57	BH
Flash calciner	340[e]	BH	90	BH	90	BH
Kettle calciner	340[e]	BH	90	BH	90	BH
Industrial Sand						
Fluid bed dryer	480	WS (ΔP = 0.8 kPa)	90	WS (ΔP = 0.8 kPa)	57	WS (ΔP = 0.8 kPa)
Rotary dryer	890	WS (ΔP = 0.8 kPa)	90	WS (ΔP = 0.8 kPa)	57	WS (ΔP = 0.8 kPa)
Kaolin						
Rotary dryer	340[e]	BH	90	BH	57	BH
Spray dryer	370	BH	90	BH	57	BH
Flash calciner	140	BH	90	BH	90	BH
Multiple hearth furnace	280	WS (ΔP = 2.0 kPa)	90	WS (ΔP = 5.7 kPa)	90	WS (ΔP = 5.7 kPa)
Rotary calciner	230	BH, WS (ΔP = 2.5 kPa)	90	BH, WS (ΔP = 6.0 kPa)	90	BH, WS (ΔP = 6.0 kPa)
Lightweight Aggregate						
Rotary calciner	210	BH, WS (ΔP = 2.5 kPa)	90	BH, WS (ΔP = 5.7 kPa)	90	BH, WS (ΔP = 5.7 kPa)
Magnesium Compounds						
Multiple hearth furnace						
$Mg(OH)_2$ feed	370	ESP (SCA = 0.81)	90	ESP (SCA = 1.30)	90	ESP (SCA = 1.30)
Magnesite feed	280	BH	90	BH	90	BH
Rotary calciner						
$Mg(OH)_2$ feed	320	ESP (SCA = 0.65)	90	ESP (SCA = 1.0)	90	ESP (SCA = 1.0)
Magnesite feed	300	BH	90	BH	90	BH
Perlite						
Rotary dryer	110	BH	90	BH	57	BH
Expansion furnace	300	BH	90	BH	90	BH
Roofing Granules						
Fluid bed dryer	320	WS (ΔP = 0.8 kPa)	90	WS (ΔP = 0.8 kPa)	57	WS (ΔP = 0.8 kPa)
Rotary dryer	330	WS (ΔP = 0.8 kPa)	90	WS (ΔP = 0.8 kPa)	57	WS (ΔP = 0.8 kPa)

(continued)

TABLE 6-4a. (continued)

Industry/facility	Alternative I (baseline)		Alternative II		Alternative III	
	mg/dscm[a]	Control device[b]	mg/dscm[a]	Control device[b]	mg/dscm[a]	Control device[b]
Talc						
Flash dryer	480	BH	90	BH	57	BH
Rotary dryer	340[e]	BH	90	BH	57	BH
Rotary calciner	440	BH	90	BH	90	BH
Titanium Dioxide						
Flash dryer	250	WS (ΔP = 5.0 kPa)	90	WS (ΔP = 8.5 kPa)	57	WS (ΔP = 10.7 kPa)
Fluid bed dryer	460	BH, WS (ΔP = 2.5 kPa)	90	BH, WS (ΔP = 8.5 kPa)	57	BH, WS (ΔP = 10.7 kPa)
Rotary dryer (direct)	340[e]	BH	90	BH	57	BH
Rotary dryer (indirect)	1,760	WS (ΔP = 0.8 kPa)	90	WS (ΔP = 2.5 kPa)	57	WS (ΔP = 4.2 kPa)
Spray dryer	280	BH	90	BH	57	BH
Rotary calciner	90	WS (ΔP = Conf.)	90	WS (ΔP = Conf.)	90	WS (ΔP = Conf.)
Vermiculite						
Fluid bed dryer	530	BH	90	BH	57	BH
Rotary dryer	530	WS (ΔP = 0.8 kPa)	90	WS (ΔP = 0.8 kPa)	57	WS (ΔP = 1.0 kPa)
Expansion furnace	390	BH	90	BH	90	BH

[a] Equivalent allowable emission level for a typical facility based on process weight rate equations and model facility operating parameters.

[b] Control devices: ESP = electrostatic precipitator; BH = baghouse; WS = wet scrubber.

[c] SCA = specific collection area, m^2 per m^3/min.

[d] Conf. = Confidential information (see Reference 4).

[e] These industries typically use baghouses for control and the State opacity limits of 20 percent are more stringent than the corresponding SIP mass emission limits. Therefore, the baseline emission limit selected for evaluation is based on an estimated grain loading at 20 percent opacity, i.e., 340 mg/dscm.

[f] Baghouses used for control at the Alternative II and III levels have a higher frequency of maintenance than the baghouses used for control at the Alternative I level.

[g] ΔP = Pressure drop across scrubber system, kilopascals (kPa).

TABLE 6-4b. CONTROL LEVELS AND ASSOCIATED CONTROL EQUIPMENT FOR REGULATORY ALTERNATIVES (English Units)

	Alternative I (baseline)		Alternative II		Alternative III	
Industry/facility	gr/dscf[a]	Control device[b]	gr/dscf[a]	Control device[b]	gr/dscf[a]	Control device[b]
Alumina						
Flash calciner	0.15	ESP (SCA = 180)[c]	0.04	ESP (SCA = Conf.)[d]	0.04	ESP (SCA = Conf.)
Rotary calciner	0.19	ESP (SCA = 280)	0.04	ESP (SCA = 380)	0.04	ESP (SCA = 380)
Ball Clay						
Rotary dryer (indirect)	0.15[e]	BH	0.04	BH[f]	0.025	BH[f]
Vibrating-grate dryer (indirect)	0.13	BH	0.04	BH	0.025	BH
Bentonite						
Fluid bed dryer	0.10	BH, ESP (SCA = 174)	0.04	BH, ESP (SCA = 300)	0.025	BH, ESP (SCA = 350)
Rotary dryer	0.09	BH	0.04	BH	0.025	BH
Diatomite						
Flash dryer	0.08	WS (ΔP = 6 in.)[g]	0.04	WS (ΔP = 14 in.)	0.025	WS (ΔP = 25 in.)
Rotary dryer	0.14	BH	0.04	BH	0.025	BH
Rotary calciner	0.10	BH, WS (ΔP = 8 in.)	0.04	BH, WS (ΔP = 23 in.)	0.04	BH, WS (ΔP = 23 in.)
Feldspar						
Fluid bed dryer	0.15[e]	BH, WS (ΔP = 10 in.)	0.04	BH	0.025	BH
Rotary dryer	0.26	WS (ΔP = 3 in.)	0.04	WS (ΔP = 4 in.)	0.025	WS (ΔP = 10 in.)
Fire Clay						
Rotary dryer	0.15[e]	BH, WS (ΔP = 3 in.)	0.04	BH, WS (ΔP = 10 in.)	0.025	BH, WS (ΔP = 14 in.)
Vibrating-grate dryer	0.07	WS (ΔP = 3 in.)	0.04	WS (ΔP = 3 in.)	0.025	WS (ΔP = 3 in.)
Rotary calciner	0.17	WS (ΔP = 6 in.)	0.04	WS (ΔP = 19 in.)	0.04	WS (ΔP = 19 in.)
Fuller's Earth						
Fluid bed dryer	0.07	BH	0.04	BH	0.025	BH
Rotary dryer	0.10	BH, WS (ΔP = 5 in.)	0.04	BH, WS (ΔP = 8 in.)	0.025	BH, WS (ΔP = 11 in.)
Rotary calciner	0.15[e]	BH, WS (ΔP = 10 in.)	0.04	BH	0.04	BH

(continued)

TABLE 6-4b. (continued)

Industry/facility	Alternative I (baseline)		Alternative II		Alternative III	
	gr/dscf[a]	Control device[b]	gr/dscf[a]	Control device[b]	gr/dscf[a]	Control device[b]
Gypsum						
Rotary dryer	0.15[e]	BH	0.04	BH	0.025	BH
Flash calciner	0.15[e]	BH	0.04	BH	0.04	BH
Kettle calciner	0.15[e]	BH	0.04	BH	0.04	BH
Industrial Sand						
Fluid bed dryer	0.21	WS (ΔP = 3 in.)	0.04	WS (ΔP = 3 in.)	0.025	WS (ΔP = 3 in.)
Rotary dryer	0.39	WS (ΔP = 3 in.)	0.04	WS (ΔP = 3 in.)	0.025	WS (ΔP = 3 in.)
Kaolin						
Rotary dryer	0.15[e]	BH	0.04	BH	0.025	BH
Spray dryer	0.16	BH	0.04	BH	0.025	BH
Flash calciner	0.06	BH	0.04	BH	0.04	BH
Multiple hearth furnace	0.12	WS (ΔP = 8 in.)	0.04	WS (ΔP = 23 in.)	0.04	WS (ΔP = 23 in.)
Rotary calciner	0.10	BH, WS (ΔP = 10 in.)	0.04	BH, WS· (ΔP = 24 in.)	0.04	BH, WS (ΔP = 24 in.)
Lightweight Aggregate						
Rotary calciner	0.09	BH, WS (ΔP = 10 in.)	0.04	BH, WS (ΔP = 23 in.)	0.04	BH, WS (ΔP = 23 in.)
Magnesium Compounds						
Multiple hearth furnace						
$Mg(OH)_2$ feed	0.16	ESP (SCA = 250)	0.04	ESP (SCA = 400)	0.04	ESP (SCA = 400)
Magnesite feed	0.12	BH	0.04	BH	0.04	BH
Rotary calciner						
$Mg(OH)_2$ feed	0.14	ESP (SCA = 200)	0.04	ESP (SCA = 300)	0.04	ESP (SCA = 300)
Magnesite feed	0.13	BH	0.04	BH	0.04	BH
Perlite						
Rotary dryer	0.05	BH	0.04	BH	0.025	BH
Expansion furnace	0.13	BH	0.04	BH	0.04	BH
Roofing Granules						
Fluid bed dryer	0.14	WS (ΔP = 3 in.)	0.04	WS (ΔP = 3 in.)	0.025	WS (ΔP = 3 in.)
Rotary dryer	0.10	WS (ΔP = 3 in.)	0.04	WS (ΔP = 3 in.)	0.025	WS (ΔP = 3 in.)

(continued)

TABLE 6-4b. (continued)

Industry/facility	Alternative I (baseline)		Alternative II		Alternative III	
	gr/dscf[a]	Control device[b]	gr/dscf[a]	Control device[b]	gr/dscf[a]	Control device[b]
Talc						
Flash dryer	0.21	BH	0.04	BH	0.025	BH
Rotary dryer	0.15[e]	BH	0.04	BH	0.025	BH
Rotary calciner	0.19	BH	0.04	BH	0.04	BH
Titanium Dioxide						
Flash dryer	0.11	WS (ΔP = 20 in.)	0.04	WS (ΔP = 34 in.)	0.025	WS (ΔP = 43 in.)
Fluid bed dryer	0.20	BH, WS (ΔP = 10 in.)	0.04	BH, WS (ΔP = 34 in.)	0.025	BH, WS (ΔP = 43 in.)
Rotary dryer (direct)	0.15[e]	BH	0.04	BH	0.025	BH
Rotary dryer (indirect)	0.77	WS (ΔP = 3 in.)	0.04	WS (ΔP = 10 in.)	0.025	WS (ΔP = 17 in.)
Spray dryer	0.12	BH	0.04	BH	0.025	BH
Rotary calciner	0.04	WS (ΔP = Conf.)	0.04	WS (ΔP = Conf.)	0.04	WS (ΔP = Conf.)
Vermiculite						
Fluid bed dryer	0.23	BH	0.04	BH	0.025	BH
Rotary dryer	0.23	WS (ΔP = 3 in.)	0.04	WS (ΔP = 3 in.)	0.025	WS (ΔP = 4 in.)
Expansion furnace	0.17	BH	0.04	BH	0.04	BH

[a] Equivalent allowable emission level for a typical facility based on process weight rate equations and model facility operating parameters.

[b] Control devices: ESP = electrostatic precipitator; BH = baghouse; WS = wet scrubber.

[c] SCA = specific collection area, $ft^2/10^3$ acfm.

[d] Conf. = Confidential information (see Reference 4).

[e] These industries typically use baghouses for control and the State opacity limits of 20 percent are more stringent than the corresponding SIP mass emission limits. Therefore, the baseline emission limit selected for evaluation is based on an estimated grain loading at 20 percent opacity, i.e., 0.15 gr/dscf.

[f] Baghouses used for control at the Alternative II and III levels have a higher frequency of maintenance than the baghouses used for control at the Alternative I level.

[g] ΔP = Pressure drop across scrubber system, inches water column (in. w.c.).

TABLE 6-5. MODEL FACILITY PARAMETERS FOR FLASH CALCINER--ALUMINA INDUSTRY

Parameter/Facility size	Large
PROCESS INFORMATION	
Production	
Design, Mg/h	Confidential[4]
(tons/h)	
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	Confidential[4]
Actual, h/yr	Confidential[4]
Feed material	Alumina trihydrate
Product	Alumina
Fuel type	Natural gas
Fuel usage, $x10^9$ Joules/Mg	Confidential[4]
($x10^6$ Btu/ton)	
Maximum operating temperature, °C	Confidential[4]
(°F)	
Retention time, min	<1
CONTROL DEVICE INFORMATION	
Control device inlet	
Gas flow rate, m^3/min	Confidential[4]
(acfm)	
Gas temperature, °C	Confidential[4]
(°F)	
Gas moisture, %	Confidential[4]
ESP[a]	
Specific collection area[b]	Confidential[4]
ΔP, kPa	Confidential[4]
(in. w.c.)	
STACK PARAMETERS	
Height, m	37
(ft)	(120)
Diameter, m	1.9
(ft)	(6.2)
Temperature, °C	150
(°F)	(300)
Moisture, %	45
Gas flow rate, m^3/min	3,100
(acfm)	(108,800)
Gas velocity, m/s	18
(ft/s)	(60)

[a] Assumed power requirement for ESP is 0.14 watts/m^2 (1.5 watts/ft^2).
[b] m^2 per m^3/min (ft^2/1,000 acfm).

TABLE 6-6. MODEL FACILITY PARAMETERS FOR ROTARY CALCINER--ALUMINA INDUSTRY

Parameter/Facility size	Small	Medium	Large
PROCESS INFORMATION			
Production			
Design, Mg/h	23	32	45
(tons/h)	(25)	(35)	(50)
Hours of operation			
Design, h/d	←	24	→
Design, h/yr	←	8,000	→
Actual, h/d	←	24	→
Actual, h/yr	←	8,000	→
Feed material	←	Alumina trihydrate	→
Product	←	Alumina	→
Fuel type	←	Natural gas, No. 6 fuel oil	→
Fuel usage, $x10^9$ Joules/Mg	←	5.1	→
($x10^6$ Btu/ton)	←	(4.4)	→
Maximum operating temperature, °C	←	1430	→
(°F)	←	(2600)	→
Retention time, min	←	120	→
CONTROL DEVICE INFORMATION			
Control device inlet			
Gas flow rate, m^3/min	2,800	3,400	4,200
(acfm)	(98,000)	(120,000)	(150,000)
Gas temperature, °C	←	330	→
(°F)	←	(620)	→
Gas moisture, %	←	42	→
ESP[a]			
Specific collection area[b]	←	1.25	→
		(380)	
ΔP, kPa	←	0.12	→
(in. w.c.)	←	(0.5)	→
STACK PARAMETERS			
Height, m	21	24	27
(ft)	(70)	(80)	(90)
Diameter, m	1.8	2.0	2.2
(ft)	(5.8)	(6.4)	(7.1)
Temperature, °C	←	290	→
(°F)	←	(560)	→
Moisture, %	←	42	→
Gas flow rate, m^3/min	2,600	3,200	4,000
(acfm)	(92,600)	(113,300)	(141,700)
Gas velocity, m/s	←	18	→
(ft/s)	←	(60)	→

[a] Assumed power requirement for ESP is 0.14 watts/m^2 (1.5 watts/ft^2).
[b] m^2 per m^3/min (ft^2/1,000 acfm).

TABLE 6-7. MODEL FACILITY PARAMETERS FOR ROTARY DRYER (INDIRECT)--BALL CLAY INDUSTRY

Parameter/Facility size	Medium
PROCESS INFORMATION	
Production	
Design, Mg/h (tons/h)	Confidential[4]
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	Confidential[4]
Actual, h/yr	Confidential[4]
Feed material	Ball clay
Product	Ball clay
Fuel type	Confidential[4]
Fuel usage, $\times 10^9$ Joules/Mg ($\times 10^6$ Btu/ton)	Confidential[4]
Maximum operating temperature, °C (°F)	Confidential[4]
Retention time, min	Confidential[4]
CONTROL DEVICE INFORMATION	
Control device inlet	
Gas flow rate, m^3/min	480
(acfm)	(17,000)
Gas temperature, °C	120
(°F)	(250)
Gas moisture, %	28
aghouse	
Cloth type	Nomex
Air-to-cloth ratio[a]	0.9:1 (3:1)
ΔP, kPa	1.1
(in. w.c.)	(4.5)
ACK PARAMETERS	
eight, m	18
(ft)	(60)
iameter, m	0.7
(ft)	(2.4)
perature, °C	110
(°F)	(225)
isture, %	28
flow rate, m^3/min	460
(acfm)	(16,400)
velocity, m/s	18
(ft/s)	(60)

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in per m^2 (ft^3/min per ft^2).

TABLE 6-8. MODEL FACILITY PARAMETERS FOR VIBRATING-GRATE DRYER (INDIRECT)--BALL CLAY INDUSTRY

Parameter/Facility size	Medium	Large
PROCESS INFORMATION		
Production		
Design, Mg/h	11	23
(tons/h)	(12)	(25)
Hours of operation		
Design, h/d	24	24
Design, h/yr	8,000	8,000
Actual, h/d	16	16
Actual, h/yr	4,000	4,000
Feed material	Ball clay	Ball clay
Product	Ball clay	Ball clay
Fuel type	Natural gas	Natural gas
Fuel usage, x10^9 Joules/Mg	0.7	0.7
(x10^6 Btu/ton)	(0.6)	(0.6)
Maximum operating temperature, °C	230	230
(°F)	(450)	(450)
Retention time, min	2.5	2.5
CONTROL DEVICE INFORMATION		
Control device inlet		
Gas flow rate, m^3/min	700	1,400
(acfm)	(25,000)	(50,000)
Gas temperature, °C	120	120
(°F)	(250)	(250)
Gas moisture, %	8	8
Baghouse		
Cloth type	Nomex	Nomex
Air-to-cloth ratio[a]	1.7:1	1.7:1
	(5.6:1)	(5.6:1)
ΔP, kPa	1.0	1.0
(in. w.c.)	(4)	(4)
STACK PARAMETERS		
Height, m	18	21
(ft)	(60)	(70)
Diameter, m	0.9	1.2
(ft)	(3.0)	(4.1)
Temperature, °C	110	110
(°F)	(225)	(225)
Moisture, %	8	8
Gas flow rate, m^3/min	680	1,360
(acfm)	(24,100)	(48,200)
Gas velocity, m/s	18	18
(ft/s)	(60)	(60)

[a] m^3/min per m^2 (ft^3/min per ft^2).

TABLE 6-9. MODEL FACILITY PARAMETERS FOR FLUID BED DRYER--BENTONITE INDUSTRY

Parameter/Facility size	Medium
PROCESS INFORMATION	
Production	
Design, Mg/h	40
(tons/h)	(45)
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	24
Actual, h/yr	6,500
Feed material	Bentonite
Product	Bentonite
Fuel type	Coal
Fuel usage, x10^9 Joules/Mg	0.37
(x10^6 Btu/ton)	(0.32)
Maximum operating temperature, °C	815
(°F)	(1,500)
Retention time, min	10
CONTROL DEVICE INFORMATION	
Control device inlet	
Gas flow rate, m^3/min	1,420
(acfm)	(50,000)
Gas temperature, °C	100
(°F)	(220)
Gas moisture, %	15/25[a]
Baghouse	
Cloth type	Nomex
Air-to-cloth ratio[b]	0.9:1
	(3:1)
ΔP, kPa	0.74
(in. w.c)	(3)
SP[c]	
Specific collection area[d]	1.0/1.15[e]
	(300)/(350)
ΔP, kPa	0.12
(in. w.c.)	(0.5)
ACK PARAMETERS	
eight, m	18
(ft)	(60)
iameter, m	1.3
(ft)	(4.2)
mperature, °C	90
(°F)	(200)
isture, %	15/25[a]
flow rate, m^3/min	1,400
(acfm)	(48,500)
velocity, m/s	18
(ft/s)	(60)

---

t number corresponds to baghouse; second number corresponds to ESP.
n per m^2 (ft^3/min per ft^2).
d power requirement for ESP is 0.14 watts/m^2 (1.5 watts/ft^2).
r m^3/min (ft^2/1,000 acfm).
number corresponds to Regulatory Alternative II; second number corresponds to Regulatory ative III.

TABLE 6-10. MODEL FACILITY PARAMETERS FOR ROTARY DRYER--BENTONITE INDUSTRY

Parameter/Facility size	Small	Medium	Large
PROCESS INFORMATION			
Production			
Design, Mg/h	18	32	54
(tons/h)	(20)	(35)	(60)
Hours of operation			
Design, h/d	←	24	→
Design, h/yr	←	8,000	→
Actual, h/d	←	16	→
Actual, h/yr	←	5,800	→
Feed material	←	Bentonite	→
Product	←	Bentonite	→
Fuel type	←	Natural gas, coal	→
Fuel usage, x10^9 Joules/Mg	←	0.6	→
(x10^6 Btu/ton)	←	(0.5)	→
Maximum operating temperature, °C	←	200	→
(°F)	←	(400)	→
Retention time, min	←	25	→
CONTROL DEVICE INFORMATION			
Control device inlet			
Gas flow rate, m^3/min	570	850	1,400
(acfm)	(20,000)	(30,000)	(50,000)
Gas temperature, °C	←	120	→
(°F)	←	(250)	→
Gas moisture, %	←	20	→
Baghouse			
Cloth type	←	Nomex	→
Air-to-cloth ratio[a]	←	1.1:1	→
	←	(3.5:1)	→
ΔP, kPa	←	1.0	→
(in. w.c.)	←	(4)	→
STACK PARAMETERS			
Height, m	15	15	18
(ft)	(50)	(50)	(60)
Diameter, m	0.8	1.0	[illegible]
(ft)	(2.6)	(3.2)	[illegible]
Temperature, °C	←	110	→
(°F)	←	(225)	→
Moisture, %	←	20	→
Gas flow rate, m^3/min	530	820	[illegible]
(acfm)	(19,300)	(28,900)	[illegible]
Gas velocity, m/s	←	18	→
(ft/s)	←	(60)	→

[a] m^3/min per ft^2 (ft^3/min per ft^2).

TABLE 6-11. MODEL FACILITY PARAMETERS FOR FLASH DRYER--DIATOMITE INDUSTRY

Parameter/Facility size	Small	Large
PROCESS INFORMATION		
Production		
Design, Mg/h	4	11
(tons/h)	(5)	(12)
Hours of operation		
Design, h/d	24	24
Design, h/yr	8,000	8,000
Actual, h/d	24	24
Actual, h/yr	8,000	8,000
Feed material	Crude diatomite	Crude diatomite
Product	Diatomite fillers, absorbents, and filter aids	Diatomite fillers, absorbents, and filter aids
Fuel type	Natural gas	Natural gas
Fuel usage, $\times 10^9$ Joules/Mg	4.1	4.1
($\times 10^6$ Btu/ton)	(3.5)	(3.5)
Maximum operating temperature, °C	540	540
(°F)	(1000)	(1000)
Retention time, min	1	1
CONTROL DEVICE INFORMATION		
Control device inlet		
Gas flow rate, m^3/min	620	1,100
(acfm)	(22,000)	(40,000)
Gas temperature, °C	120	120
(°F)	(250)	(250)
Gas moisture, %	10	10
crubber		
ΔP, kPa	3.5/6.2[a]	3.5/6.2[a]
(in. w.c.)	(14)/(25)	(14)/(25)
Liquid-to-gas ratio[b]	1,335	1,335
	(10)	(10)
CK PARAMETERS		
eight, m	15	15
(ft)	(50)	(50)
ameter, m	0.8	1.1
(ft)	(2.8)	(3.7)
perature, °C	60	60
(°F)	(140)	(140)
sture, %	20	20
flow rate, m^3/min	602	1,080
acfm)	(20,900)	(38,000)
velocity, m/s	18	18
ft/s)	(60)	(60)

number corresponds to Regulatory Alternative II (RA II); second number corresponds to
atory Alternative III (RA III).
00 m^3 (gal/1,000 acf).

TABLE 6-12. MODEL FACILITY PARAMETERS FOR ROTARY DRYER--DIATOMITE INDUSTRY

Parameter/Facility size	Medium
PROCESS INFORMATION	
Production	
Design, Mg/h	9
(tons/h)	(10)
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	16
Actual, h/yr	4,200
Feed material	Crude diatomite
Product	Diatomite fillers & absorbents
Fuel type	Natural gas
Fuel usage, $\times 10^9$ Joules/Mg	5.2
($\times 10^6$ Btu/ton)	(4.5)
Maximum operating temperature, °C	760
(°F)	(1400)
Retention time, min	18
CONTROL DEVICE INFORMATION	
Control device inlet	
Gas flow rate, m^3/min	420
(acfm)	(15,000)
Gas temperature, °C	120
(°F)	(250)
Gas moisture, %	15
Baghouse	
Cloth type	Nomex
Air-to-cloth ratio[a]	1.2:1
	(4:1)
ΔP, kPa	0.61
(in. w.c.)	(2.5)
STACK PARAMETERS	
Height, m	15
(ft)	(50)
Diameter, m	0.7
(ft)	(2.3)
Temperature, °C	110
(°F)	(225)
Moisture, %	15
Gas flow rate, m^3/min	410
(acfm)	(14,500)
Gas velocity, m/s	18
(ft/s)	(60)

[a] m^3/min per m^2 (ft^3/min per ft^2).

TABLE 6-13. MODEL FACILITY PARAMETERS FOR ROTARY CALCINER--DIATOMITE INDUSTRY

Parameter/Facility size	Small	Large
PROCESS INFORMATION		
Production		
Design, Mg/h	4	11
(tons/h)	(5)	(12)
Hours of operation		
Design, h/d	24	24
Design, h/yr	8,000	8,000
Actual, h/d	24	24
Actual, h/yr	6,500	6,500
Feed material	Crude diatomite	Crude diatomite
Product	Diatomite powders	Diatomite powders
Fuel type	Natural gas	Natural gas
Fuel usage, x10^9 Joules/Mg	5.2	5.2
(x10^6 Btu/ton)	(4.5)	(4.5)
Maximum operating temperature, °C	1150	1150
(°F)	(2100)	(2100)
Retention time, min	30-80	30-80
CONTROL DEVICE INFORMATION		
Control device inlet		
Gas flow rate, m^3/min	420	850
(acfm)	(15,000)	(30,000)
Gas temperature, °C	230	230
(°F)	(440)	(440)
Gas moisture, %	5	5
Baghouse		
Cloth type	Nomex	Nomex
Air-to-cloth ratio[a]	0.6:1	0.6:1
	(2:1)	(2:1)
ΔP, kPa	0.98	0.98
(in. w.c.)	(4)	(4)
crubber		
ΔP, kPa	5.7	5.7
(in. w.c.)	(23)	(23)
Liquid-to-gas ratio[b]	1,335	1,335
	(10)	(10)
ACK PARAMETERS[c]		
eight, m	15	15
(ft)	(50)	(50)
ameter, m	0.7/0.6	0.9
(ft)	(2.2)/(2.1)	(3.1)/(2.9)
perature, °C	180/60	180/60
(°F)	(350)/(140)	(350)/(140)
sture, %	5/20	5/20
flow rate, m^3/min	380/340	760/670
(acfm)	(13,500)/(11,900)	(27,000)/(23,800)
velocity, m/s	18	18
(ft/s)	(60)	(60)

---

n per m^2 (ft^3/min per ft^2).

00 m^3 (gal/1,000 acf).

number corresponds to baghouse; second number corresponds to scrubber.

TABLE 6-14. MODEL FACILITY PARAMETERS FOR FLUID BED DRYER--FELDSPAR INDUSTRY

Parameter/Facility size	Medium	Large
PROCESS INFORMATION		
Production		
Design, Mg/h	Confidential[4]	Confidential[4]
(tons/h)		
Hours of operation		
Design, h/d	24	24
Design, h/yr	8,000	8,000
Actual, h/d	Confidential[4]	Confidential[4]
Actual, h/yr	Confidential[4]	Confidential[4]
Feed material	Pegmatite or alaskite ore	Pegmatite or alaskite ore
Product	Feldspar	Feldspar
Fuel type	Confidential[4]	Confidential[4]
Fuel usage, $\times 10^9$ Joules/Mg	Confidential[4]	Confidential[4]
($\times 10^6$ Btu/ton)		
Maximum operating temperature, °C	Confidential[4]	Confidential[4]
(°F)		
Retention time, min	Confidential[4]	Confidential[4]
CONTROL DEVICE INFORMATION		
Control device inlet		
Gas flow rate, m^3/min	280	480
(acfm)	(10,000)	(17,000)
Gas temperature, °C	120	120
(°F)	(250)	(250)
Gas moisture, %	6	6
Baghouse		
Cloth type	Nomex	Nomex
Air-to-cloth ratio[a]	1.4:1	1.4:1
	(4.5:1)	(4.5:1)
ΔP, kPa	0.74	0.74
(in. w.c.)	(3)	(3)
STACK PARAMETERS		
Height, m	15	[illegible]
(ft)	(50)	[illegible]
Diameter, m	0.6	[illegible]
(ft)	(1.9)	[illegible]
Temperature, °C	110	110
(°F)	(225)	[illegible]
Moisture, %	6	6
Gas flow rate, m^3/min	270	[illegible]
(acfm)	(9,600)	(16,[illegible])
Gas velocity, m/s	18	[illegible]
(ft/s)	(60)	[illegible]

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[a] m^3/min per m^2 (ft^3/min per ft^2).

TABLE 6-15. MODEL FACILITY PARAMETERS FOR ROTARY DRYER-- FELDSPAR INDUSTRY

Parameter/Facility size	Small	Medium	Large
PROCESS INFORMATION			
Production			
Design, Mg/h	Confidential[4]	18	27
(tons/h)		(20)	(30)
Hours of operation			
Design, h/d	←	24	→
Design, h/yr	←	8,000	→
Actual, h/d	Confidential[4]	16	16
Actual, h/yr	Confidential[4]	4,500	5,200
Feed material	←	Pegmatite or alaskite ore	→
Product	←	Feldspar	→
Fuel type	Confidential[4]	No. 2 oil, natural gas	No. 2 oil, natural gas
Fuel usage, $x10^9$ Joules/Mg	Confidential[4]	1.2	1.2
($x10^6$ Btu/ton)		(1)	(1)
Maximum operating temperature, °C	Confidential[4]	230	230
(°F)		(450)	(450)
Retention time, min	Confidential[4]	10-15	10-15
CONTROL DEVICE INFORMATION			
Control device inlet			
Gas flow rate, m^3/min	Confidential[4]	350	600
(acfm)		(12,500)	(21,000)
Gas temperature, °C	Confidential[4]	120	120
(°F)		(250)	(250)
Gas moisture, %	Confidential[4]	10	10
crubber			
ΔP, kPa	Confidential[4]	$1.0/2.5^a$	$1.0/2.5^a$
(in. w.c.)		(4)/(10)	(4)/(10)
Liquid-to-gas ratio^b	Confidential[4]	1,335	1,335
		(10)	(10)
ACK PARAMETERS			
eight, m	Confidential[4]	12	15
(ft)		(40)	(50)
iameter, m	Confidential[4]	0.6	0.6
(ft)		(2.1)	(2.7)
perature, °C	Confidential[4]	60	60
(°F)		(140)	(140)
isture, %	Confidential[4]	20	20
flow rate, m^3/min	Confidential[4]	340	570
(acfm)		(11,900)	(20,000)
velocity, m/s	Confidential[4]	18	18
(ft/s)		(60)	(60)

t number corresponds to RA II; second number corresponds to RA III.

000 m^3 (gal/1,000 acf).

TABLE 6-16. MODEL FACILITY PARAMETERS FOR ROTARY DRYER--FIRE CLAY INDUSTRY

Parameter/Facility size	Small	Medium	Large
PROCESS INFORMATION			
Production			
Design, Mg/h	9	27	45
(tons/h)	(10)	(30)	(50)
Hours of operation			
Design, h/d	←	24	→
Design, h/yr	←	8,000	→
Actual, h/d	←	8	→
Actual, h/yr	←	3,000	→
Feed material	←	Plastic, flint, bauxite clays	→
Product	←	Dried clays	→
Fuel type	←	Natural gas, No. 2 oil	→
Fuel usage, x10^9 Joules/Mg	←	0.8	→
(x10^6 Btu/ton)	←	(0.7)	→
Maximum operating temperature, °C	←	204	→
(°F)	←	(400)	→
Retention time, min	←	15-60	→
CONTROL DEVICE INFORMATION			
Control device inlet			
Gas flow rate, m^3/min	310	510	710
(acfm)	(11,000)	(18,000)	(25,000)
Gas temperature, °C	←	120	→
(°F)	←	(250)	→
Gas moisture, %	←	6	→
Baghouse			
Cloth type	←	Nomex	→
Air-to-cloth ratio[a]	←	1.4:1	→
	←	(4.5:1)	→
ΔP, kPa	←	0.98	→
(in. w.c.)	←	(2)	→
Scrubber			
ΔP, kPa	←	2.5/3.5[b]	→
(in. w.c.)	←	(10)/(14)	→
Liquid-to-gas ratio[c]	←	1,335	→
	←	(10)	→
STACK PARAMETERS[d]			
Height, m	12	12	15
(ft)	(40)	(40)	(50)
Diameter, m	0.6	0.8	0.9
(ft)	(2.0)	(2.5)	(3.0)
Temperature, °C	←	110/60	→
(°F)	←	(225)/(140)	→
Moisture, %	←	6/20	→
Gas flow rate, m^3/m	300/310	490/510	680/700
(acfm)	(10,600)/ (10,900)	(17,400)/ (17,900)	(24,100)/ (24,[illegible])
Gas velocity, m/s	←	18	→
(ft/s)	←	(60)	→

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[a] m^3/min per m^2 (ft^3/min per ft^2).
[b] First number corresponds to RA II; second number corresponds to RA III.
[c] ℓ/1,000 m^3 (gal/1,000 acf).
[d] First number corresponds to baghouse; second number corresponds to scrubber.

TABLE 6-17. MODEL FACILITY PARAMETERS FOR VIBRATING-GRATE DRYER--FIRE CLAY INDUSTRY

Parameter/Facility size	Medium
PROCESS INFORMATION	
Production	
Design, Mg/h	23
(tons/h)	(25)
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	6
Actual, h/yr	2,000
Feed material	Crude clay
Product	Dried clay
Fuel type	Natural gas, No. 2 oil
Fuel usage, $x10^9$ Joules/Mg	0.5
($x10^6$ Btu/ton)	(0.4)
Maximum operating temperature, °C	260
(°F)	(500)
tention time, min	10-15
ONTROL DEVICE INFORMATION	
ontrol device inlet	
Gas flow rate, m^3/min	1,760
(acfm)	(62,000)
Gas temperature, °C	135
(°F)	(275)
as moisture, %	6
ubber	
P, kPa	0.8/0.8[a]
(in. w.c.)	(3)/(3)
iquid-to-gas ratio[b]	270
	(5)
K PARAMETERS	
ight, m	15
(ft)	(50)
eter, m	1.4
ft)	(4.6)
perature, °C	60
F)	(140)
ture, %	20
flow rate, m^3/min	1,700
cfm)	(59,500)
velocity, m/s	18
/s)	(60)

---

number corresponds to RA II; second number corresponds to RA III.

0 m^3 (gal/1,000 acf).

TABLE 6-18. MODEL FACILITY PARAMETERS FOR ROTARY CALCINER--FIRE CLAY INDUSTRY

Parameter/Facility size	Small	Medium
PROCESS INFORMATION		
Production		
Design, Mg/h	9	18
(tons/h)	(10)	(20)
Hours of operation		
Design, h/d	24	24
Design, h/yr	8,000	8,000
Actual, h/d	24	24
Actual, h/yr	8,000	8,000
Feed material	Crude kaolinitic clays	Crude kaolinitic clays
Product	Calcined clays	Calcined clays
Fuel type	Natural gas, No. 2 oil	Natural gas, No. 2 oil
Fuel usage, x10^9 Joules/Mg	4.9	4.9
(x10^6 Btu/ton)	(4.2)	(4.2)
Maximum operating temperature, °C	1400	1400
(°F)	(2500)	(2500)
Retention time, min	100	120
CONTROL DEVICE INFORMATION		
Control device inlet		
Gas flow rate, m^3/min	700	1,100
(acfm)	(25,000)	(40,000)
Gas temperature, °C	230	230
(°F)	(450)	(450)
Gas moisture, %	14	14
Scrubber		
ΔP, kPa	4.7	4.7
(in. w.c.)	(19)	(19)
Liquid-to-gas ratio[a]	1,335 (10)	1,335 (10)
STACK PARAMETERS		
Height, m	11	15
(ft)	(35)	(50)
Diameter, m	0.8	1.0
(ft)	(2.5)	(3.2)
Temperature, °C	60	60
(°F)	(140)	(140)
Moisture, %	20	20
Gas flow rate, m^3/min	500	800
(acfm)	(17,700)	(28,400)
Gas velocity, m/s	18	18
(ft/s)	(60)	(60)

[a] ℓ/1,000 m^3 (gal/1,000 acf).

TABLE 6-19. MODEL FACILITY PARAMETERS FOR FLUID BED DRYER--FULLER'S EARTH INDUSTRY

Parameter/Facility size	Large
PROCESS INFORMATION	
Production	
Design, Mg/h (tons/h)	Confidential[4]
Hours of operation	
Design, h/d	Confidential[4]
Design, h/yr	Confidential[4]
Actual, h/d	Confidential[4]
Actual, h/yr	Confidential[4]
Feed material	Fuller's earth
Product	Fuller's earth
Fuel type	Natural gas, No. 5 oil
Fuel usage, $x10^9$ Joules/Mg ($x10^6$ Btu/ton)	Confidential[4]
Maximum operating temperature, °C	980
(°F)	(1800)
Retention time, min	30
CONTROL DEVICE INFORMATION	
Control device inlet	
Gas flow rate, m^3/min	3,500
(acfm)	(124,000)
Gas temperature, °C	150
(°F)	(300)
Gas moisture, %	24
Baghouse	
Cloth type	Nomex
Air-to-cloth ratio[a]	1.4:1 (4.5:1)
ΔP, kPa	0.98
(in. w.c.)	(4)
STACK PARAMETERS	
Height, m	15
(ft)	(50)
Diameter, m	1.9
(ft)	(6.3)
Temperature, °C	110
(°F)	(235)
Moisture, %	24
Gas flow rate, m^3/min	3,200
(acfm)	(113,400)
as velocity, m/s	18
(ft/s)	(60)

min per m^2 (ft^3/min per ft^2).

TABLE 6-20. MODEL FACILITY PARAMETERS FOR ROTARY DRYER--FULLER'S EARTH INDUSTRY

Parameter/Facility size	Small	Medium	Large
PROCESS INFORMATION			
Production			
Design, Mg/h	4	14	27
(tons/h)	(5)	(15)	(30)
Hours of operation			
Design, h/d	←	24	→
Design, h/yr	←	8,000	→
Actual, h/d	←	24	→
Actual, h/yr	←	7,500	→
Feed material	←	Fuller's earth	→
Product	←	Fuller's earth	→
Fuel type	←	Natural gas, No. 4 oil	→
Fuel usage, x10^9 Joules/Mg	2.6	2.3	2.3
(x10^6 Btu/ton)	(2.2)	(2.0)	(2.0)
Maximum operating temperature, °C	←	200	→
(°F)	←	(400)	→
Retention time, min	←	23	→
CONTROL DEVICE INFORMATION			
Control device inlet			
Gas flow rate, m^3/min	570	850	1,300
(acfm)	(20,000)	(30,000)	(45,000)
Gas temperature, °C	←	145	→
(°F)	←	(290)	→
Gas moisture, %	←	20	→
Baghouse			
Cloth type	←	Nomex	→
Air-to-cloth ratio[a]	←	1.2:1	→
	←	(4:1)	→
ΔP, kPa	←	1.0	→
(in. w.c.)	←	(4)	→
Scrubber			
ΔP, kPa	←	2.0/2.7[b]	→
(in. w.c.)	←	(8)/(11)	→
Liquid-to-gas ratio[c]	←	1,335	→
	←	(10)	→
STACK PARAMETERS[d]			
Height, m	12	15	18
(ft)	(40)	(50)	(60)
Diameter, m	0.8/0.7	1.0/0.9	1.2/1.1
(ft)	(2.7)/(2.4)	(3.2)/(2.9)	(4.0)/(3.6)
Temperature, °C	←	130/60	→
(°F)	←	(270)/(140)	→
Moisture, %	←	20	→
Gas flow rate, m^3/min	550/450	830/680	1200/1,020
(acfm)	(19,500)/ (16,000)	(29,200)/ (24,000)	(43,000)/ (36,000)
Gas velocity, m/s	←	18	→
(ft/s)	←	(60)	→

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[a] m^3/min per m^2 (ft^3/min per ft^2).
[b] First number corresponds to RA II; second number corresponds to RA III.
[c] ℓ/1,000 m^3 (gal/1,000 acf).
[d] First number corresponds to baghouse; second number corresponds to scrubber.

TABLE 6-21. MODEL FACILITY PARAMETERS FOR ROTARY CALCINER--FULLER'S EARTH INDUSTRY

Parameter/Facility size	Small	Medium	Large
PROCESS INFORMATION			
Production			
Design, Mg/h	4	23	40
(tons/h)	(5)	(25)	(45)
Hours of operation			
Design, h/d	←	24	→
Design, h/yr	←	8,000	→
Actual, h/d	←	24	→
Actual, h/yr	←	8,000	→
Feed material	←	Fuller's earth	→
Product	←	Fuller's earth	→
Fuel type	←	Natural gas, fuel oil	→
Fuel usage, $x10^9$ Joules/Mg	←	2.4	→
($x10^6$ Btu/ton)	←	(2.1)	→
aximum operating temperature, °C	←	980	→
(°F)	←	(1800)	→
etention time, min	←	60	→
NTROL DEVICE INFORMATION			
ntrol device inlet			
Gas flow rate, m^3/min	340	850	1,100
(acfm)	(12,000)	(30,000)	(40,000)
as temperature, °C	←	230	→
(°F)	←	(450)	→
as moisture, %	←	20	→
ouse			
oth type	←	Nomex	→
r-to-cloth ratio[a]	←	0.6:1	→
	←	(2:1)	→
kPa	←	0.74	→
in. w.c.)	←	(3)	→
PARAMETERS			
ght, m	12	15	18
t)	(40)	(50)	(60)
eter, m	0.6	1.0	1.1
t)	(2.0)	(3.2)	(3.7)
erature, °C	←	200	→
F)	←	(400)	→
ture, %	←	20	→
low rate, m^3/min	320	800	1,100
fm)	(11,300)	(28,400)	(37,800)
locity, m/s	←	18	→
s)	←	(60)	→

per m^2 (ft^3/min per ft^2).

TABLE 6-22. MODEL FACILITY PARAMETERS FOR ROTARY DRYER--GYPSUM INDUSTRY

Parameter/Facility size	Medium	Large
PROCESS INFORMATION		
Production		
Design, Mg/h	45	73
(tons/h)	(50)	(80)
Hours of operation		
Design, h/d	24	24
Design, h/yr	8,000	8,000
Actual, h/d	16	16
Actual, h/yr	5,600	5,600
Feed material	Gypsum	Gypsum
Product	Gypsum	Gypsum
Fuel type	Natural gas, distillate oil	Natural gas, distillate oil
Fuel usage, $\times 10^9$ Joules/Mg	0.17	0.17
($\times 10^6$ Btu/ton)	(0.15)	(0.15)
Maximum operating temperature, °C	260	260
(°F)	(500)	(500)
Retention time, min	8	8
CONTROL DEVICE INFORMATION		
Control device inlet		
Gas flow rate, m^3/min	350	470
(acfm)	(12,500)	(16,600)
Gas temperature, °C	120	120
(°F)	(250)	(250)
Gas moisture, %	8	8
Baghouse		
Cloth type	Nomex	Nomex
Air-to-cloth ratio[a]	1.2:1	1.2:1
	(4:1)	(4:1)
ΔP, kPa	0.98	0.98
(in. w.c.)	(4)	(4)
STACK PARAMETERS		
Height, m	15	18
(ft)	(50)	(60)
Diameter, m	0.6	0.7
(ft)	(2.1)	(2.4)
Temperature, °C	110	110
(°F)	(225)	(225)
Moisture, %	8	8
Gas flow rate, m^3/min	340	450
(acfm)	(12,100)	(16,000)
Gas velocity, m/s	18	18
(ft/s)	(60)	(60)

[a] m^3/min per m^2 (ft^3/min per ft^2).

TABLE 6-23. MODEL FACILITY PARAMETERS FOR FLASH CALCINER--GYPSUM INDUSTRY

Parameter/Facility size	Medium
PROCESS INFORMATION	
Production	
Design, Mg/h	9
(tons/h)	(10)
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	24
Actual, h/yr	5,600
Feed material	Gypsum
Product	Stucco
Fuel type	Natural gas, distillate oil, No. 6 oil
Fuel usage, $x10^9$ Joules/Mg	0.9
($x10^6$ Btu/ton)	(0.8)
Maximum operating temperature, °C	230
(°F)	(450)
Retention time, s	2-5
CONTROL DEVICE INFORMATION	
Control device inlet	
Gas flow rate, m^3/min	120
(acfm)	(4,100)
Gas temperature, °C	180
(°F)	(350)
Gas moisture, %	40
Baghouse	
Cloth type	Fiberglass
Air-to-cloth ratio[a]	0.6:1 (2:1)
ΔP, kPa	0.98
(in. w.c.)	(4)
TACK PARAMETERS	
Height, m	21
(ft)	(70)
Diameter, m	0.7
(ft)	(2.2)
Temperature, °C	165
(°F)	(325)
oisture, %	40
as flow rate, m^3/min	110
(acfm)	(4,000)
as velocity, m/s	26
(ft/s)	(85)

in per m^2 (ft^3/min per ft^2).

TABLE 6-24. MODEL FACILITY PARAMETERS FOR KETTLE CALCINER--GYPSUM INDUSTRY

Parameter/Facility Size	Medium
PROCESS INFORMATION	
Production	
Design, Mg/h	11
(tons/h)	(12)
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	24
Actual, h/yr	5,600
Feed material	Gypsum
Product	Stucco
Fuel type	Natural gas, distillate oil
Fuel usage, $\times 10^9$ Joules/Mg	1.2
($\times 10^6$ Btu/ton)	(1)
Maximum operating temperature, °C	230
(°F)	(450)
Retention time, min	120 (batch)
CONTROL DEVICE INFORMATION	
Control device inlet	
Gas flow rate, m^3/min	120
(acfm)	(4,100)
Gas temperature, °C	120
(°F)	(250)
Gas moisture, %	30
Baghouse	
Cloth type	Fiberglass
Air-to-cloth ratio[a]	0.6:1
	(2:1)
ΔP, kPa	0.98
(in. w.c.)	(4)
STACK PARAMETERS	
Height, m	21
(ft)	(70)
Diameter, m	0.3
(ft)	(1.1)
Temperature, °C	110
(°F)	(225)
Moisture, %	30
Gas flow rate, m^3/min	110
(acfm)	(4,000)
Gas velocity, m/s	18
(ft/s)	(60)

[a] m^3/min per m^2 (ft^3/min per ft^2).

TABLE 6-25. MODEL FACILITY PARAMETERS FOR FLUID BED DRYER--INDUSTRIAL SAND INDUSTRY

Parameter/Facility size	Small	Medium	Large
PROCESS INFORMATION			
Production			
Design, Mg/h	45	90	180
(tons/h)	(50)	(100)	(200)
Hours of operation			
Design, h/d	←	24	→
Design, h/yr	←	8,000	→
Actual, h/d	8	24	24
Actual, h/yr	2,000	6,400	6,400
Feed material	←	Industrial sand	→
Product	←	Industrial sand	→
Fuel type	←	Natural gas, No. 2 oil, propane	→
Fuel usage, $\times 10^9$ Joules/Mg	←	0.3	→
($\times 10^6$ Btu/ton)	←	(0.3)	→
Maximum operating temperature, °C	←	260	→
(°F)	←	(500)	→
Retention time, min	←	4	→
CONTROL DEVICE INFORMATION			
Control device inlet			
Gas flow rate, m^3/min	420	850	2,000
(acfm)	(15,000)	(30,000)	(70,000)
Gas temperature, °C	←	110	→
(°F)	←	(230)	→
Gas moisture, %	←	10	→
crubber			
ΔP, kPa	←	0.8/0.8[a]	→
(in. w.c.)	←	(3)/(3)	→
Liquid-to-gas ratio[b]	←	1,335	→
	←	(10)	→
ACK PARAMETERS			
Height, m	12	15	18
(ft)	(40)	(50)	(60)
iameter, m	0.7	1.0	1.5
(ft)	(2.3)	(3.3)	(5.0)
emperature, °C	←	60	→
(°F)	←	(140)	→
oisture, %	←	20	→
s flow rate, m^3/min	410	830	1,940
(acfm)	(14,700)	(29,300)	(68,500)
s velocity, m/s	←	18	→
(ft/s)	←	(60)	→

t number corresponds to RA II; second number corresponds to RA III.

,000 m^3 (gal/1,000 acf).

TABLE 6-26. MODEL FACILITY PARAMETERS FOR ROTARY DRYER--INDUSTRIAL SAND INDUSTRY

Parameter/Facility size	Small	Medium	Large
PROCESS INFORMATION			
Production			
Design, Mg/h	45	90	135
(tons/h)	(50)	(100)	(150)
Hours of operation			
Design, h/d	←	24	→
Design, h/yr	←	8,000	→
Actual, h/d	8	8	16
Actual, h/yr	1,800	1,800	4,000
Feed material	←	Industrial sand	→
Product	←	Industrial sand	→
Fuel type	←	Natural gas	→
Fuel usage, $\times 10^9$ Joules/Mg	←	0.2	→
($\times 10^6$ Btu/ton)	←	(0.2)	→
Maximum operating temperature, °C	←	260	→
(°F)	←	(500)	→
Retention time, min	←	9	→
CONTROL DEVICE INFORMATION			
Control device inlet			
Gas flow rate, m^3/min	310	570	990
(acfm)	(11,000)	(20,000)	(35,000)
Gas temperature, °C	←	120	→
(°F)	←	(250)	→
Gas moisture, %	←	10	→
Scrubber			
ΔP, kPa	←	0.8/0.8[a]	→
(in. w.c.)	←	(3)/(3)	
Liquid-to-gas ratio[b]	←	1,335	→
	←	(10)	
STACK PARAMETERS			
Height, m	9	12	15
(ft)	(30)	(40)	(50)
Diameter, m	0.6	0.8	1.1
(ft)	(1.9)	(2.6)	(3.5)
Temperature, °C	←	60	→
(°F)	←	(140)	→
Moisture, %	←	20	→
Gas flow rate, m^3/min	300	540	940
(acfm)	(10,500)	(19,000)	(33,300)
Gas velocity, m/s	←	18	→
(ft/s)	←	(60)	→

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[a] First number corresponds to RA II; second number corresponds to RA III.

[b] ℓ/1,000 m^3 (gal/1,000 acf).

TABLE 6-27. MODEL FACILITY PARAMETERS FOR ROTARY DRYER--KAOLIN INDUSTRY

Parameter/Facility size	Medium
PROCESS INFORMATION	
Production	
Design, Mg/h	18
(tons/h)	(20)
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	16
Actual, h/yr	3,000
Feed material	Crude kaolin
Product	Dried kaolin
Fuel type	Natural gas, No. 2 oil
Fuel usage, x10^9 Joules/Mg	0.1
(x10^6 Btu/ton)	(0.1)
Maximum operating temperature, °C	260
(°F)	(500)
Retention time, min	15
CONTROL DEVICE INFORMATION	
Control device inlet	
Gas flow rate, m^3/min	480
(acfm)	(17,000)
Gas temperature, °C	120
(°F)	(250)
Gas moisture, %	8
Baghouse	
Cloth type	Nomex
Air-to-cloth ratio[a]	1.1:1 (3.5:1)
ΔP, kPa	1.2
(in. w.c.)	(5)
STACK PARAMETERS	
Height, m	11
(ft)	(35)
Diameter, m	0.7
(ft)	(2.4)
Temperature, °C	110
(°F)	(225)
Moisture, %	8
Gas flow rate, m^3/min	460
(acfm)	(16,400)
Gas velocity, m/s	18
(ft/s)	(60)

^{3}/min per m^2 (ft^3/min per ft^2).

TABLE 6-28. MODEL FACILITY PARAMETERS FOR SPRAY DRYER--KAOLIN INDUSTRY

Parameter/Facility size	Medium	Large
PROCESS INFORMATION		
Production		
Design, Mg/h	14	27
(ton/h)	(15)	(30)
Hours of operation		
Design, h/d	24	24
Design, h/yr	8,000	8,000
Actual, h/d	24	24
Actual, h/yr	8,000	8,000
Feed material	Kaolin clay	Kaolin clay
Product	Kaolin clay	Kaolin clay
Fuel type	Natural gas, No. 2 oil	Natural gas, No. 2 oil
Fuel usage, x10^9 Joules/Mg	2.4	2.4
(x10^6 Btu/ton)	(2.1)	(2.1)
Maximum operating temperature, °C	590	590
(°F)	(1100)	(1100)
Retention time, s	5	5
CONTROL DEVICE INFORMATION		
Control device inlet		
Gas flow rate, m³/min	990	1,700
(acfm)	(35,000)	(60,000)
Gas temperature, °C	120	120
(°F)	(250)	(250)
Gas moisture, %	30	30
Baghouse		
Cloth type	Nomex	Nomex
Air-to-cloth ratio[a]	0.9:1	0.9:1
	(3:1)	(3:1)
ΔP, kPa	1.2	1.2
(in. w.c.)	(5)	(5)
STACK PARAMETERS		
Height, m	27	27
(ft)	(90)	(90)
Diameter, m	1.1	1.4
(ft)	(3.5)	(4.6)
Temperature, °C	110	110
(°F)	(225)	(225)
Moisture, %	30	30
Gas flow rate, m³/min	960	1,600
(acfm)	(33,800)	(57,900)
Gas velocity, m/s	18	18
(ft/s)	(60)	(60)

[a] m³/min per m² (ft³/min per ft²).

TABLE 6-29. MODEL FACILITY PARAMETERS FOR FLASH CALCINER--KAOLIN INDUSTRY

Parameter/Facility size	Small
PROCESS INFORMATION	
Production	
Design, Mg/h	Confidential[4]
(tons/h)	
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	Confidential[4]
Actual, h/yr	Confidential[4]
Feed material	Dry kaolin
Product	Calcined kaolin
Fuel type	Natural gas, kerosene
Fuel usage, x10^9 Joules/Mg	Confidential[4]
(x10^6 Btu/ton)	
Maximum operating temperature, °C	Confidential[4]
(°F)	
Retention time, s	Confidential[4]
CONTROL DEVICE INFORMATION	
Control device inlet	
Gas flow rate, m^3/min	Confidential[4]
(acfm)	
Gas temperature, °C	Confidential[4]
(°F)	
Gas moisture, %	Confidential[4]
Baghouse	
Cloth type	Fiberglass
Air-to-cloth ratio[a]	0.6:1
	(2:1)
ΔP, kPa	0.98
(in. w.c.)	(4)
TACK PARAMETERS	
Height, m	18
(ft)	(60)
Diameter, m	0.9
(ft)	(3.1)
Temperature, °C	180
(°F)	(350)
oisture, %	4
s flow rate, m^3/min	750
(acfm)	(26,400)
s velocity, m/s	18
(ft/s)	(60)

in per m^2 (ft^3/min per ft^2).

TABLE 6-30. MODEL FACILITY PARAMETERS FOR MULTIPLE HEARTH FURNACE--KAOLIN INDUSTRY

Parameter/Facility size	Small
PROCESS INFORMATION	
Production	
Design, Mg/h	4
(tons/h)	(5)
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	24
Actual, h/yr	8,000
Feed material	Spray dried kaolin
Product	Calcined kaolin
Fuel type	Natural gas, No. 2 oil
Fuel usage, $x10^9$ Joules/Mg	3.5
($x10^6$ Btu/ton)	(3)
Maximum operating temperature, °C	1100
(°F)	(2000)
Retention time, min	30
CONTROL DEVICE INFORMATION	
Control device inlet	
Gas flow rate, m^3/min	340
(acfm)	(12,000)
Gas temperature, °C	280
(°F)	(500)
Gas moisture, %	16
Scrubber	
ΔP, kPa	5.7
(in. w.c.)	(23)
Liquid-to-gas ratio[a]	1,335 (10)
STACK PARAMETERS	
Height, m	18
(ft)	(60)
Diameter, m	0.5
(ft)	(1.7)
Temperature, °C	60
(°F)	(140)
Moisture, %	20
Gas flow rate, m^3/min	220
(acfm)	(7,900)
Gas velocity, m/s	18
(ft/s)	(60)

[a] ℓ/1,000 m^3 (gal/1,000 acf).

TABLE 6-31. MODEL FACILITY PARAMETERS FOR ROTARY CALCINER--KAOLIN INDUSTRY

Parameter/Facility size	Small
PROCESS INFORMATION	
Production	
Design, Mg/h	5
(tons/h)	(6)
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	24
Actual, h/yr	8,000
Feed material	Kaolin clays
Product	Calcined kaolin
Fuel type	Pulverized coal, natural gas
Fuel usage, $\times 10^9$ Joules/Mg	3.5
($\times 10^6$ Btu/ton)	(3)
Maximum operating temperature, °C	820
(°F)	(1500)
Retention time, min	45
CONTROL DEVICE INFORMATION	
Control device inlet	
Gas flow rate, m^3/min	680
(acfm)	(24,000)
Gas temperature, °C	200
(°F)	(400)
Gas moisture, %	10
aghouse	
Cloth type	Nomex
Air-to-cloth ratio[a]	0.6:1
	(2:1)
ΔP, kPa	0.74
(in. w.c.)	(3)
rubber	
ΔP, kPa	6.0
(in. w.c.)	(24)
Liquid-to-gas ratio[b]	1,335
	(10)
CK PARAMETERS[c]	
ight, m	37
(ft)	(120)
ameter, m	0.9/0.8
(ft)	(2.9)/(2.6)
perature, °C	180/60
(°F)	(350)/(140)
sture, %	10/20
flow rate, m^3/min	640/530
(acfm)	(22,600)/(18,800)
velocity, m/s	18
(ft/s)	(60)

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in per m^2 (ft^3/min per ft^2).

00 m^3 (gal/1,000 acf).

number corresponds to baghouse; second number corresponds to scrubber.

TABLE 6-32. MODEL FACILITY PARAMETERS FOR ROTARY CALCINER--LIGHTWEIGHT AGGREGATE INDUSTRY

Parameter/Facility size	Small	Medium	Large
PROCESS INFORMATION			
Production			
Design, Mg/h	18	27	36
(tons/h)	(20)	(30)	(40)
Hours of operation			
Design, h/d	←	24	→
Design, h/yr	←	8,000	→
Actual, h/d	←	24	→
Actual, h/yr	←	8,000	→
Feed material	←	Shale, slate, clay	→
Product	←	Lightweight aggregate	→
Fuel type	←	Pulverized coal	→
Fuel usage, x10^9 Joules/Mg	←	3.3	→
(x10^6 Btu/ton)	←	(2.8)	→
Maximum operating temperature, °C	←	1100	→
(°F)	←	(2000)	→
Retention time, min	←	30-45	→
CONTROL DEVICE INFORMATION			
Control device inlet			
Gas flow rate, m^3/min	1,800[a]/ 1,200[b]	2,800[a]/ 1,900[b]	3,700[a]/ 2,500[b]
(acfm)	(65,000)[a]/ (44,000)[b]	(100,000)[a]/ (68,000)[b]	(130,000)[a]/ (89,000)[b]
Gas temperature, °C	←	425[a]/205[b]	→
(°F)	←	(800)[a]/(400)[b]	→
Gas moisture, %	←	5	→
Baghouse			
Cloth type	←	Nomex	→
Air-to-cloth ratio[c]	←	1.5:1	→
	←	(5:1)	→
ΔP, kPa	←	0.98	→
(in. w.c.)	←	(4)	→
Scrubber			
ΔP, kPa	←	5.7	→
(in. w.c.)	←	(23)	→
Liquid-to-gas ratio[d]	←	1,335	→
	←	(10)	→
STACK PARAMETERS[e]			
Height, m	15	18	21
(ft)	(50)	(60)	(70)
Diameter, m	1.2/1.1	1.5/1.4	1.7/1.6
(ft)	(3.9)/(3.6)	(4.8)/(4.5)	(5.5)/(5.2)
Temperature, °C	←	180/60	→
(°F)	←	(350)/(140)	→
Moisture, %	←	5/20	→
Gas flow rate, m^3/min	1,200/ 1,000	1,800/ 1,600	2,400/ 2,100
(acfm)	(41,400)/ (36,800)	(64,000)/ (56,500)	(83,800)/ (73,500)
Gas velocity, m/s	←	18	→
(ft/s)	←	(60)	→

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[a] Wet scrubber inlet.

[b] Baghouse inlet.

[c] m^3/min per m^2 (ft^3/min per ft^2).

[d] ℓ/1,000 m^3 (gal/1,000 acf).

[e] First number corresponds to baghouse; second number corresponds to scrubber.

TABLE 6-33. MODEL FACILITY PARAMETERS FOR MULTIPLE HEARTH FURNACE--MAGNESIUM COMPOUNDS INDUSTRY

Parameter/Facility size	Small	Medium	Large
PROCESS INFORMATION			
Production			
Design, Mg/h	2	Confidential[4]	Confidential[4]
(tons/h)	(2)		
Hours of operation			
Design, h/d	←	24	→
Design, h/yr	←	8,000	→
Actual, h/d	←	Confidential[4]	→
Actual, h/yr	←	Confidential[4]	→
Feed material	$Mg(OH)_2$	$Mg(OH)_2$/ Magnesite	$Mg(OH)_2$/ Magnesite
Product	←	Magnesia	→
Fuel type	←	Confidential[4]	→
Fuel usage, $x10^9$ Joules/Mg	10.5	10.5 (9)[a]/	10.5 (9)/
($x10^6$ Btu/ton)	(9)	Confidential[4,b]	Confidential[4,b]
Maximum operating temperature, °C (°F)	←	Confidential[4]	→
Retention time, min	←	Confidential[4]	→
CONTROL DEVICE INFORMATION			
Control device	ESP[a]	ESP[a]/Baghouse[b]	ESP[a]/Baghouse[b]
Control device inlet			
Gas flow rate, m^3/min	460	1,400/ Confidential[4,b]	2,000/ Confidential[4,b]
(acfm)	(16,400)	(50,000)/ Confidential[4,b]	(70,000)/ Confidential[4,b]
Gas temperature, °C	370	370/180	370/180
(°F)	(700)	(700)/(350)	(700)/(350)
Gas moisture, %	25	25/Confidential[4,b]	25/Confidential[4,b]
[c]			
Specific collection area[d]	←	1.30	→
	←	(400)	→
P, kPa	←	0.12	→
(in. w.c.)	←	(0.5)	→
ouse			
loth type		Fiberglass	Fiberglass
r-to-cloth ratio[e]		0.4:1	0.4:1
		(1.4:1)	(1.4:1)
, kPa		1.2	1.2
(in. w.c.)		(5)	(5)
PARAMETERS			
ght, m	9	18/12	21/15
(ft)	(30)	(60)/(40)	(70)/(50)
eter, m	0.7	1.2/0.9	1.4/1.1
ft)	(2.3)	(4.0)/(2.8)	(4.7)/(3.6)
erature, °C	290	290/165	290/165
F)	(550)	(550)/(328)	(550)/(328)
ture, %	25	25/3	25/3
flow rate, m^3/min	400	1,200/630	1,700/990
cfm)	(14,300)	(43,500)/(22,400)	(61,000)/(35,000)
velocity, m/s	←	18	→
/s)	←	(60)	→

(OH)$_2$ feed.
nesite feed.
power requirements for ESP is 0.14 watt/m^2 (1.5 watts/ft^2).
m^3/min (ft^2/1,000 acfm).
per m^2 (ft^3/min per ft^2).

TABLE 6-34. MODEL FACILITY PARAMETERS FOR ROTARY CALCINER--MAGNESIUM COMPOUNDS INDUSTRY

Parameter/Facility size	Small	Medium	Large
PROCESS INFORMATION			
Production			
Design, Mg/h (tons/h)	4 (5)	9 (10)	Confidential[4]
Hours of operation			
Design, h/d	←	24	
Design, h/yr	←	8,000	
Actual, h/d	←	24	Confidential[4]
Actual, h/yr	←	8,000	Confidential[4]
Feed material	$Mg(OH)_2$	$Mg(OH)_2$	Magnesite
Product	←	Magnesia	
Fuel type	←	Natural gas, fuel oils, coal, coke	Confidential[4]
Fuel usage, x10^9 Joules/Mg (x10^6 Btu/ton)	11.6 (10)	11.6 (10)	Confidential[4]
Maximum operating temperature, °C (°F)	2100 (3800)	2100 (3800)	Confidential[4]
Retention time, min	120-270	120-270	Confidential[4]
CONTROL DEVICE INFORMATION			
Control device inlet			
Gas flow rate, m^3/min (acfm)	1,400 (50,000)	2,100 (75,000)	Confidential[4]
Gas temperature, °C (°F)	280 (500)	280 (500)	150 (300)
Gas moisture, %	45	45	Confidential[4]
ESP[a]			
Specific collection area[b]	1.0 (300)	1.0 (300)	
ΔP, kPa (in. w.c.)	0.12 (0.5)	0.12 (0.5)	
Baghouse			
Cloth type			Fiberglass
Air-to-cloth ratio[c]			[illegible] ([illegible])
ΔP, kPa (in. w.c.)			[illegible] ([illegible])
STACK PARAMETERS			
Height, m (ft)	20 (65)	21 (70)	[illegible] ([illegible])
Diameter, m (ft)	1.2 (4.1)	1.5 (5.0)	[illegible] ([illegible])
Temperature, °C (°F)	220 (425)	220 (425)	[illegible] ([illegible])
Moisture, %	45	45	Confidential[4]
Gas flow rate, m^3/min (acfm)	1,300 (46,100)	2,000 (69,100)	Confidential[4]
Gas velocity, m/s (ft/s)	18 (60)	18 (60)	

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[a] Assumed power requirement for ESP is 0.14 watt/m^2 (1.5 watts/ft^2).
[b] m^2 per m^3/min (ft^2/1,000 acfm).
[c] m^3/min per m^2 (ft^3/min per ft^2).

TABLE 6-35. MODEL FACILITY PARAMETERS FOR ROTARY DRYER--PERLITE INDUSTRY

Parameter/Facility size	Medium	Large
PROCESS INFORMATION		
Production		
Design, Mg/h	23	Confidential[4]
(tons/h)	(25)	
Hours of operation		
Design, h/d	24	24
Design, h/yr	8,000	8,000
Actual, h/d	8	Confidential[4]
Actual, h/yr	2,900	Confidential[4]
Feed material	Perlite	Perlite
Product	Perlite	Perlite
Fuel type	Natural gas, No. 2 oil	Natural gas, No.2 oil
Fuel usage, $x10^9$ Joules/Mg ($x10^6$ Btu/ton)	Confidential[4]	Confidential[4]
Maximum operating temperature, °C	280	280
(°F)	(500)	(500)
Retention time, min	10-20	10-20
CONTROL DEVICE INFORMATION		
Control device inlet		
Gas flow rate, m^3/min	1,100	1,800
(acfm)	(40,000)	(65,000)
Gas temperature, °C	120	120
(°F)	(250)	(250)
Gas moisture, %	13	13
ghouse		
Cloth type	Nomex	Nomex
Air-to-cloth ratio[a]	1.2:1	1.2:1
	(4:1)	(4:1)
P, kPa	1.5	1.5
(in. w.c.)	(6)	(6)
CK PARAMETERS		
ight, m	9	12
(ft)	(30)	(40)
meter, m	1.1	1.5
(ft)	(3.7)	(4.7)
perature, °C	105	105
°F)	(220)	(220)
sture, %	13	13
flow rate, m^3/min	1,100	1,800
cfm)	(38,300)	(62,300)
velocity, m/s	18	18
t/s)	(60)	(60)

per m^2 (ft^3/min per ft^2).

TABLE 6-36. MODEL FACILITY PARAMETERS FOR EXPANSION FURNACE--PERLITE INDUSTRY

Parameter/Facility size	Small
PROCESS INFORMATION	
Production	
Design, Mg/h	0.9
(tons/h)	(1)
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	8
Actual, h/yr	1,600
Feed material	Dried perlite
Product	Expanded perlite
Fuel type	Natural gas, No. 2 oil
Fuel usage, $\times10^9$ Joules/Mg	2.0
($\times10^6$ Btu/ton)	(1.7)
Maximum operating temperature, °C	980
(°F)	(1800)
Retention time, s	4
CONTROL DEVICE INFORMATION	
Control device inlet	
Gas flow rate, m^3/min	170
(acfm)	(6,000)
Gas temperature, °C	205
(°F)	(400)
Gas moisture, %	5
Baghouse	
Cloth type	Fiberglass
Air-to-cloth ratio[a]	0.6:1
	(2:1)
ΔP, kPa	1.5
(in. w.c.)	(6)
STACK PARAMETERS	
Height, m	11
(ft)	(35)
Diameter, m	0.5
(ft)	(1.5)
Temperature, °C	190
(°F)	(375)
Moisture, %	5
Gas flow rate, m^3/min	160
(acfm)	(5,800)
Gas velocity, m/s	18
(ft/s)	(60)

[a] m^3/min per m^2 (ft^3/min per ft^2).

TABLE 6-37. MODEL FACILITY PARAMETERS FOR FLUID BED DRYER--ROOFING GRANULES INDUSTRY

Parameter/Facility size	Medium
PROCESS INFORMATION	
Production	
Design, Mg/h	36
(tons/h)	(40)
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	16
Actual, h/yr	4,000
Feed material	Coal-fired boiler slag
Product	Dried coal-fired boiler slag (uncoated)
Fuel type	Natural gas
Fuel usage, x10^9 Joules/Mg	0.005
(x10^6 Btu/ton)	(0.004)
Maximum operating temperature, °C	650
(°F)	(1200)
Retention time, min	1
CONTROL DEVICE INFORMATION	
Control device inlet	
Gas flow rate, m^3/min	710
(acfm)	(25,000)
Gas temperature, °C	135
(°F)	(275)
Gas moisture, %	5
Scrubber	
ΔP, kPa	0.8/0.8[a]
(in. w.c.)	(3)/(3)
Liquid-to-gas ratio[b]	1,335
	(10)
STACK PARAMETERS	
Height, m	12
(ft)	(40)
Diameter, m	0.9
(ft)	(3.0)
Temperature, °C	60
(°F)	(140)
Moisture, %	20
Gas flow rate, m^3/min	670
(acfm)	(24,200)
Gas velocity, m/s	18
(ft/s)	(60)

t number corresponds to RA II; second number corresponds to RA III.

,000 m^3 (gal/1,000 acf).

TABLE 6-38. MODEL FACILITY PARAMETERS FOR ROTARY DRYER--ROOFING GRANULES INDUSTRY

Parameter/Facility size	Small	Medium	Large
PROCESS INFORMATION			
Production			
Design, Mg/h	14	54	200
(tons/h)	(15)	(60)	(220)
Hours of operation			
Design, h/d	←	24	[illegible]
Design, h/yr	←	8,000	[illegible]
Actual, h/d	20	24	16
Actual, h/yr	6,000	6,000	4,200
Feed material	←	Rhyolite, diabase, greenstone, quartzite, graystone, granite, syenite.	[illegible]
Product	←	Roofing granule materials.	[illegible]
Fuel type	←	Natural gas, No. 2 oil	[illegible]
Fuel usage, x10^9 Joules/Mg	←	0.3	[illegible]
(x10^6 Btu/ton)	←	(0.3)	[illegible]
Maximum operating temperature, °C	←	200	[illegible]
(°F)	←	(400)	[illegible]
Retention time, min	←	5	[illegible]
CONTROL DEVICE INFORMATION			
Control device inlet			
Gas flow rate, m^3/min	570	850	1,1
(acfm)	(20,000)	(30,000)	(40,0
Gas temperature, °C	←	121	[illegible]
(°F)	←	(250)	[illegible]
Gas moisture, %	←	5	[illegible]
Scrubber			
ΔP, kPa	←	0.8/0.8[a]	[illegible]
(in. w.c.)	←	(3)/(3)	[illegible]
Liquid-to-gas ratio[b]	←	1,335	[illegible]
	←	(10)	[illegible]
STACK PARAMETERS			
Height, m	9	9	[illegible]
(ft)	(30)	(30)	[illegible]
Diameter, m	0.8	1.0	[illegible]
(ft)	(2.7)	(3.3)	[illegible]
Temperature, °C	←	60	
(°F)	←	(140)	
Moisture, %	←	20	
Gas flow rate, m^3/min	570	860	[illegible]
(acfm)	(20,100)	(30,100)	[illegible]
Gas velocity, m/s	←	18	
(ft/s)	←	(60)	

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[a] First number corresponds to RA II; second number corresponds to RA III.

[b] ℓ/1,000 m^3 (gal/1,000 acf).

TABLE 6-39. MODEL FACILITY PARAMETERS FOR FLASH DRYER--TALC INDUSTRY

Parameter/Facility size	Small
PROCESS INFORMATION	
Production	
Design, Mg/h	Confidential[4]
(tons/h)	
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	Confidential[4]
Actual, h/yr	Confidential[4]
Feed material	Talc
Product	Talc
Fuel type	No. 2 oil
Fuel usage, $x10^9$ Joules/Mg	Confidential[4]
($x10^6$ Btu/ton)	
Maximum operating temperature, °C	Confidential[4]
(°F)	
Retention time, s	5
CONTROL DEVICE INFORMATION	
Control device inlet	
Gas flow rate, m^3/min	230
(acfm)	(8,000)
Gas temperature, °C	150
(°F)	(300)
Gas moisture, %	11
Baghouse	
Cloth type	Nomex
Air-to-cloth ratio[a]	0.9:1
	(3:1)
ΔP, kPa	1.5
(in. w.c.)	(6)
TACK PARAMETERS	
Height, m	15
(ft)	(50)
Diameter, m	0.5
(ft)	(1.6)
Temperature, °C	120
(°F)	(250)
Moisture, %	11
as flow rate, m^3/min	210
(acfm)	(7,500)
as velocity, m/s	18
(ft/s)	(60)

min per m^2 (ft^3/min per ft^2).

TABLE 6-40. MODEL FACILITY PARAMETERS FOR ROTARY DRYER--TALC INDUSTRY

Parameter/Facility size	Medium	Large
PROCESS INFORMATION		
Production		
Design, Mg/h	9	18
(tons/h)	(10)	(20)
Hours of operation		
Design, h/d	24	24
Design, h/yr	8,000	8,000
Actual, h/d	24	24
Actual, h/yr	7,400	7,400
Feed material	Talc	Talc
Product	Talc	Talc
Fuel type	Butane, No. 2 oil	Butane, No. 2 oil
Fuel usage, x10^9 Joules/Mg	0.2	0.2
(x10^6 Btu/ton)	(0.2)	(0.2)
Maximum operating temperature, °C	200	200
(°F)	(400)	(400)
Retention time, min	20	20
CONTROL DEVICE INFORMATION		
Control device inlet		
Gas flow rate, m^3/min	280	990
(acfm)	(10,000)	(35,000)
Gas temperature, °C	120	120
(°F)	(250)	(250)
Gas moisture, %	3	3
Baghouse		
Cloth type	Nomex	Nomex
Air-to-cloth ratio[a]	0.9:1	0.9:1
	(3:1)	(3:1)
ΔP, kPa	0.7	0.7
(in. w.c.)	(3)	(3)
STACK PARAMETERS		
Height, m	15	15
(ft)	(50)	(50)
Diameter, m	0.6	1.1
(ft)	(2.0)	(3.5)
Temperature, °C	110	110
(°F)	(225)	(225)
Moisture, %	3	3
Gas flow rate, m^3/min	270	960
(acfm)	(9,600)	(33,000)
Gas velocity, m/s	18	18
(ft/s)	(60)	(60)

[a] m^3/min per m^2 (ft^3/min per ft^2).

TABLE 6-41. MODEL FACILITY PARAMETERS FOR ROTARY CALCINER--TALC INDUSTRY

Parameter/Facility size	Small
PROCESS INFORMATION	
Production	
Design, Mg/h	4
(tons/h)	(5)
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	24
Actual, h/yr	8,000
Feed material	Talc
Product	Talc
Fuel type	Natural gas, butane
Fuel usage, x10^9 Joules/Mg	4.1
(x10^6 Btu/ton)	(3.5)
Maximum operating temperature, °C	1100
(°F)	(2000)
Retention time, min	30
CONTROL DEVICE INFORMATION	
ontrol device inlet	
Gas flow rate, m^3/min	570
(acfm)	(20,000)
Gas temperature, °C	200
(°F)	(400)
Gas moisture, %	7
ghouse	
loth type	Nomex
ir-to-cloth ratio[a]	0.6:1 (2:1)
P, kPa	0.7
(in. w.c.)	(3)
K PARAMETERS	
ight, m	15
(ft)	(50)
meter, m	0.8
(ft)	(2.6)
perature, °C	180
F)	(350)
sture, %	7
flow rate, m^3/min	830
cfm)	(19,000)
velocity, m/s	18
/s)	(60)

per m^2 (ft^3/min per ft^2).

TABLE 6-42. MODEL FACILITY PARAMETERS FOR FLASH DRYER--TITANIUM DIOXIDE INDUSTRY

Parameter/Facility size	Large
PROCESS INFORMATION	
Production	
Design, Mg/h	23
(tons/h)	(25
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	24
Actual, h/yr	8,000
Feed material	Wet 110,
Product	Dry 110,
Fuel type	Natural ga
Fuel usage, $\times 10^9$ Joules/Mg ($\times 10^6$ Btu/ton)	Not reporte
Maximum operating temperature, °C (°F)	Not reporte
Retention time, min	Not reporte
CONTROL DEVICE INFORMATION	
Control device inlet	
Gas flow rate, m³/min	2,1
(acfm)	(75,
Gas temperature, °C	[illegible]
(°F)	[illegible]
Gas moisture, %	[illegible]
Scrubber	
ΔP, kPa	8.5/1
(in. w.c.)	(34)/(
Liquid-to-gas ratio[b]	1.
	(
STACK PARAMETERS	
Height, m	
(ft)	[illegible]
Diameter, m	[illegible]
(ft)	[illegible]
Temperature, °C	
(°F)	[illegible]
Moisture, %	
Gas flow rate, m³/min	1.
(acfm)	[illegible]
Gas velocity, m/s	
(ft/s)	

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[a] First number corresponds to RA II; second number corresponds to RA III.
[b] ℓ/1,000 m³ (gal/1,000 acf).

TABLE 6-43. MODEL FACILITY PARAMETERS FOR FLUID BED DRYER-- TITANIUM DIOXIDE INDUSTRY

Parameter/Facility size	Large
ROCESS INFORMATION	
roduction	Confidential[4]
Design, Mg/h	
(tons/h)	
ours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	Confidential[4]
Actual, h/yr	Confidential[4]
ed material	Confidential[4]
oduct	Confidential[4]
l type	Confidential[4]
l usage, x10^9 Joules/Mg	Confidential[4]
(x10^6 Btu/ton)	
imum operating temperature, °C	Confidential[4]
°F)	
ention time, min	Confidential[4]
ROL DEVICE INFORMATION	
rol device inlet	
s flow rate, m^3/min	960
(acfm)	(34,000)
s temperature, °C	200
(°F)	(400)
s moisture, %	10
use	
th type	Nomex
-to-cloth ratio[a]	1.2:1
	(4.1:1)
kPa	0.98
in. w.c.)	(4)
er	
kPa	8.5/10.7[b]
n. w.c.)	(34)/(43)
id-to-gas ratio[c]	1,335
	(10)
ARAMETERS[d]	
t, m	21
)	(70)
ter, m	1.0/0.9
)	(3.4)/(3.1)
rature, °C	180/60
)	(350)/(140)
re, %	10/20
ow rate, m^3/min	900/760
m)	(32,000)/(26,700)
locity, m/s	18
s)	(60)

---

per m^2 (ft^3/min per ft^2)

mber corresponds to RA II; second number corresponds to RA III.

m^3 (gal/1,000 acf).

mber corresponds to baghouse; second number corresponds to scrubber.

TABLE 6-44. MODEL FACILITY PARAMETERS FOR ROTARY DRYER--TITANIUM DIOXIDE INDUSTRY

Parameter/Facility size	Small	Medium	Large
PROCESS INFORMATION			
Production			
Design, Mg/h	2	6	Confidential
(tons/h)	(2)	(7)	
Hours of operation			
Design, h/d	←	24	
Design, h/yr	←	8,000	
Actual, h/d	24	24	Confidential
Actual, h/yr	8,000	8,000	Confidential
Feed material	←	TiO_2 ore	
Product	←	Dry TiO_2 ore	
Fuel type	←	Natural gas, No. 2 or No. 6 fuel oil	
Fuel usage, x10^9 Joules/Mg	←	1.4	
(x10^6 Btu/ton)	←	(1.2)	
Maximum operating temperature, °C	←	430	
(°F)	←	(800)	
Retention time, min	←	20	
CONTROL DEVICE INFORMATION			
Control device inlet			
Gas flow rate, m^3/min	70	180	
(acfm)	(2,500)	(6,500)	
Gas temperature, °C	←	170	
(°F)	←	(340)	
Gas moisture, %	←	7	
Baghouse			
Cloth type	←	Nomex	
Air-to-cloth ratio[a]	←	1.2:1	
	←	(4:1)	
ΔP, kPa	←	1.2	
(in. w.c.)	←	(5)	
STACK PARAMETERS			
Height, m	9	12	
(ft)	(30)	(40)	
Diameter, m	0.3	0.5	
(ft)	(0.9)	(1.5)	
Temperature, °C	←	155	
(°F)	←	(310)	
Moisture, %	←	7	
Gas flow rate, m^3/min	70	180	
(acfm)	(2,400)	(6,300)	
Gas velocity, m/s	←	18	
(ft/s)	←	(60)	

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[a] m^3/min per m^2 (ft^3/min per ft^2).

TABLE 6-45. MODEL FACILITY PARAMETERS FOR ROTARY DRYER (INDIRECT)--TITANIUM DIOXIDE INDUSTRY

Parameter/Facility size	Medium
PROCESS INFORMATION	
Production	
Design, Mg/h	11
(tons/h)	(12)
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	24
Actual, h/yr	8,000
Feed material	TiO_2 ore
Product	Dry TiO_2 ore
Fuel type	Natural gas
Fuel usage, x10^9 Joules/Mg	1.2
(x10^6 Btu/ton)	(1)
Maximum operating temperature, °C	135
(°F)	(275)
Retention time, min	20
CONTROL DEVICE INFORMATION	
Control device inlet	
Gas flow rate, m^3/min	80
(acfm)	(2,850)
Gas temperature, °C	95
(°F)	(200)
Gas moisture, %	5
Scrubber	
ΔP, kPa	2.5/4.2[a]
(in. w.c.)	(10)/(17)
Liquid-to-gas ratio[b]	1.1
	(8)
STACK PARAMETERS	
Height, m	11
(ft)	(35)
Diameter, m	0.3
(ft)	(1.0)
Temperature, °C	40
(°F)	(107)
Moisture, %	8
Gas flow rate, m^3/min	70
(acfm)	(2,500)
Gas velocity, m/s	18
(ft/s)	(60)

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[a] First number corresponds to RA II; second number corresponds to RA III.
[b] 1,000 m^3 (gal/1,000 acf).

TABLE 6-46. MODEL FACILITY PARAMETERS FOR SPRAY DRYER--TITANIUM DIOXIDE INDUSTRY

Parameter/Facility size	Small	Medium	Large
PROCESS INFORMATION			
Production Design, Mg/h (tons/h)	←	Confidential[4]	→
Hours of operation Design, h/d	←	24	→
Design, h/yr	←	8,000	→
Actual, h/d	←	Confidential[4]	→
Actual, h/yr	←	Confidential[4]	→
Feed material	←	TiO_2 slurry	→
Product	←	TiO_2	→
Fuel type	←	Natural gas	→
Fuel usage, x10^9 Joules/Mg	←	4.9	→
(x10^6 Btu/ton)	←	(4.2)	→
Maximum operating temperature, °C	←	700	→
(°F)	←	(1300)	→
Retention time, s	←	5	→
CONTROL DEVICE INFORMATION			
Control device inlet Gas flow rate, m³/min	340	850	1,400
(acfm)	(12,000)	(30,000)	(48,000)
Gas temperature, °C	←	150	→
(°F)	←	(300)	→
Gas moisture, %	←	21	→
Baghouse Cloth type	←	Nomex	→
Air-to-cloth ratio[a]	←	1.2:1	→
	←	(4:1)	→
ΔP, kPa	←	1.2	→
(in. w.c.)	←	(5)	→
STACK PARAMETERS			
Height, m	18	21	
(ft)	(60)	(70)	
Diameter, m	0.6	1.0	
(ft)	(2.0)	(3.2)	
Temperature, °C	←	130	→
(°F)	←	(270)	→
Moisture, %	←	21	→
Gas flow rate, m³/min	330	820	
(acfm)	(11,500)	(28,800)	
Gas velocity, m/s	←	18	→
(ft/s)	←	(60)	→

[a] m³/min per m² (ft³/min per ft²).

TABLE 6-47. MODEL FACILITY PARAMETERS FOR ROTARY CALCINER--TITANIUM DIOXIDE INDUSTRY

Parameter/Facility size	Small	Medium
PROCESS INFORMATION		
Production		
Design, Mg/h	Confidential[4]	Confidential[4]
Hours of operation		
Design, h/d	24	24
Design, h/yr	8,000	8,000
Actual, h/d	Confidential[4]	Confidential[4]
Actual, h/yr	Confidential[4]	Confidential[4]
Feed material	TiO_2 slurry	TiO_2 slurry
Product	TiO_2	TiO_2
Fuel type	Confidential[4]	Confidential[4]
Fuel usage, $x10^9$ Joules/Mg ($x10^6$ Btu/ton)	Confidential[4]	Confidential[4]
Maximum operating temperature, °C	1100	1100
(°F)	(2000)	(2000)
Retention time, h	12	12
CONTROL DEVICE INFORMATION		
Control device inlet		
Gas flow rate, m^3/min (acfm)	Confidential[4]	Confidential[4]
Gas temperature, °C (°F)	Confidential[4]	Confidential[4]
Gas moisture, %	Confidential[4]	Confidential[4]
crubber		
ΔP, kPa (in. w.c)	Confidential[4]	Confidential[4]
Liquid-to-gas ratio[a]	Confidential[4]	Confidential[4]
ACK PARAMETERS		
eight, m	11	14
(ft)	(35)	(45)
ameter, m	0.9	1.3
(ft)	(3.1)	(4.4)
perature, °C	60	60
(°F)	(140)	(140)
isture, %	20	20
flow rate, m^3/min	760	1,500
(acfm)	(26,700)	(53,300)
velocity, m/s	18	18
(ft/s)	(60)	(60)

000 m^3 (gal/1,000 acf).

TABLE 6-48. MODEL FACILITY PARAMETERS FOR FLUID BED DRYER--VERMICULITE INDUSTRY

Parameter/Facility size	Large
PROCESS INFORMATION	
Production	
Design, Mg/h	54
(tons/h)	(60)
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	24
Actual, h/yr	4,800
Feed material	Vermiculite
Product	Vermiculite
Fuel type	Propane, No. 5 oil
Fuel usage, x10^9 Joules/Mg	0.01
(x10^6 Btu/ton)	(0.01
Maximum operating temperature, °C	[illegible]
(°F)	[illegible]
Retention time, min	[illegible]
CONTROL DEVICE INFORMATION	
Control device inlet	
Gas flow rate, m^3/min	[illegible]
(acfm)	(35,0[illegible]
Gas temperature, °C	[illegible]
(°F)	[illegible]
Gas moisture, %	[illegible]
Baghouse	
Cloth type	[illegible]
Air-to-cloth ratio[a]	[illegible]
	[illegible]
ΔP, kPa	[illegible]
(in. w.c.)	[illegible]
STACK PARAMETERS	
Height, m	[illegible]
(ft)	[illegible]
Diameter, m	[illegible]
(ft)	[illegible]
Temperature, °C	[illegible]
(°F)	[illegible]
Moisture, %	[illegible]
Gas flow rate, m^3/min	[illegible]
(acfm)	[illegible]
Gas velocity, m/s	[illegible]
(ft/s)	[illegible]

[a] m^3/min per m^2 (ft^3/min per ft^2).

TABLE 6-49. MODEL FACILITY PARAMETERS FOR ROTARY DRYER-- VERMICULITE INDUSTRY

Parameter/Facility size	Medium	Large
PROCESS INFORMATION		
Production		
Design, Mg/h	9 (10)	18 (20)
Hours of operation		
Design, h/d	24	24
Design, h/yr	8,000	8,000
Actual, h/d	8	8
Actual, h/yr	2,500	2,500
Feed material	Vermiculite	Vermiculite
Product	Vermiculite	Vermiculite
Fuel type	No. 2, 4, 5 oil	No. 2, 4, 5 oil
Fuel usage, x10^9 Joules/Mg (x10^6 Btu/ton)	0.5 (0.4)	0.5 (0.4)
Maximum operating temperature, °C (°F)	200 (400)	200 (400)
Retention time, min	25	25
CONTROL DEVICE INFORMATION		
Control device inlet		
Gas flow rate, m^3/min	570	600
(acfm)	(20,000)	(21,000)
Gas temperature, °C	160	160
(°F)	(325)	(325)
Gas moisture, %	8	8
Scrubber		
ΔP, kPa	0.8/1.0[a]	0.8/1.0[a]
(in. w.c.)	(3)/(4)	(3)/(4)
Liquid-to-gas ratio[b]	1,335 (10)	1,335 (10)
STACK PARAMETER		
Height, m	12	12
(ft)	(40)	(40)
Diameter, m	0.8	0.8
(ft)	(2.5)	(2.6)
Temperature, °C	60	60
(°F)	(140)	(140)
Moisture, %	20	20
Gas flow rate, m^3/min	500	520
(acfm)	(17,600)	(18,500)
Gas velocity, m/s	18	18
(ft/s)	(60)	(60)

First number corresponds to RA II; second number corresponds to RA III.

/1,000 m^3 (gal/1,000 acf).

TABLE 6-50. MODEL FACILITY PARAMETERS FOR EXPANSION FURNACE--VERMICULITE INDUSTRY

Parameter/Facility size	Small
PROCESS INFORMATION	
Production	
Design, Mg/h	0.9
(tons/h)	(1)
Hours of operation	
Design, h/d	24
Design, h/yr	8,000
Actual, h/d	16
Actual, h/yr	3,000
Feed material	Dried vermiculite
Product	Expanded vermiculite
Fuel type	Natural gas, No. 2 oil
Fuel usage, $x10^9$ Joules/Mg	2.2
($x10^6$ Btu/ton)	(1.9)
Maximum operating temperature, °C	815
(°F)	(1500)
Retention time, min	20
CONTROL DEVICE INFORMATION	
Control device inlet	
Gas flow rate, m^3/min	140
(acfm)	(5,000)
Gas temperature, °C	120
(°F)	(250)
Gas moisture, %	4
Baghouse	
Cloth type	Fiberglass
Air-to-cloth ratio[a]	0.6:1 (2:1)
ΔP, kPa	0.74
(in. w.c.)	(3)
STACK PARAMETERS	
Height, m	11
(ft)	(35)
Diameter, m	0.4
(ft)	(1.3)
Temperature, °C	110
(°F)	(225)
Moisture, %	4
Gas flow rate, m^3/min	140
(acfm)	(4,800)
Gas velocity, m/s	18
(ft/s)	(60)

[a] m^3/min per m^2 (ft^3/min per ft^2).

6.3 REFERENCES FOR CHAPTER 6

1. Memo from Shular, J. A., and Y. N. Doshi, MRI, to Neuffer, W. J., EPA/ISB. Revised final model facility parameters, baseline control emission levels, and regulatory alternatives. September 7, 1984.

2. Memo from Carney, L., MRI, to 7702-L Project File. Determination of baseline emission levels. June 29, 1984.

3. Memo from Doshi, Y. N., MRI, to 7702-L Project File. Baseline control technology selection summary. May 31, 1984.

4. Memo from Kowalski, A. J., and M. E. Upchurch, MRI, to 7702-L Project File. Confidential addendum to Calciners and Dryers in Mineral Industries BID document. July 12, 1985.

7. ENVIRONMENTAL AND ENERGY IMPACTS

An analysis of the environmental and energy impacts of the regulatory alternatives specified in Chapter 6 for control of particulate matter emissions from dryers and calciners in mineral industries is presented in this chapter. The incremental increase or decrease in air pollution, water pollution, solid waste, and energy consumption for RA II and RA III as compared to the baseline emission level (RA I) are discussed. The baseline control level represents no change from existing regulations. All impacts are based on the typical-size model facility parameters presented in Chapter 6 and on industry growth projections discussed in Chapter 9. Documentation of the calculations that were made to evaluate the environmental and energy impacts presented in Chapter 7 is provided in Reference 1.

Table 7-1 presents industry growth projections as the production ubject to new source performance standards (NSPS) in 1990. Table 7-2 resents the production subject to NSPS in 1990 for each affected facility n each industry. In some industries, the raw material is processed in ore than one affected facility to produce the final product (e.g., tanium dioxide industry). Also, in a few industries, only a portion the raw material mined is dried or calcined (e.g., ball clay industry).

1 AIR POLLUTION IMPACTS

In this section, the impact of each regulatory alternative on air lution is considered. Two impacts were addressed in this analysis: ary impacts, the reduction of particulate matter emissions associated each regulatory alternative, and secondary impacts, those pollutants lting from generation of the energy necessary to operate the control ces. The impact on ambient air quality in the vicinity of the sources is evaluated by means of dispersion modeling for each model facility. Dispersion modeling is discussed in Subsections 7.1.1.1 and 7.1.1.2.

7.1.1 Primary Air Pollution Impacts

Table 7-3 presents the total annual particulate matter emissions under each regulatory alternative from typical-size facilities in each mineral industry. Table 7-4 presents the annual emission reduction below the baseline level for each source and each regulatory alternative. Table 7-5 summarizes the nationwide annual particulate matter emissions and reductions below baseline.

The total baseline particulate matter emissions from all affected facilities are 10,200 megagrams per year (Mg/yr) (11,300 tons/yr). The particulate matter emissions from all affected facilities for RA II and RA III are 2,700 Mg/yr (3,000 tons/yr) and 2,300 Mg/yr (2,500 tons/yr), respectively. The total annual particulate matter emission reduction below baseline for RA II is 7,500 Mg/yr (8,300 tons/yr), or 74 percent. The total annual particulate matter emission reduction below baseline for RA III is 7,900 Mg/yr (8,800 tons), or 78 percent.

Dispersion modeling was used to predict the contribution by dryers and calciners in each mineral industry to the ambient particulate matter concentration. The dispersion model used and the results obtained are discussed in the following subsections.

7.1.1.1 Model Description. The model used in this dispersion analysis was the Industrial Source Complex (ISC) model in the short-term mode (ISCST) and in the long-term mode (ISCLT). The ISCST model was used to calculate 24-hour impacts, and the ISCLT model was used to calculate annual impacts. General modeling parameters needed for the ISC models are presented in Table 7-6. The ISC models require input data on sources, meteorology, and receptors. These items are discussed below.

7.1.1.1.1 Source data. Table 7-6 also presents the particle size distribution data included for modeling for all sources and regulatory alternatives. Sensitivity tests were performed with the model to evaluate the significance of gravitational settling because only a small fraction of the emitted particles were larger than 20 μm (8 $\mathrm{x}10^{-4}$ in.). Analysis [illegible] modeling results, with particle settling and without settling, indicated that the differences between downwind concentration impacts were about 6 percent. For this reason, particle settling was not considered in the final modeling runs, and all emissions were treated as gaseous emissions.[2]

The following data are required by the ISC models for each facility and regulatory alternative:

1. Emission height, in meters (m);
2. Exit diameter, in meters (m);
3. Exit velocity, in meters per second (m/s);
4. Exit temperature, in degrees kelvin (K); and
5. Particulate matter emission rate, in grams per second (g/s).

Table 7-7 summarizes these characteristics for each dryer and calciner for the three regulatory alternatives described in Chapter 6.

7.1.1.1.2 Meteorological data. The STAR meteorological data bases used with ISCLT are listed in Reference 2, together with the geographic regions they represent. Wind roses for these sets are also presented in Reference 2. The mixing height was set at 1,600 m (5,250 ft), and the atmospheric temperature was set at 298K (77°F) for all ISCLT runs.

The hourly meteorological data bases used with ISCST are presented in Reference 2. To reduce the amount of meteorological data to be processed, a program (METSORT) was written to sort a year of data in decreasing order of maximum estimated 24-hour average concentration impact, and to select the 10 percent subset of the year (37 days) with the highest estimated 24-hour impacts for a given emission source. The only units for which this procedure was not used were rotary dryers (indirect) in the titanium dioxide industry and expansion furnaces in he vermiculite industry. These two sources have the short stacks and ould be most severely affected by building downwash. For each of these wo sources, a full year of meteorological data was used.

7.1.1.1.3 Receptor grids. The ISC models calculate concentration pacts for receptors at specified radial distances from the center of source. The set of ring distances used for each source is presented Reference 2.

7.1.1.2 Discussion of Dispersion Calculations. Annual arithmetic concentrations were calculated by the ISCLT model. Annual geometric mean concentrations were not calculated because of the problems inherent in the specification of an appropriate background concentration. Concentration impact results were computed with an assumed ambient background concentration equal to zero.

The maximum annual arithmetic mean of total suspended particulate (TSP) concentrations calculated by the ISCLT model are presented in Table 7-8 for each of the regulatory alternatives for each source. Table 7-9 presents maximum 24-hour and highest second-highest 24-hour TSP concentrations calculated by the ISCST for each of the regulatory alternatives for each source. Although modeling was performed using more than one meteorological data set for each source, only the worst case impacts are listed.

The ambient particulate matter concentrations in Tables 7-8 and 7-9 include those calculated for full-time operation and, where appropriate, for part-time operation. The latter concentrations are shown in parentheses. In the context of 24-hour average concentrations, "full-time" refers to 24 hours per day of operation, and "part-time" refers to 12 hours per day of operation (applicable to dryers only). In the context of annual average concentrations, "full-time" refers to 8,000 hours per year of operation, and "part-time" refers to 4,000 hours per year of operation.

The impacts of the modeled TSP concentrations can be compared to the following National Ambient Air Quality Standards (NAAQS):

Averaging time	Standard	Particulate matter concentration, µg/m³
Annual geometric mean	Primary	75
24-hour maximum (not to be exceeded more than once per year)	Primary Secondary	260 150

7.1.1.2.1 Annual concentration impacts. The highest calculated annual average concentrations for RA II and RA III are 4.0 and 2.5 μg/m^3, respectively, from a rotary dryer (indirect) in the titanium dioxide industry. These figures are well below the primary and secondary annual TSP NAAQS.

7.1.1.2.2 Twenty-four hour concentration impacts. The maximum calculated highest second-highest 24-hour average concentrations for RA II and RA III, respectively, are 38 μg/m^3 from a roofing granules rotary dryer and 36 μg/m^3 from a titanium dioxide rotary calciner. These figures are well below the primary and secondary highest second-highest 24-hour TSP NAAQS.

7.1.2 Secondary Air Pollution Impacts

Generation of the electric power required to operate the control devices will cause particulate matter, SO_2, and oxides of nitrogen (NO_x) emissions to be produced by the electric power generator. Secondary emissions were calculated assuming that electric power to the control devices was supplied by a coal-fired power plant and that the power plant complies with the standards of performance for electric utility steam generating units. The applicable standards limit particulate matter emissions to 13 nanograms per Joule (ng/J) (0.03 lb/million British thermal unit [Btu]) heat input, SO_2 emissions to 520 ng/J (1.20 lb/million Btu) heat input, and NO_x emissions to 260 ng/J (0.6 lb/million Btu) heat input.[3]

The nationwide secondary particulate matter emissions above baseline for RA II and RA III, respectively, are 2 Mg/yr (3 tons/yr) and 3 Mg/yr (3 tons/yr). The nationwide secondary SO_2 emissions above baseline for RA II and RA III, respectively, are 80 Mg/yr (90 tons/yr) and 90 Mg/yr (90 tons/yr). The nationwide secondary NO_x emissions above baseline for RA II and RA III, respectively, are 40 Mg/yr (40 tons/yr) and 40 Mg/yr (50 tons/yr).

7.2 WATER POLLUTION IMPACTS

Wet scrubbers (WS's) are the only control devices in the mineral industries that generate wastewater streams requiring treatment or disposal. Typically, a water stream contaminated with particulate matter from a scrubber is treated and clarified in a pond on the site. The clarified water is recirculated to the scrubber and the sludge is periodically removed from the pond. There is no water discharge from the scrubber into navigable waterways. Therefore, there would be no adverse water pollution impacts due to implementation of any of the regulatory alternatives.

7.3 SOLID WASTE IMPACTS

The material collected by baghouses (BH's) and ESP's is typically recycled back to the production process or is sold directly. Therefore, there are no solid waste impacts from BH's and ESP's. The only solid waste impacts would be from the solids in the sludge produced by WS's. Typical sludge from a settling pond contains about 70 percent water.[4,5] The solids in the sludge are composed primarily of minerals that are processed by dryers and calciners. Table 7-10 presents the amount of solid waste generated over baseline levels for each process unit under each regulatory alternative. The nationwide solid waste increase (as sludge containing 70 percent moisture) over baseline levels in 1990 would be 7,000 Mg/yr (7,700 tons/yr) for RA II and 7,500 Mg/yr (8,300 tons/yr) for RA III. There are no solid waste impacts from WS's used in the magnesium compounds and titanium dioxide industries because the sludge generated by WS's used in these industries is recycled to the process.

Solid wastes from WS's that are used to control emissions from dryers and calciners in mineral industries presently are not classified as hazardous wastes under the regulations adopted to implement the Resource Conservation and Recovery Act (RCRA).[5]

7.4 ENERGY IMPACTS

Operation of BH's, ESP's, and WS's to control particulate matter emissions requires the use of electrical energy. The electricity is used to operate fans to move air through BH's, ESP's, and WS's, and for pumps to circulate water for WS's. For ESP's, electricity is also required to create the corona discharge.

Table 7-11 shows the annual amount of energy required to operate control devices for affected facilities under each regulatory alternative.

Table 7-12 shows the incremental amount of energy required over baseline levels to operate control devices for affected facilities and the amount of energy required to operate the facilities. For RA II and RA III, the nationwide increase in the amount of energy required to operate control devices over baseline levels is 16,000 MWh and 17,000 MWh, respectively. To meet this additional electrical energy demand, less than 1 percent of the capacity of a new 500 MW power plant would be required. The incremental increase in the amount of energy required to operate control equipment for RA II and RA III are negligible (less than 1 percent) compared to the amount of energy required to operate dryers and calciners. Therefore, the additional amount of electrical energy required to operate control equipment for RA II and RA III above the baseline level will not significantly increase the demand for electrical energy at mineral processing plants.

7.5 OTHER ENVIRONMENTAL IMPACTS

The noise introduced by air pollution control equipment at new or modified facilities (e.g., fan noise) will not significantly increase the noise levels beyond those already produced by processing equipment at the plant.

7.6 OTHER ENVIRONMENTAL CONCERNS

7.6.1 Irreversible and Irretrievable Commitment of Resources

As discussed in Section 7.4, the regulatory alternatives will cause an increase in the irreversible and irretrievable commitment of energy resources. However, this increased demand for energy to operate pollution control equipment for dryers and calciners is insignificant (less than 1 percent) compared to the energy demands to operate the entire plant.

7.6.2 Environmental Impact of Delayed Standards

The impacts of delay in proposal of the standards from 1985 to 1988 re discussed in this section. Tables 7-13 and 7-14 present industry rowth projections as the production subject to NSPS in 1993 for proposal n 1985 and 1988, respectively. Tables 7-15 and 7-16 present the produc-on subject to NSPS in 1993 for each affected facility for proposal in 85 and 1988, respectively.

Tables 7-17 and 7-18 present the total annual particulate matter emissions in 1993 under each regulatory alternative from each facility for proposal in 1985 and 1988, respectively. Table 7-19 summarizes and compares the emission reduction of delayed standards (proposal in 1988) with the emission reduction that would be achieved in the same year if standards were proposed in 1985. As shown, the emission reductions in 1993 would decrease from 12,500 to 8,400 Mg (13,800 to 9,300 tons) under RA II and would decrease from 13,200 to 9,000 Mg (14,600 to 9,900 tons) under RA III.

Since there is no water pollution impact and only negligible energy consumption impacts associated with RA II and RA III, there is no significant benefit to be obtained from delaying the proposed standards. Furthermore, there does not appear to be any emerging emission control technology that could further decrease particulate matter emissions or control costs below that represented by the control devices considered here. Consequently, there are no benefits or advantages to delaying the proposed standards.

TABLE 7-1. PROJECTION OF PRODUCTION FROM NEW/REPLACED FACILITIES (1985-1990)

Industry	Annual production, 10^3 Mg	Annual production, (10^3 tons)	Growth rate, %[a]	1985 production, 10^3 Mg	1985 production, (10^3 tons)	1990 production, 10^3 Mg	1990 production, (10^3 tons)	Production subject to NSPS,[b] 10^3 Mg (10^3 tons) New		Replacement		Total	
Alumina	5,960	(6,570)[c]	6.3	7,611	(8,389)	10,329	(11,386)	2,719	(2,997)	1,268	(1,398)	3,987	(4,395)
Ball clay	708	(708)[d]	3	773	(852)	896	(988)	123	(136)	129	(142)	252	(278)
Bentonite	2,540	(2,800)[d]	3	2,776	(3,060)	3,218	(3,547)	442	(487)	463	(510)	904	(997)
Diatomite	553	(610)[d]	2	587	(647)	648	(714)	61	(67)	98	(108)	159	(175)
Feldspar	526	(580)[d]	2	559	(616)	617	(680)	58	(64)	93	(103)	152	(167)
Fire clay	934	(1,030)[d]	3	1,022	(1,126)	1,184	(1,305)	162	(179)	171	(188)	333	(367)
Fuller's earth	1,533	(1,690)[d]	3	1,676	(1,847)	1,942	(2,141)	267	(294)	279	(308)	546	(602)
Gypsum	12,741	(14,044)[d]	3.3	14,044	(15,481)	16,520	(18,210)	2,476	(2,729)	2,341	(2,580)	4,816	(5,309)
Industrial sand	23,769	(26,200)[d]	1.5	24,855	(27,397)	26,775	(29,514)	1,921	(2,117)	4,142	(4,566)	6,063	(6,683)
Kaolin	5,715	(6,300)[d]	3	6,245	(6,884)	7,239	(7,980)	994	(1,096)	1,041	(1,147)	2,035	(2,243)
Lightweight aggregate	4,440	(4,894)[c]	3[e]	4,997	(5,508)	5,792	(6,385)	796	(877)	833	(918)	1,628	(1,795)
Magnesium compounds	680	(750)[d]	1.8	718	(791)	785	(865)	67	(74)	120	(132)	187	(206)
Perlite	481	(530)[d]	3	525	(579)	609	(671)	83	(92)	88	(97)	171	(189)
Roofing granules	4,069	(4,485)[c]	1.2	4,267	(4,704)	4,530	(4,993)	262	(289)	711	(784)	973	(1,073)
Talc	962	(1,060)[d]	2	1,021	(1,125)	1,127	(1,242)	106	(117)	171	(188)	277	(305)
Titanium dioxide	576	(635)[d]	2	611	(674)	675	(744)	64	(70)	102	(112)	165	(182)
Vermiculite													
Crude	281	(310)[d]	2	298	(329)	329	(363)	31	(34)	50	(55)	81	(89)
Expanded	249	(274)[c]	2	269	(297)	298	(328)	28	(31)	45	(50)	73	(81)

[a] Bureau of Mines data.
[b] 30 year life assumed.
[c] 1981 production.
[d] 1982 production.
[e] Assume same growth as for other clays: i.e., 3 percent.

TABLE 7-2. PRODUCTION SUBJECT TO NSPS FOR EACH AFFECTED FACILITY (1985-1990)

Industry/facility	New: Percent new	New: 10^3 Mg	New: (10^3 tons/yr)	Replacement: Percent replaced	Replacement: 10^3 Mg	Replacement: (10^3 tons/yr)	Total: 10^3 Mg	Total: (10^3 tons/yr)
Alumina								
Flash calciner	50	1,360	(1,499)	0	0	(0)	1,360	(1,499)
Rotary calciner	50	1,360	(1,499)	100	1,268	(1,398)	2,628	(2,897)
Ball clay[a]								
Rotary dryer (indirect)	15	18	(20)	5	6	(7)	24	(27)
Vibrating-grate dryer (indirect)	35	44	(48)	45	58	(64)	102	(112)
Bentonite[b]								
Fluid bed dryer	0	0	(0)	16	74	(82)	74	(82)
Rotary dryer	80	354	(390)	64	296	(326)	650	(716)
Diatomite								
Flash dryer	70	43	(47)	70	69	(76)	112	(123)
Rotary dryer	30	18	(20)	30	29	(32)	47	(52)
Rotary calciner	90	54	(60)	90	88	(97)	142	(157)
Feldspar								
Fluid bed dryer	50	29	(32)	25	15	(16)	44	(48)
Rotary dryer	50	29	(32)	75	44	(48)	73	(80)
Fire clay								
Rotary dryer	81	132	(145)	81	138	(152)	269	(297)
Vibrating-grate dryer	9	15	(16)	9	15	(17)	30	(33)
Rotary calciner	20	33	(36)	20	34	(38)	67	(74)
Fuller's earth								
Fluid bed dryer	10	26	(29)	10	28	(31)	54	(60)
Rotary dryer	40	107	(118)	40	112	(123)	218	(241)
Rotary calciner	50	133	(147)	50	140	(154)	273	(301)
Gypsum								
Rotary dryer	100	2,476	(2,729)	100	2,341	(2,580)	4,816	(5,309)
Flash calciner	50	1,238	(1,365)	50	1,170	(1,290)	2,409	(2,655)
Kettle calciner	50	1,238	(1,365)	50	1,170	(1,290)	2,409	(2,655)
Industrial sand								
Fluid bed dryer	60	1,152	(1,270)	50	2,071	(2,283)	3,223	(3,553)
Rotary dryer	40	768	(847)	50	2,071	(2,283)	2,840	(3,130)
Kaolin[c]								
Rotary dryer	27	269	(296)	27	281	(310)	550	(606)
Spray dryer	63	626	(690)	63	656	(723)	1,282	(1,413)
Flash calciner	0.1	1	(1)	0.1	1	(1)	2	(2)
Multiple hearth furnace	9.8	97	(107)	9.8	102	(112)	199	(219)
Rotary calciner	0.1	1	(1)	0.1	1	(1)	2	(2)

TABLE 7-2. (continued)

Industry/facility	New: Percent new	New: 10^3 Mg	New: (10^3 tons/yr)	Replacement: Percent replaced	Replacement: 10^3 Mg	Replacement: (10^3 tons/yr)	Total: 10^3 Mg	Total: (10^3 tons/yr)
Lightweight aggregate								
Rotary calciner	100	796	(877)	100	833	(918)	1,628	(1,795)
Magnesium compounds								
Multiple hearth furnace	60	40	(44)	50	34	(37)	73	(81)
Rotary calciner	40	27	(30)	50	34	(37)	61	(67)
Perlite								
Rotary dryer	100	83	(92)	100	88	(97)	171	(189)
Expansion furnace	60	50	(55)	60	53	(58)	103	(113)
Roofing granules								
Fluid bed dryer	5	13	(14)	5	35	(39)	48	(53)
Rotary dryer	95	249	(275)	95	676	(745)	925	(1,020)
Talc								
Flash dryer	90	95	(105)	90	153	(169)	249	(274)
Rotary dryer	10	11	(12)	10	17	(19)	28	(31)
Rotary calciner	30	32	(35)	30	51	(56)	83	(91)
Titanium dioxide								
Flash dryer	20	13	(14)	0	0	(0)	13	(14)
Fluid bed dryer[f]	0	0	(0)	0	0	(0)	0	(0)
Rotary dryer (direct)	63	40	(44)	63	64	(71)	104	(115)
Rotary dryer (indirect)	32	20	(22)	32	33	(36)	53	(58)
Spray dryer	57	36	(40)	77	78	(86)	114	(126)
Rotary calciner	18	12	(13)	18	18	(20)	30	(33)
Vermiculite								
Fluid bed dryer	50[d]	15	(17)	50[d]	25	(28)	41	(45)
Rotary dryer	50[d]	15	(17)	50[d]	25	(28)	41	(45)
Expansion furnace	100[e]	28	(31)	100[e]	45	(50)	73	(81)

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[a] 50 percent of ball clay produced is dried. Trend is toward vibrating-grate dryer.

[b] 80 percent of bentonite produced is dried.

[c] 90 percent of kaolin produced is dried or calcined. 10 percent is unprocessed. 10 percent is both dried and calcined.

[d] 50 percent of crude vermiculite is processed by rotary dryers and 50 percent by fluid bed dryers.

[e] 100 percent of expanded vermiculite is processed by expansion furnaces.

[f] Only one fluid bed dryer (a new unit) is used in this industry and, according to industry sources, there is no trend toward the use of fluid bed dryers.

TABLE 7-3. ANNUAL PARTICULATE EMISSIONS FROM DRYERS AND CALCINERS (1990)

Industry/facility	Particulate emissions, Mg/yr (tons/yr)					
	RA I[a]		RA II		RA III	
Alumina						
Flash calciner	586	(646)	156	(172)	156	(172)
Rotary calciner	2,379	(2,622)	501	(552)	501	(552)
Ball clay						
Rotary dryer (indirect)	7	(8)	2	(2)	9	(1)
Vibrating-grate dryer (indirect)	81	(89)	25	(27)	15	(17)
Bentonite						
Fluid bed dryer	13	(14)	5	(60)	3	(3)
Rotary dryer	128	(141)	57	(63)	35	(39)
Diatomite						
Flash dryer	112	(124)	56	(62)	35	(39)
Rotary dryer	27	(30)	7	(8)	5	(5)
Rotary calciner	85	(94)	34	(37)	34	(37)
Feldspar						
Fluid bed dryer	13	(14)	4	(4)	2	(2)
Rotary dryer[b]	38	(42)	5	(6)	4	(4)
Fire clay						
Rotary dryer	73	(80)	19	(21)	12	(13)
Vibrating-grate dryer	18	(20)	10	(11)	6	(7)
Rotary calciner	49	(54)	12	(13)	12	(13)
Fuller's earth						
Fluid bed dryer	16	(18)	10	(11)	6	(7)
Rotary dryer	211	(233)	84	(93)	53	(58)
Rotary calciner	98	(108)	26	(29)	26	(29)
Gypsum						
Rotary dryer	530	(584)	141	(156)	88	(97)
Flash calciner	248	(273)	66	(73)	66	(73)
Kettle calciner	275	(303)	73	(81)	73	(81)
Industrial sand						
Fluid bed dryer	600	(661)	114	(126)	72	(79)
Rotary dryer	699	(770)	72	(79)	44	(49)
Kaolin						
Rotary dryer	205	(226)	54	(60)	34	(38)
Spray dryer	1,068	(1,177)	267	(294)	167	(184)
Flash calciner	3	(3)	2	(2)	2	(2)
Multiple hearth furnace	113	(125)	38	(42)	38	(42)
Rotary calciner	2	(2)	1	(1)	1	(1)
Lightweight aggregate[b]						
Rotary calciner	834	(919)	370	(408)	370	(408)
Magnesium compounds						
Multiple hearth furnace	121	(133)	30	(33)	30	(33)
Rotary calciner		(122)	32	(35)	32	(35)
Perlite						
Rotary dryer	38	(42)	33	(36)	19	(21)
Expansion furnace	111	(220)	62	(68)	62	(68)
Roofing granules						
Fluid bed dryer	13	(14)	4	(4)	2	(2)
Rotary dryer	141	(155)	56	(62)	35	(39)

(continued)

TABLE 7-3. (continued)

Industry/facility	Particulate emissions, Mg/yr (tons/yr)					
	RA I[a]		RA II		RA III	
Talc						
Flash dryer	368	(406)	71	(78)	44	(48)
Rotary dryer	13	(14)	4	(4)	2	(2)
Rotary calciner	153	(169)	33	(36)	33	(36)
Titanium dioxide						
Flash dryer	10	(11)	4	(4)	3	(3)
Fluid bed dryer[c]	0	(0)	0	(0)	0	(0)
Rotary dryer (direct)	35	(39)	10	(11)	6	(7)
Rotary dryer (indirect)	32	(35)	2	(2)	1	(1)
Spray dryer	193	(213)	64	(71)	40	(44)
Rotary calciner	48	(53)	48	(53)	48	(53)
Vermiculite						
Fluid bed dryer	15	(17)	3	(3)	2	(2)
Rotary dryer	50	(55)	9	(10)	5	(6)
Expansion furnace	191	(211)	44	(49)	44	(49)
TOTAL	10,241	(11,289)	2,720	(2,998)	2,269	(2,501)
ROUNDED TOTAL	10,200	(11,300)	2,700	(3,000)	2,300	(2,500)

[a] Baseline.

[b] Based on control device inlet parameters for wet scrubbers instead of baghouses to represent the worst case scenario.

[c] Only one fluid bed dryer (a new unit) is known to be used in this industry.

TABLE 7-4. ANNUAL PARTICULATE MATTER EMISSION REDUCTIONS BELOW BASELINE LEVELS[a] (1990)

Industry/facility	Particulate emission reductions below baseline, Mg/yr (tons/yr)			
	RA II		RA III	
Alumina				
Flash calciner	430	(474)	430	(474)
Rotary calciner	1,878	(2,070)	1,878	(2,070)
Ball clay				
Rotary dryer (indirect)	5	(6)	6	(7)
Vibrating-grate dryer (indirect)	56	(62)	65	(72)
Bentonite				
Fluid bed dryer	7	(8)	10	(11)
Rotary dryer	71	(78)	93	(102)
Diatomite				
Flash dryer	56	(62)	77	(85)
Rotary dryer	20	(22)	23	(25)
Rotary calciner	52	(57)	52	(57)
Feldspar				
Fluid bed dryer	9	(10)	11	(12)
Rotary dryer	33	(36)	34	(38)
Fire clay				
Rotary dryer	54	(59)	61	(67)
Vibrating-grate dryer	8	(9)	12	(13)
Rotary calciner	37	(41)	37	(41)
Fuller's earth				
Fluid bed dryer	6	(7)	10	(11)
Rotary dryer	127	(140)	159	(175)
Rotary calciner	72	(79)	72	(79)
Gypsum				
Rotary dryer	388	(428)	442	(487)
Flash calciner	181	(200)	181	(200)
Kettle calciner	201	(222)	201	(222)
Industrial sand				
Fluid bed dryer	485	(535)	527	(582)
Rotary dryer	627	(691)	654	(721)

(continued)

TABLE 7-4. (continued)

Industry/facility	Particulate emission reduction below baseline, Mg/yr (tons/yr) RA II		RA III	
Kaolin				
Rotary dryer	151	(166)	171	(188)
Spray dryer	801	(883)	901	(993)
Flash calciner	1	(1)	1	(1)
Multiple hearth furnace	75	(83)	75	(83)
Rotary calciner	1	(1)	1	(1)
Lightweight aggregate				
Rotary calciner	464	(511)	464	(511)
Magnesium compounds				
Multiple hearth furnace	91	(100)	91	(100)
Rotary calciner	79	(87)	79	(87)
Perlite				
Rotary dryer	5	(6)	19	(21)
Expansion furnace	138	(152)	138	(152)
Roofing granules				
Fluid bed dryer	9	(10)	11	(12)
Rotary dryer	84	(93)	105	(116)
Talc				
Flash dryer	298	(328)	325	(358)
Rotary dryer	9	(10)	11	(12)
Rotary calciner	121	(133)	121	(133)
Titanium dioxide				
Flash dryer	6	(7)	7	(8)
Fluid bed dryer[b]	0	(0)	0	(0)
Rotary dryer (direct)	25	(28)	29	(32)
Rotary dryer (indirect)	30	(33)	31	(34)
Spray dryer	129	(142)	153	(169)
Rotary calciner	0	(0)	0	(0)
Vermiculite				
Fluid bed dryer	13	(14)	14	(15)
Rotary dryer	41	(45)	44	(49)
Expansion furnace	147	(162)	147	(162)
TOTAL	7,521	(8,291)	7,973	(8,788)
ROUNDED TOTAL	7,500	(8,300)	8,000	(8,800)

[a] Baseline is Regulatory Alternative I.

[b] Only one fluid bed dryer (a new unit) is known to be used in this industry.

TABLE 7-5. TOTAL AND INCREMENTAL NATIONWIDE ANNUAL EMISSIONS AND REDUCTIONS[a] (1990)

Regulatory Alternative	Total emissions, Mg/yr (tons/yr)	Incremental emission reduction below baseline	
		Mg/yr (tons/yr)	Percentage
I	10,200 (11,300)	--[b]	--[b]
II	2,700 (3,000)	7,500 (8,300)	73
III	2,300 (2,500)	7,900 (8,800)	78

[a] Metric and English units may not convert exactly because values were rounded independently.

[b] Regulatory Alternative I is baseline level.

TABLE 7-6. GENERAL MODELING PARAMETERS

Parameter	Description
Meteorological Data	
Geographic terrain[a]	• Uniform • Rolling • Valley
Setting	• Rural
Receptor Data	
Plant boundaries	• Emission source(s) may be as close as 100 meters from plant boundary
Receptors	• See Reference 1
Source Data	
Pollutant	• Particulate
Particle size[b]	• 0-10 μm (83 percent) 10-20 μm (14 percent) 20-30 μm (1 percent) 30-40 μm (1 percent) 40-50 μm (1 percent)
Particle settling	• Not included (based on insignificant differences in modeling results)
Averaging times	• Annual arithmetic mean concentrations • Highest and second-highest 24-hour concentrations
Special considerations	• Certain industries have the potential for downwash of the plume in the wake of a nearby building (height = 10 meters; length = 90 meters; width = 60 meters)

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[a] Inherent in meteorological data.

[b] A single particle size distribution was used for all sources and for all the regulatory alternatives because complete data for each individual were not available.

TABLE 7-7. SUMMARY OF SOURCE DATA FOR DRYERS AND CALCINERS

Case	Industry/facility	Stack height, m	Stack diameter, m	Exit velocity, m/s	Exit temp., K	Emission rate, g/s Reg. Alt. I	Emission rate, g/s Reg. Alt. II	Emission rate, g/s Reg. Alt. III
1.	Alumina							
	Flash calciner	37[a]	1.9	18	423	6.75	1.80	1.80
	Rotary calciner	27[a]	2.2	18	563	8.55	1.80	1.80
2.	Ball clay							
	Rotary dryer (indirect)	18	0.7	18	383	1.46	0.39	0.24
	Vibrating-grate dryer (indirect)	21	1.2	18	383	4.62	1.42	0.89
3.	Bentonite							
	Fluid bed dryer	18[a]	0.9	18	383	1.70	0.68	0.43
	Rotary dryer	18[a]	1.2	18	383	2.78	1.24	0.78
4.	Diatomite							
	Flash dryer	15	1.1	18	353	2.06	1.03	0.64
	Rotary dryer	15	0.7	18	383	1.44	0.41	0.26
	Rotary calciner	15	0.9	18	453	1.80	0.72	0.72
5.	Feldspar							
	Fluid bed dryer	15	0.7	18	383	1.68	0.45	0.28
	Rotary dryer	15	0.8	18	338	4.03	0.62	0.39
6.	Fire clay							
	Rotary dryer	15[a]	0.9	18	343	2.81	0.75	0.47
	Vibrating-grate dryer	15[a]	1.4	18	393	3.59	2.05	1.28
	Rotary calciner	15[a]	1.1	18	423	3.61	0.85	0.85
7.	Fuller's earth							
	Fluid bed dryer	15	1.3	18	388	4.64	2.65	1.66
	Rotary dryer	18	1.2	18	393	2.63	1.05	0.66
	Rotary calciner	18	1.1	18	473	2.63	0.70	0.70
8.	Gypsum							
	Rotary dryer	18[a]	0.8	18	383	1.84	0.49	0.31
	Flash calciner	21[a]	0.7	26	438	0.26	0.07	0.07
	Kettle calciner	21[a]	0.3	18	383	0.34	0.09	0.09
9.	Industrial sand							
	Fluid bed dryer	18	1.4	18	328	10.76	2.05	1.28
	Rotary dryer	15	1.0	18	343	9.75	1.00	0.63
10.	Kaolin							
	Rotary dryer	11[a]	0.7	18	383	1.88	0.50	0.31
	Spray dryer	27[a]	1.4	18	383	5.40	1.35	0.84
	Flash calciner	18[a]	0.9	18	453	1.07	0.71	0.71
	Multiple hearth furnace	18[a]	0.5	18	383	0.81	0.27	0.27
	Rotary calciner	37[a]	0.9	18	453	1.43	0.57	0.57
11.	Lightweight aggregate							
	Rotary calciner	21	1.8	18	453	3.87	1.66	1.66
12.	Magnesium compounds							
	Multiple hearth furnace							
	$Mg(OH)_2$ feed	21[a]	1.4	18	563	4.12	1.03	1.03
	Magnesite feed	15[a]	1.1	18	438	2.94	0.98	1.98
	Rotary calciner							
	$Mg(OH)_2$ feed	21[a]	1.5	18	488	3.43	0.98	0.98
	Magnesite feed	21[a]	1.3	18	383	4.91	1.51	1.51

(continued)

TABLE 7-7. (continued)

Case	Industry/facility	Stack height, m	Stack diameter, m	Exit velocity, m/s	Exit temp., K	Emission rate, g/s Reg. Alt. I	Reg. Alt. II	Reg. Alt. III
13.	Perlite							
	Rotary dryer	12	1.5	18	378	2.29	1.84	1.15
	Expansion furnace	11	0.5	18	463	0.49	0.15	0.15
14.	Roofing granules							
	Fluid bed dryer	12[a]	0.9	18	353	2.59	0.74	0.46
	Rotary dryer	12[a]	1.1	18	353	2.83	1.13	0.71
15.	Talc							
	Flash dryer	15[a]	0.5	18	393	1.13	0.21	0.13
	Rotary dryer	15[a]	1.1	18	383	4.09	1.09	0.68
	Rotary calciner	15[a]	0.8	18	453	2.38	0.50	0.50
16.	Titanium dioxide							
	Flash dryer	36	3.3	3.6	363	5.00	1.82	1.14
	Fluid bed dryer[b]	--	--	--	--	--	--	--
	Rotary dryer (direct)	15[a]	0.6	18	428	1.31	0.35	0.22
	Rotary dryer (indirect)	11[a]	0.6	4	313	1.78	0.09	0.06
	Spray dryer	24[a]	1.2	18	403	3.41	1.14	0.71
	Rotary calciner	14[a]	1.4	18	328	2.03	2.03	2.03
17.	Vermiculite							
	Fluid bed dryer	15	1.4	18	383	5.63	0.98	0.61
	Rotary dryer	12	0.8	18	363	3.16	0.55	0.34
	Expansion furnace	11	0.4	18	383	0.64	0.15	0.15

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[a] Consider downwash of plume in the wake of a nearby building.

[b] Only one fluid bed dryer (a new unit) is used in this industry and was not operational when modeling was performed.

TABLE 7-8. SUMMARY OF ANNUAL ARITHMETIC AVERAGE CONCENTRATIONS

Industry/facility	Meteorological data set	Annual average impacts[a] TSP concentrations, µg/m³ RA I	RA II	RA III	Range, m
Alumina					
Flash calciner	Houston, Tex.	0.38 (0.19)	0.1 (0.05)	0.1 (0.05)	2,000
Rotary calciner	Houston, Tex.	0.29 (0.14)	0.06 (0.03)	0.06 (0.03)	2,000
Ball clay					
Rotary dryer (indirect)	Knoxville, Tenn.	1.02 (0.51)	0.27 (0.14)	0.17 (0.09)	500
Vibrating-grate dryer (indirect)	Knoxville, Tenn.	1.07 (0.54)	0.33 (0.16)	0.21 (0.1)	750
Bentonite					
Fluid bed dryer	Fort Bridger, Wyo.	4.99 (2.49)	1.99 (1)	1.24 (0.62)	101
Rotary dryer	Fort Bridger, Wyo.	5.54 (2.77)	2.47 (1.24)	1.54 (0.78)	101
Diatomite					
Flash dryer	Long Beach, Calif.	1.39 (0.7)	0.7 (0.35)	0.43 (0.22)	500
Rotary dryer	Long Beach, Calif.	1.78 (0.89)	0.51 (0.25)	0.32 (0.16)	300
Rotary calciner	Long Beach, Calif.	0.96 (0.48)	0.38 (0.19)	0.38 (0.19)	500
Feldspar					
Fluid bed dryer	Long Beach, Calif.	2.07 (1.04)	0.56 (0.28)	0.35 (0.17)	300
Rotary dryer	Long Beach, Calif.	5.86 (2.93)	0.9 (0.45)	0.56 (0.28)	300
Fire clay					
Rotary dryer	St. Louis, Mo.	4.3 (2.15)	1.15 (0.57)	0.72 (0.36)	101
Vibrating-grate dryer	Akron, Ohio	1.9 (0.95)	1.09 (0.54)	0.68 (0.34)	101
Rotary calciner	Akron, Ohio	2.81 (1.41)	0.66 (0.33)	0.66 (0.33)	101
Fuller's earth					
Fluid bed dryer	Miami, Fla.	1.49 (0.75)	0.85 (0.43)	0.53 (0.27)	[illegible]
Rotary dryer	Miami, Fla.	0.85 (0.43)	0.34 (0.17)	0.21 (0.11)	[illegible]
Rotary calciner	Miami, Fla.	0.7 (0.35)	0.19 (0.09)	0.19 (0.09)	[illegible]
Gypsum					
Rotary dryer	Austin, Tex.	3.22 (1.61)	0.86 (0.43)	0.54 (0.27)	[illegible]
Flash calciner	Austin, Tex.	0.18 (0.09)	0.05 (0.02)	0.05 (0.02)	[illegible]
Kettle calciner	Austin, Tex.	1.53 (0.77)	0.41 (0.2)	0.41 (0.2)	[illegible]
Industrial sand					
Fluid bed dryer	St. Louis, Mo.	4.21 (2.11)	0.8 (0.4)	0.5 (0.25)	[illegible]
Rotary dryer	St. Louis, Mo.	6.44 (3.22)	0.66 (0.33)	0.41 (0.21)	[illegible]
Kaolin					
Rotary dryer	Atlanta, Ga.	7.22 (3.61)	1.92 (0.96)	1.2 (0.6)	[illegible]
Spray dryer	Atlanta, Ga.	0.88 (0.44)	0.22 (0.11)	0.14 (0.07)	[illegible]
Flash calciner	Atlanta, Ga.	0.68 (0.34)	0.45 (0.22)	0.45 (0.22)	[illegible]
Multiple hearth furnace	Atlanta, Ga.	1.71 (0.86)	0.57 (0.28)	0.57 (0.28)	[illegible]
Rotary calciner	Atlanta, Ga.	0.25 (0.12)	0.1 (0.05)	0.1 (0.05)	[illegible]
Lightweight aggregate					
Rotary calciner	Minot, N.D.	0.44 (0.22)	0.2 (0.10)	0.2 (0.10)	[illegible]
Magnesium compounds					
Multiple hearth furnace					
$Mg(OH)_2$ feed	Long Beach, Calif.	0.48 (0.24)	0.12 (0.06)	0.12 (0.06)	[illegible]
Magnesite feed	Detroit, Mich.	2.7 (1.35)	0.9 (0.45)	0.9 (0.45)	[illegible]
Rotary calciner					
$Mg(OH)_2$ feed	Long Beach, Calif.	0.42 (0.21)	0.12 (0.06)	0.12 (0.06)	[illegible]
Magnesite feed	Long Beach, Calif.	1.5 (0.75)	0.46 (0.23)	0.46 (0.23)	[illegible]

(con

TABLE 7-8. (continued)

		Annual average impacts[a]			
		TSP concentrations, µg/m³			
Industry/facility	Meteorological data set	RA I	RA II	RA III	Range, m
Perlite					
Rotary dryer	Alamogordo, N. Mex.	0.61 (0.31)	0.49 (0.25)	0.31 (0.15)	750
Expansion furnace	Minot, N.D.	0.88 (0.44)	0.27 (0.13)	0.27 (0.13)	300
Roofing granules					
Fluid bed dryer	Madison, Wis.	5.39 (2.69)	1.54 (0.77)	0.96 (0.48)	101
Rotary dryer	Madison, Wis.	4.17 (2.08)	1.66 (0.83)	1.04 (0.52)	101
Talc					
Flash dryer	Burlington, Vt.	7.19 (3.6)	1.34 (0.67)	0.84 (0.42)	101
Rotary dryer	Burlington, Vt.	7.7 (3.85)	2.05 (1.02)	1.28 (0.64)	101
Rotary calciner	Burlington, Vt.	6.34 (3.17)	1.33 (0.67)	1.33 (0.67)	101
Titanium dioxide					
Flash dryer	Albany, N.Y.	0.93 (0.46)	0.34 (0.17)	0.21 (0.11)	1,500
Fluid bed dryer[b]	--	--	--	--	--
Rotary dryer (direct)	Albany, N.Y.	3.91 (1.96)	1.04 (0.52)	0.65 (0.33)	101
Rotary dryer (indirect)	Albany, N.Y.	78.2 (39.1)	3.95 (1.98)	2.47 (1.24)	101
Spray dryer	Albany, N.Y.	0.98 (0.49)	0.33 (0.16)	0.2 (0.1)	1,000
Rotary calciner	Albany, N.Y.	3.06 (1.53)	3.06 (1.53)	3.06 (1.53)	101
Vermiculite					
Fluid bed dryer	Helena, Mont.	1.44 (0.72)	0.25 (0.13)	0.16 (0.08)	1,000
Rotary dryer	Helena, Mont.	3.28 (1.64)	0.57 (0.29)	0.36 (0.18)	600
Expansion furnace	Atlanta, Ga.	2 (1)	0.47 (0.23)	0.47 (0.23)	300

NOTE: RA = Regulatory Alternative.

[a] The first value in each pair is based on 8,000 hours per year of plant operation, and the value in parenthesis is based on 4,000 hours per year.

[b] Only one fluid bed dryer (a new unit) is used in this industry and was not operational when modeling was performed.

TABLE 7-9. SUMMARY OF 24-HOUR AVERAGE CONCENTRATIONS

Industry/facility	Maximum 24-hour impacts[a]				Highest second-highest 24-hour impacts[a]			
	TSP concentrations, μg/m³			Range, m	TSP concentrations, μg/m³			Range, m
	RA I	RA II	RA III		RA I	RA II	RA III	
Alumina								
Flash calciner	7.44	1.98	1.98	1,500	5.51	1.47	1.47	1,500
Rotary calciner	6.97	1.47	1.47	2,000	5.25	1.11	1.11	2,000
Ball clay								
Rotary dryer (indirect)	18.2	4.87	3.04	750	14.8	3.95	2.47	500
	(12.8)	(3.44)	(2.15)		(10.4)	(2.79)	(1.74)	
	16.6	4.44	2.78	500	15.8	4.22	2.64	500
	(10.2)	(2.73)	(1.71)		(9.72)	(2.6)	(1.63)	
Vibrating-grate dryer (indirect)	22.1	6.8	4.25	1,000	18.1	5.56	(3.48)	1,000
	(15.6)	(4.8)	(3)		(12.8)	(3.92)	(2.45)	
	20.7	6.36	3.98	1,000	19.5	6	3.75	1,000
	(12.7)	(3.91)	2.44		(12)	(3.69)	(2.31)	
Bentonite								
Fluid bed dryer	36.4	14.6	9.13	100	29.5	11.8	7.38	100
	(25)	(10)	(6.25)		(20.2)	(8.09)	(5.06)	
Rotary dryer	43.5	19.4	12.1	100	37.4	16.7	10.4	100
	(29.8)	(13.3)	(8.31)		(25.6)	(11.4)	(7.13)	
Diatomite								
Flash dryer	18.8	9.4	5.88	500	17	8.5	5.31	750
	(13.3)	(6.63)	(4.14)		(12)	(6)	(3.75)	
Rotary dryer	19.8	5.64	3.53	600	19.6	5.58	3.49	600
	(14)	(3.98)	(2.49)		(13.8)	(3.94)	(2.46)	
Rotary calciner	14.2	5.7	5.7	750	12.5	5.01	5.01	750
Feldspar								
Fluid bed dryer	24.2	6.48	4.05	600	17.1	4.58	2.86	600
	(18.7)	(5.02)	(3.14)		(13.2)	(3.54)	(2.21)	
	23.1	6.18	3.86	600	22.9	6.13	3.83	600
	(16.3)	(4.37)	(2.73)		(16.2)	(4.33)	(2.71)	
Rotary dryer	62.7	9.64	6.03	600	45.8	7.05	4.41	600
	(48.5)	(7.46)	(4.66)		(35.4)	(5.46)	(3.41)	
	58.7	9.08	5.68	600	57.9	8.91	5.57	600
	(41.4)	(6.41)	(4.01)		(40.9)	(6.29)	(3.93)	
Fire clay								
Rotary dryer	75.5	20.1	12.6	100	55.3	14.8	9.25	100
	(67.1)	(17.9)	(11.2)		(49.1)	(13.2)	(8.25)	
	72.9	19.4	12.1	100	60.8	16.2	10.13	100
	(60.3)	(16)	(10)		(50.3)	(13.4)	(8.38)	
Vibrating-grate dryer	51.1	29.2	18.2	100	46.4	26.5	16.6	100
	(42.3)	(24.2)	(15.1)		(38.4)	(23.6)	(14.7)	
Rotary calciner	64.6	15.2	15.2	100	57.2	13.5	13.5	100
Fuller's earth								
Fluid bed dryer	24.2	13.8	8.6	1,000	16.7	9.53	5.96	1,000
	(18.7)	(10.7)	(6.69)		(12.9)	(7.38)	(4.61)	
	22.6	12.9	8.06	1,000	21.3	12.2	7.63	1,000
	(13.9)	(7.94)	(4.96)		(13.1)	(7.51)	(4.69)	
Rotary dryer	13.4	5.33	3.33	1,000	9.43	3.76	2.35	1,000
	(10.4)	(4.13)	(2.58)		(7.3)	(2.91)	(1.82)	
	12.8	5.09	3.18	1,000	12	4.81	3.01	1,000
	(7.88)	(3.13)	(1.96)		(7.38)	(2.96)	(1.85)	
Rotary calciner	11.2	2.99	2.99	1,000	8.26	2.2	2.2	1,000
	11.1	2.96	2.96	1,000	10.7	2.84	2.84	1,000

(conti

TABLE 7-9. (continued)

	Maximum 24-hour impacts[a]				Highest second-highest 24-hour impacts[a]			
	TSP concentrations, µg/m³			Range,	TSP concentrations, µg/m³			Range,
Industry/facility	RA I	RA II	RA III	m	RA I	RA II	RA III	m
Gypsum								
Rotary dryer	31	8.26	5.16	100	27.7	7.38	4.61	100
	(27.6)	(7.34)	(4.59)		(24.6)	(6.56)	(4.1)	
Flash calciner	1.59	0.43	0.43	100	0.99	0.27	0.27	1,000
	1.36	0.37	0.37	100	1.27	0.34	0.34	100
Kettle calciner	10.2	2.71	2.71	200	7.62	2.02	2.02	100
	9.26	2.45	2.45	200	8.42	2.23	2.23	200
Industrial sand								
Fluid bed dryer	72.6	13.8	8.63	750	70.7	13.5	8.44	750
	(52.8)	(10)	(6.25)		(51.4)	(9.82)	(6.14)	
Rotary dryer	116	11.9	7.44	500	107	11	6.88	500
	(84.4)	(8.65)	(5.41)		(77.8)	(8)	(5)	
Kaolin								
Rotary dryer	128	34.2	21.4	100	118	31.4	19.6	100
	(78.8)	(21)	(13.1)		(72.6)	(19.3)	(12.1)	
Spray dryer	15.2	3.8	2.38	1,000	10.2	2.55	1.59	1,000
	(11.8)	(2.94)	(1.84)		(7.9)	(1.97)	(1.23)	
	13.7	3.43	2.14	1,000	13.1	3.27	2.04	1,000
	(8.43)	(2.11)	(1.32)		(8.06)	(2.01)	(1.26)	
Flash calciner	13.5	8.97	8.97	100	13.3	8.8	8.8	100
Multiple hearth furnace	25.8	8.61	8.61	100	23.4	7.8	7.8	200
Rotary calciner	3.55	1.42	1.42	1,000	3.38	1.35	1.35	1,000
Lightweight aggregate								
Rotary calciner	9.79	4.21	4.21	1,000	7.54	3.24	3.24	1,000
Magnesium compounds								
Multiple hearth furnace								
$Mg(OH)_2$ feed	13.4	3.35	3.35	300	12.2	3.05	3.05	300
Magnesite feed	62.6	20.8	20.8	100	58.1	19.4	19.4	100
Rotary calciner								
$Mg(OH)_2$ feed	11	3.14	3.14	300	10.3	2.94	2.94	300
Magnesite feed	32.7	10	10	100	29.8	9.18	9.18	100
Perlite								
Rotary dryer	11.4	9.18	5.74	500	9.66	7.76	4.85	750
	(8.29)	(6.68)	(4.18)		(7.02)	(5.64)	(3.53)	
Expansion furnace	15	4.59	4.59	300	10.9	3.34	3.34	300
	14.2	4.35	4.35	300	12.9	3.95	3.95	300
Roofing granules								
Fluid bed dryer	149	42.6	26.6	100	97.5	27.8	17.4	100
	(102)	(29.2)	(18.2)		(68.8)	(19.6)	(12.2)	
Rotary dryer	141	56.5	35.3	100	93.3	37.2	23.2	100
	(96.7)	(38.7)	(24.2)		(64)	(25.5)	(15.9)	
	127	50.8	31.7	100	94.7	37.8	23.6	100
	(89.6)	(35.8)	(22.4)		(66.8)	(26.7)	(16.7)	
alc								
Flash dryer	48.4	9	5.63	100	42.3	7.86	4.91	100
	(43)	(8)	(5)		(37.6)	(6.99)	(4.37)	
	43.5	8.09	5.06	100	42.7	7.94	4.96	100
	(41.8)	(7.77)	(4.86)		(41)	(7.62)	(4.76)	
Rotary dryer	81.1	21.6	13.5	100	74.2	19.8	12.4	100
	(72.1)	(19.2)	(12)		(66)	(17.6)	(11)	
Rotary calciner	59.5	12.5	12.5	100	53.5	11.2	11.2	100

(continued)

TABLE 7-9. (continued)

Industry/facility	Maximum 24-hour impacts[a]				Highest second-highest 24-hour impacts[a]			
	TSP concentrations, μg/m³			Range, m	TSP concentrations, μg/m³			Range, m
	RA I	RA II	RA III		RA I	RA II	RA III	
Titanium dioxide								
Flash dryer	10.6	3.87	2.42	1,500	9.78	3.56	2.23	1,500
	(7.71)	(2.81)	(1.76)		(7.11)	(2.59)	(1.62)	
Fluid bed dryer[b]	--	--	--	--	--	--	--	--
Rotary dryer (direct)	60.4	16.1	10.1	100	52.8	14.1	8.81	100
	(43.9)	(11.7)	(7.31)		(38.4)	(10.2)	(6.38)	
Rotary dryer (indirect)	580	29.3	18.3	100	423	21.4	13.4	100
	(422)	(21.3)	(13.3)		(308)	(15.6)	(9.8)	
Spray dryer	13.3	4.44	2.78	1,000	13	4.36	2.73	1,000
	(9.67)	(3.23)	(2.02)		(9.45)	(3.17)	(1.98)	
Rotary calciner	57.3	57.3	57.3	100	36.2	36.2	36.2	100
Vermiculite								
Fluid bed dryer	26.6	4.64	2.9	1,000	17.9	3.12	1.95	1,000
	(20.6)	(3.59)	(2.24)		(13.8)	(2.42)	(1.51)	
	24.2	4.22	2.64	1,000	23	4	2.5	1,000
	(14.9)	(2.6)	(1.63)		(14.2)	(2.46)	(1.54)	
Rotary dryer	52.4	9.12	5.7	600	36.2	6.29	3.93	600
	(40.6)	(7.06)	(4.41)		(28)	(4.87)	(3.04)	
	50.4	8.78	5.54	600	47.3	8.23	5.14	600
	(31)	(5.4)	(3.38)		(29.1)	(5.06)	(3.16)	
Expansion furnace	30.6	7.18	7.18	300	27.6	6.46	6.46	300

[a] Where a pair of concentrations appear, the first value in each pair is based on 24 hours per day plant operation. The value in parenthesis presents 12 hours per day of operation.

[b] Only one fluid bed dryer (a new unit) is used in this industry and was not operational when modeling was performed.

TABLE 7-10. INCREMENTAL SOLID WASTE GENERATED BY WET SCRUBBERS OVER BASELINE LEVELS (1990)[a]

Industry/facility	Incremental solid waste generated over baseline by wet scrubbers, Mg/yr (tons/yr) RA II		RA III	
Diatomite				
Flash dryer	188	(207)	257	(283)
Rotary calciner	173	(190)	173	(190)
Feldspar				
Rotary dryer	109	(120)	115	(127)
Fire clay				
Rotary dryer[b]	179	(197)	203	(224)
Vibrating-grate dryer	27	(30)	40	(44)
Rotary calciner	124	(137)	124	(137)
Fuller's earth				
Rotary dryer[b]	424	(467)	530	(584)
Industrial sand				
Fluid bed dryer	1,618	(1,783)	1,760	(1,940)
Rotary dryer	2,089	(2,303)	2,180	(2,403)
Kaolin				
Multiple hearth furnace	251	(277)	251	(277)
Rotary calciner[b]	4	(4)	4	(4)
Lightweight aggregate				
Rotary calciner[b]	1,545	(1,703)	1,545	(1,703)
Roofing granules				
Fluid bed dryer	31	(34)	36	(40)
Rotary dryer	281	(310)	351	(387)
Vermiculite				
Rotary dryer	136	(150)	148	(163)
TOTAL	7,005	(7,722)	7,544	(8,316)
ROUNDED TOTAL	7,000	(7,700)	7,500	(8,300)

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[a] Baseline is Regulatory Alternative I.

[b] These units are currently controlled by baghouses and wet scrubbers. However, for the worst case solid waste impact analysis, it is assumed that these units will be controlled by only wet scrubbers.

TABLE 7-11. ANNUAL AMOUNT OF ELECTRIC ENERGY REQUIRED TO OPERATE CONTROL DEVICES (1990)

		Control device electric energy, MWh		
Industry/facility	Control device[a]	RA I	RA II	RA III
Alumina				
Flash calciner	ESP	1,064	1,315	1,315
Rotary calciner	ESP	6,326	8,029	8,029
Ball clay				
Rotary dryer (indirect)	BH	22	22	22
Vibrating-grate dryer (indirect)	BH	221	221	221
Bentonite				
Fluid bed dryer	BH/ESP	89/42	89/61	89/69
Rotary dryer	BH	541	541	541
Diatomite				
Flash dryer	WS	1,019	1,514	2,139
Rotary dryer	BH	51	51	51
Rotary calciner	BH/WS	439/279	439/1,275	439/1,275
Feldspar				
Fluid bed dryer	BH	33	33	33
Rotary dryer	WS	72	84	142
Fire clay				
Rotary dryer	BH/WS	149/236	149/473	149/561
Vibrating-grate dryer	WS	106	106	106
Rotary calciner	WS	214	371	371
Fuller's earth				
Fluid bed dryer	BH	103	103	103
Rotary dryer	BH/WS	971/1,430	971/1,790	971/2,185
Rotary calciner	BH	315	315	315
Gypsum				
Rotary dryer	BH	1,242	1,242	1,242
Flash calciner	BH	1,209	1,209	1,207
Kettle calciner	BH	842	842	842
Industrial sand				
Fluid bed dryer	WS	1,396	1,396	1,396
Rotary dryer	WS	852	852	852

(continued)

TABLE 7-11. (continued)

Industry/facility	Control device[a]	Control device electric energy, MWh		
		RA I	RA II	RA III
Kaolin				
Rotary dryer	BH	541	541	541
Spray dryer	BH	3,140	3,140	3,140
Flash calciner	BH	22	22	22
Multiple hearth furnace	WS	839	1,558	1,558
Rotary calciner	BH/WS	7/20	7/30	7/30
Lightweight aggregate				
Rotary calciner	BH/WS	4,038/ 9,192	4,038/ 14,502	4,038/ 14,502
Magnesium compounds				
Multiple hearth furnace	ESP[b]	376	503	503
Rotary calciner	ESP[b]	381	481	481
Perlite				
Rotary dryer	BH	417	417	417
Expansion furnace	BH	1,144	1,144	1,144
Roofing granules				
Fluid bed dryer	WS	42	42	42
Rotary dryer	WS	681	681	681
Talc				
Flash dryer	BH	1,052	1,052	1,052
Rotary dryer	BH	23	23	23
Rotary calciner	BH	299	299	299
Titanium dioxide				
Flash dryer	WS	127	176	201
Fluid bed dryer[c]	BH/WS	0/0	0/0	0/0
Rotary dryer (direct)	BH	119	119	119
Rotary dryer (indirect)	WS	18	40	51
Spray dryer	BH	809	809	809
Rotary calciner	WS	1,543	1,543	1,543
Vermiculite				
Fluid bed dryer	BH	52	52	52
Rotary dryer	WS	110	110	134
Expansion furnace	BH	324	324	324
TOTAL		33,310/ 39,266	36,529/ 48,967	37,756/ 50,685
ROUNDED TOTAL		33,000/ 39,000	37,000/ 49,000	38,000/ 51,000

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[a] BH = baghouse; ESP = electrostatic precipitator; WS = wet scrubber.

[b] Most of the magnesia is produced by brine process which uses ESP control.

[c] Additional electric energy will not be required because this facility is not expected to become an affected facility before 1990.

TABLE 7-12. AMOUNT OF ENERGY REQUIRED OVER BASELINE LEVELS TO OPERATE CONTROL DEVICES AND ANNUAL AMOUNT OF ENERGY REQUIRED TO OPERATE FACILITIES (1990)[a]

Industry/facility	Incremental electric energy, MWh RA II	Incremental electric energy, MWh RA III	Facility energy requirements $(10)^9$ Btu	Facility energy requirements MWh[b]
Alumina				
Flash calciner	251	251	4,647	516,000
Rotary calciner	1,703	1,703	12,747	1,416,000
Ball clay				
Rotary dryer (indirect)	0	0	41	4,500
Vibrating-grate dryer (indirect)	0	0	67	7,500
Bentonite				
Fluid bed dryer	47[c]	47[c]	26	2,900
Rotary dryer	0	0	358	39,800
Diatomite				
Flash dryer	495	1,120	431	47,900
Rotary dryer	0	0	234	26,000
Rotary calciner	836[c]	836[c]	707	78,600
Feldspar				
Fluid bed dryer	0	0	43	4,800
Rotary dryer	12	70	80	8,000
Fire clay				
Rotary dryer	324[c]	412[c]	208	23,100
Vibrating-grate dryer	0	0	13	1,400
Rotary calciner	157	157	311	34,600
Fuller's earth				
Fluid bed dryer	0	0	125	13,900
Rotary dryer	819[c]	1,214[c]	530	58,900
Rotary calciner	0	0	632	70,200
Gypsum				
Rotary dryer	0	0	796	88,500
Flash calciner	0	0	2,124	236,000
Kettle calciner	0	0	2,655	295,000
Industrial sand				
Fluid bed dryer	0	0	1,066	118,400
Rotary dryer	0	0	626	69,600

(continued)

TABLE 7-12. (continued)

Industry/facility	Incremental electric energy, MWh		Facility energy requirements[b]	
	RA II	RA III	$(10)^9$ Btu	MWh[b]
Kaolin				
Rotary dryer	0	0	75	8,300
Spray dryer	0	0	2,967	329,700
Flash calciner	0	0	6	700
Multiple hearth furnace	719[c]	719[c]	657	73,000
Rotary calciner	23[c]	23[c]	6	700
Lightweight aggregate				
Rotary calciner	10,464[c]	10,464[c]	5,026	558,400
Magnesium compounds				
Multiple hearth furnace	127	127	729	81,000
Rotary calciner	100	100	670	74,400
Perlite				
Rotary dryer	0	0	66	7,300
Expansion furnace	0	0	192	21,300
Roofing granules				
Fluid bed dryer	0	0	0.2	20
Rotary dryer	0	0	306	34,000
Talc				
Flash dryer	0	0	274	30,400
Rotary dryer	0	0	5	600
Rotary calciner	0	0	319	35,400
Titanium dioxide				
Flash dryer	49	74	14	1,600
Fluid bed dryer	0	0	0	0
Rotary dryer (direct)	0	0	138	15,300
Rotary dryer (indirect)	22	33	58	6,400
Spray dryer	0	0	529	58,800
Rotary calciner	0	0	347	38,600
Vermiculite				
Fluid bed dryer	0	0	0.5	60
Rotary dryer	0	24	18	2,000
Expansion furnace	0	0	154	17,100
TOTAL	16,148	17,374	41,024	4,556,680
ROUNDED TOTAL	16,000	17,000	41,000	4,557,000

[a] Baseline is Regulatory Alternative I.

[b] Equivalent electricity produced at power plant.

[c] Worst case incremental electric energy requirement between wet scrubber and baghouse controls.

TABLE 7-13. PROJECTION OF PRODUCTION FROM NEW/REPLACED FACILITIES (1985-1993)

Industry	Annual production, 10^3 Mg	Annual production, (10^3 tons)	Growth rate, %[a]	1985 production, 10^3 Mg	1985 production, (10^3 tons)	1993 production, 10^3 Mg	1993 production, (10^3 tons)	Production subject to NSPS, 10^3 Mg (10^3 tons): New		Replacement[b]		Total	
Alumina	5,960	(6,570)[c]	6.3	7,611	(8,389)	12,408	(13,677)	4,797	(5,288)	2,029	(2,237)	6,827	(7,525)
Ball clay	708	(708)[d]	3	773	(852)	980	(1,080)	207	(228)	206	(227)	413	(455)
Bentonite	2,540	(2,800)[d]	3	2,776	(3,060)	3,515	(3,875)	739	(815)	740	(816)	1,480	(1,631)
Diatomite	553	(610)[d]	2	587	(647)	688	(758)	101	(111)	157	(173)	258	(284)
Feldspar	526	(580)[d]	2	559	(616)	655	(722)	94	(104)	149	(164)	243	(268)
Fire clay	934	(1,030)[d]	3	1,022	(1,126)	1,294	(1,426)	272	(300)	272	(300)	544	(600)
Fuller's earth	1,533	(1,690)[d]	3	1,676	(1,847)	2,122	(2,339)	446	(492)	447	(493)	894	(985)
Gypsum	12,741	(14,044)[d]	3.3	14,044	(15,481)	18,209	(20,072)	4,165	(4,591)	3,745	(4,128)	7,910	(8,719)
Industrial sand	23,769	(26,200)[d]	1.5	24,855	(27,397)	27,998	(30,862)	3,143	(3,465)	6,628	(7,306)	9,771	(10,771)
Kaolin	5,715	(6,300)[d]	3	6,245	(6,884)	7,910	(8,719)	1,665	(1,835)	1,666	(1,836)	3,330	(3,671)
Lightweight aggregate	4,440	(4,894)[c]	3[e]	4,997	(5,508)	6,330	(6,978)	1,334	(1,470)	1,333	(1,469)	2,666	(2,939)
Magnesium compounds	680	(750)[d]	1.8	718	(791)	828	(913)	111	(122)	191	(211)	302	(333)
Perlite	481	(530)[d]	3	525	(579)	666	(734)	141	(155)	140	(154)	280	(309)
Roofing granules	4,069	(4,485)[c]	1.2	4,267	(4,704)	4,695	(5,175)	427	(471)	1,138	(1,254)	1,565	(1,725)
Talc	962	(1,060)[d]	2	1,039	(1,145)	1,217	(1,342)	179	(197)	277	(305)	455	(502)
Titanium dioxide	576	(635)[d]	2	611	(674)	717	(790)	103	(114)	163	(180)	267	(294)
Vermiculite													
Crude	281	(310)[d]	2	298	(329)	349	(385)	51	(56)	80	(88)	131	(144)
Expanded	249	(274)[c]	2	269	(297)	316	(348)	44	(49)	72	(79)	116	(128)
Total												37,452	(41,283)
Rounded total												37,500	(41,300)

[a] Bureau of Mines data for growth rates up to 1990. It is assumed that the industries will maintain the same growth rate until 1993.

[b] 30 year life assumed.

[c] 1981 production.

[d] 1982 production.

[e] Assume same growth as for other clays: i.e., 3 percent.

TABLE 7-14. PROJECTION OF PRODUCTION FROM NEW/REPLACED FACILITIES (1968-1993)

Industry	Annual production, 10^3 Mg	Annual production, (10^3 tons)	Growth rate, %[a]	1988 production, 10^3 Mg	1988 production, (10^3 tons)	1993 production, 10^3 Mg	1993 production, (10^3 tons)	Production subject to NSPS,[b] 10^3 Mg (10^3 tons): New		Replacement[b]		Total	
Alumina	5,960	(6,570)[c]	6.3	9,141	(10,076)	12,406	(13,675)	3,266	(3,600)	1,523	(1,679)	4,789	(5,279)
Ball clay	708	(708)[d]	3	845	(931)	980	(1,080)	135	(149)	141	(155)	276	(304)
Bentonite	2,540	(2,800)[d]	3	3,033	(3,343)	3,515	(3,875)	483	(532)	505	(557)	988	(1,089)
Diatomite	553	(610)[d]	2	623	(687)	688	(758)	64	(71)	103	(114)	168	(185)
Feldspar	526	(580)[d]	2	592	(653)	654	(721)	62	(68)	99	(109)	161	(177)
Fire clay	934	(1,030)[d]	3	1,116	(1,230)	1,294	(1,426)	178	(196)	186	(205)	364	(401)
Fuller's earth	1,533	(1,690)[d]	3	1,831	(2,018)	2,122	(2,339)	291	(321)	305	(336)	596	(657)
Gypsum	12,741	(14,044)[d]	3.3	15,480	(17,064)	18,209	(20,072)	2,729	(3,008)	2,580	(2,844)	5,309	(5,852)
Industrial sand	23,769	(26,200)[d]	1.5	25,989	(28,648)	27,998	(30,862)	2,009	(2,214)	4,332	(4,775)	6,340	(6,989)
Kaolin	5,715	(6,300)[d]	3	6,824	(7,522)	7,910	(8,719)	1,086	(1,197)	1,138	(1,254)	2,224	(2,451)
Lightweight aggregate	4,440	(4,894)[c]	3[e]	5,460	(6,019)	6,330	(6,978)	870	(959)	910	(1,003)	1,780	(1,962)
Magnesium compounds	680	(750)[d]	1.8	758	(835)	828	(913)	71	(78)	126	(139)	197	(217)
Perlite	481	(530)[d]	3	574	(633)	666	(734)	92	(101)	95	(105)	187	(206)
Roofing granules	4,069	(4,485)[c]	1.2	4,424	(4,876)	4,695	(5,175)	271	(299)	738	(813)	1,009	(1,112)
Talc	962	(1,060)[d]	2	1,083	(1,194)	1,196	(1,318)	112	(124)	181	(199)	293	(323)
Titanium dioxide	576	(635)[d]	2	649	(715)	716	(789)	67	(74)	108	(119)	175	(193)
Vermiculite													
Crude	281	(310)[d]	2	317	(349)	349	(385)	33	(36)	53	(58)	85	(94)
Expanded	249	(274)[c]	2	286	(315)	315	(347)	29	(32)	47	(52)	76	(84)
Total												25,016	(27,575)
Rounded total												25,000	(27,600)

[a] Bureau of Mines data for growth rates up to 1990. It is assumed that the industries will maintain the same growth rate until 1993.
[b] 30 year life assumed.
[c] 1981 production.
[d] 1982 production.
[e] Assume same growth as for other clays: i.e., 3 percent.

TABLE 7-15. PRODUCTION SUBJECT TO NSPS IN 1993 FOR EACH AFFECTED FACILITY
(Proposal in 1985)

Industry/facility	New			Replacement			Total	
	Percent new	10^3 Mg	(10^3 tons/yr)	Percent replaced	10^3 Mg	(10^3 tons/yr)	10^3 Mg	(10^3 tons/yr)
Alumina								
Flash calciner	50	2,399	(2,644)	0	0	(0)	2,399	(2,644)
Rotary calciner	50	2,399	(2,644)	100	2,029	(2,237)	4,428	(4,881)
Ball clay[a]								
Rotary dryer (indirect)	15	31	(34)	5	10	(11)	41	(45)
Vibrating-grate dryer (indirect)	35	73	(80)	45	93	(102)	165	(182)
Bentonite[b]								
Fluid bed dryer	0	0	(0)	16	119	(131)	119	(131)
Rotary dryer	80	591	(652)	64	474	(522)	1,065	(1,174)
Diatomite								
Flash dryer	70	71	(78)	70	110	(121)	181	(199)
Rotary dryer	30	30	(33)	30	47	(52)	77	(85)
Rotary calciner	90	91	(100)	90	142	(156)	232	(256)
Feldspar								
Fluid bed dryer	50	47	(52)	25	37	(41)	84	(93)
Rotary dryer	50	47	(52)	75	112	(123)	159	(175)
Fire clay								
Rotary dryer	81	220	(243)	81	220	(243)	441	(486)
Vibrating-grate dryer	9	24	(27)	9	24	(27)	49	(54)
Rotary calciner	20	54	(60)	20	54	(60)	109	(120)
Fuller's earth								
Fluid bed dryer	10	45	(50)	10	44	(49)	90	(99)
Rotary dryer	40	179	(197)	40	179	(197)	357	(394)
Rotary calciner	50	223	(246)	50	224	(247)	447	(493)
Gypsum								
Rotary dryer	100	4,165	(4,591)	100	3,745	(4,128)	7,910	(8,719)
Flash calciner	50	2,083	(2,296)	50	1,872	(2,064)	3,955	(4,360)
Kettle calciner	50	2,083	(2,296)	50	1,872	(2,064)	3,955	(4,360)
Industrial sand								
Fluid bed dryer	60	1,886	(2,079)	50	3,314	(3,653)	5,200	(5,732)
Rotary dryer	40	1,257	(1,386)	50	3,314	(3,653)	4,571	(5,039)
Kaolin[c]								
Rotary dryer	27	449	(495)	27	450	(496)	899	(991)
Spray dryer	63	1,049	(1,156)	63	1,050	(1,157)	2,098	(2,313)
Flash calciner	0.1	2	(2)	0.1	2	(2)	4	(4)
Multiple hearth furnace	9.8	163	(180)	9.8	163	(180)	327	(360)
Rotary calciner	0.1	2	(2)	0.1	2	(2)	4	(4)

(continued)

TABLE 7-15. (continued)

Industry/facility	New: Percent new	New: 10^3 Mg	New: (10^3 tons/yr)	Replacement: Percent replaced	Replacement: 10^3 Mg	Replacement: (10^3 tons/yr)	Total: 10^3 Mg	Total: (10^3 tons/yr)
Lightweight aggregate								
Rotary calciner	100	1,334	(1,470)	100	1,333	(1,469)	2,666	(2,939)
Magnesium compounds								
Multiple hearth furnace	60	66	(73)	50	96	(106)	162	(179)
Rotary calciner	40	44	(49)	50	96	(106)	141	(155)
Perlite								
Rotary dryer	100	141	(155)	100	140	(154)	280	(309)
Expansion furnace	60	84	(93)	60	83	(92)	168	(185)
Roofing granules								
Fluid bed dryer	5	22	(24)	5	57	(63)	79	(87)
Rotary dryer	95	406	(447)	95	1,080	(1,191)	1,486	(1,638)
Talc								
Flash dryer	90	161	(177)	90	249	(275)	410	(452)
Rotary dryer	10	18	(20)	10	28	(31)	46	(51)
Rotary calciner	30	54	(59)	30	83	(92)	137	(151)
Titanium dioxide								
Flash dryer	20	21	(23)	0	0	(0)	21	(23)
Fluid bed dryer[f]	0	0	(0)	0	0	(0)	0	(0)
Rotary dryer (direct)	63	65	(72)	63	103	(113)	168	(185)
Rotary dryer (indirect)	32	33	(36)	32	53	(58)	85	(94)
Spray dryer	57	59	(65)	77	126	(139)	185	(204)
Rotary calciner	18	19	(21)	18	29	(32)	48	(53)
Vermiculite								
Fluid bed dryer	50[d]	25	(28)	50[d]	40	(44)	65	(72)
Rotary dryer	50[d]	25	(28)	50[d]	40	(44)	65	(72)
Expansion furnace	100[e]	44	(49)	100[e]	72	(79)	116	(128)

[a] 50 percent of ball clay produced is dried. Trend is toward vibrating-grate dryer.

[b] 80 percent of bentonite produced is dried.

[c] 90 percent of kaolin produced is dried or calcined. 10 percent is unprocessed. 10 percent is both dried and calcined.

[d] 50 percent of crude vermiculite is processed by rotary dryers and 50 percent by fluid bed dryers.

[e] 100 percent of expanded vermiculite is processed by expansion furnaces.

[f] Only one fluid bed dryer (a new unit) is used in this industry and, according to industry sources, there is no trend toward the use of fluid bed dryers.

TABLE 7-16. PRODUCTION SUBJECT TO NSPS IN 1993 FOR EACH AFFECTED FACILITY
(Proposal in 1988)

	New			Replacement			Total	
Industry/facility	Percent new	10^3 Mg	(10^3 tons/yr)	Percent replaced	10^3 Mg	(10^3 tons/yr)	10^3 Mg	(10^3 tons/yr)
Alumina								
Flash calciner	50	1,633	(1,800)	0	0	(0)	1,633	(1,800)
Rotary calciner	50	1,633	(1,800)	100	1,523	(1,679)	3,156	(3,479)
Ball clay[a]								
Rotary dryer (indirect)	15	20	(22)	5	7	(8)	27	(30)
Vibrating-grate dryer (indirect)	35	47	(52)	45	64	(70)	111	(122)
Bentonite[b]								
Fluid bed dryer	0	0	(0)	16	81	(89)	81	(89)
Rotary dryer	80	386	(426)	64	323	(356)	709	(782)
Diatomite								
Flash dryer	70	45	(50)	70	73	(80)	118	(130)
Rotary dryer	30	19	(21)	30	31	(34)	50	(55)
Rotary calciner	90	58	(64)	90	93	(103)	152	(167)
Feldspar								
Fluid bed dryer	50	31	(34)	25	24	(27)	55	(61)
Rotary dryer	50	31	(34)	75	74	(82)	105	(116)
Fire clay								
Rotary dryer	81	144	(159)	81	151	(166)	295	(325)
Vibrating-grate dryer	9	16	(18)	9	16	(18)	33	(36)
Rotary calciner	20	35	(39)	20	37	(41)	73	(80)
Fuller's earth								
Fluid bed dryer	10	29	(32)	10	31	(34)	60	(66)
Rotary dryer	40	116	(128)	40	122	(134)	238	(262)
Rotary calciner	50	146	(161)	50	152	(168)	298	(329)
Gypsum								
Rotary dryer	100	2,729	(3,008)	100	2,580	(2,844)	5,309	(5,852)
Flash calciner	50	1,364	(1,504)	50	1,290	(1,422)	2,654	(2,926)
Kettle calciner	50	1,364	(1,504)	50	1,290	(1,422)	2,654	(2,926)
Industrial sand								
Fluid bed dryer	60	1,205	(1,328)	50	2,166	(2,388)	3,371	(3,716)
Rotary dryer	40	804	(886)	50	2,166	(2,388)	2,970	(3,274)
Kaolin[c]								
Rotary dryer	27	293	(323)	27	308	(339)	601	(662)
Spray dryer	63	684	(754)	63	717	(790)	1,401	(1,544)
Flash calciner	0.1	1	(1)	0.1	1	(1)	2	(2)
Multiple hearth furnace	9.8	106	(117)	9.8	112	(123)	218	(240)
Rotary calciner	0.1	1	(1)	0.1	1	(1)	2	(2)

(continued)

TABLE 7-16. (continued)

	New			Replacement			Total	
Industry/facility	Percent new	10^3 Mg	(10^3 tons/yr)	Percent replaced	10^3 Mg	(10^3 tons/yr)	10^3 Mg	(10^3 tons/yr)
Lightweight aggregate								
Rotary calciner	100	870	(959)	100	910	(1,003)	1,780	(1,962)
Magnesium compounds								
Multiple hearth furnace	60	43	(47)	50	64	(70)	106	(117)
Rotary calciner	40	28	(31)	50	64	(70)	92	(101)
Perlite								
Rotary dryer	100	92	(101)	100	95	(105)	187	(206)
Expansion furnace	60	55	(61)	60	57	(63)	112	(124)
Roofing granules								
Fluid bed dryer	5	14	(15)	5	37	(41)	51	(56)
Rotary dryer	95	258	(284)	95	700	(772)	958	(1,056)
Talc								
Flash dryer	90	102	(112)	90	162	(179)	264	(291)
Rotary dryer	10	11	(12)	10	18	(20)	28	(31)
Rotary calciner	30	34	(37)	30	54	(60)	88	(97)
Titanium dioxide								
Flash dryer	20	14	(15)	0	0	(0)	14	(15)
Fluid bed dryer[f]	0	0	(0)	0	0	(0)	0	(0)
Rotary dryer (direct)	63	43	(47)	63	68	(75)	111	(122)
Rotary dryer (indirect)	32	22	(24)	32	34	(38)	56	(62)
Spray dryer	57	38	(42)	77	83	(92)	122	(134)
Rotary calciner	18	12	(13)	18	19	(21)	31	(34)
Vermiculite								
Fluid bed dryer	50[d]	16	(18)	50[d]	26	(29)	43	(47)
Rotary dryer	50[d]	16	(18)	50[d]	26	(29)	43	(47)
Expansion furnace	100[e]	29	(32)	100[e]	47	(52)	76	(84)

[a] 50 percent of ball clay produced is dried. Trend is toward vibrating-grate dryer.
[b] 80 percent of bentonite produced is dried.
[c] 90 percent of kaolin produced is dried or calcined. 10 percent is unprocessed. 10 percent is both dried and calcined.
[d] 50 percent of crude vermiculite is processed by rotary dryers and 50 percent by fluid bed dryers.
[e] 100 percent of expanded vermiculite is processed by expansion furnace.
[f] Only one fluid bed dryer (a new unit) is used in this industry and, according to industry sources, there is no trend toward the use of fluid bed dryers.

TABLE 7-17. EIGHTH YEAR (1985-1993) ANNUAL PARTICULATE EMISSIONS FROM DRYERS AND CALCINERS

Industry/facility	Particulate emissions, Mg/yr (tons/yr)					
	RA I[a]		RA II		RA III	
Alumina						
Flash calciner	1,034	(1,140)	276	(304)	276	(304)
Rotary calciner	4,008	(4,418)	844	(930)	844	(930)
Ball clay						
Rotary dryer (indirect)	12	(13)	4	(4)	2	(2)
Vibrating-grate dryer (indirect)	132	(145)	40	(44)	25	(28)
Bentonite						
Fluid bed dryer	20	(22)	8	(9)	5	(6)
Rotary dryer	210	(231)	93	(103)	58	(64)
Diatomite						
Flash dryer	182	(201)	91	(100)	57	(63)
Rotary dryer	44	(48)	13	(14)	13	(14)
Rotary calciner	139	(153)	55	(61)	55	(61)
Feldspar						
Fluid bed dryer	24	(26)	6	(7)	4	(4)
Rotary dryer	83	(91)	13	(14)	8	(9)
Fire clay						
Rotary dryer	119	(131)	32	(35)	20	(22)
Vibrating-grate dryer	29	(32)	16	(18)	10	(11)
Rotary calciner	79	(87)	19	(21)	19	(21)
Fuller's earth						
Fluid bed dryer	27	(30)	15	(17)	10	(11)
Rotary dryer	345	(380)	138	(152)	86	(95)
Rotary calciner	160	(176)	43	(47)	43	(47)
Gypsum						
Rotary dryer	870	(959)	231	(255)	144	(159)
Flash calciner	407	(449)	109	(120)	109	(120)
Kettle calciner	452	(498)	121	(133)	121	(133)
Industrial sand						
Fluid bed dryer	967	(1,066)	184	(203)	115	(127)
Rotary dryer	1,125	(1,240)	115	(127)	73	(80)
Kaolin						
Rotary dryer	336	(370)	90	(99)	56	(62)
Spray dryer	1,748	(1,927)	437	(482)	273	(301)
Flash calciner	5	(6)	4	(4)	4	(4)
Multiple hearth furnace	186	(205)	62	(68)	62	(68)
Rotary calciner	4	(4)	2	(2)	2	(2)
Lightweight aggregate[b]						
Rotary calciner	1,364	(1,504)	607	(669)	607	(669)
Magnesium compounds						
Multiple hearth furnace	266	(293)	66	(73)	66	(73)
Rotary calciner	255	(281)	73	(80)	73	(80)
Perlite						
Rotary dryer	63	(69)	50	(55)	31	(34)
Expansion furnace	327	(361)	101	(111)	101	(111)
Roofing granules						
Fluid bed dryer	20	(22)	5	(6)	4	(4)
Rotary dryer	226	(249)	91	(100)	56	(62)

(continued)

TABLE 7-17. (continued)

Industry/facility	Particulate emissions, Mg/yr (tons/yr)					
	RA I[a]		RA II		RA III	
Talc						
Flash dryer	608	(670)	116	(128)	73	(80)
Rotary dryer	21	(23)	5	(6)	4	(4)
Rotary calciner	255	(281)	54	(59)	54	(59)
Titanium dioxide						
Flash dryer	17	(19)	6	(7)	4	(4)
Fluid bed dryer[c]	0	(0)	0	(0)	0	(0)
Rotary dryer (direct)	57	(63)	15	(17)	10	(11)
Rotary dryer (indirect)	51	(56)	3	(3)	2	(2)
Spray dryer	314	(346)	104	(115)	65	(72)
Rotary calciner	77	(85)	77	(85)	77	(85)
Vermiculite						
Fluid bed dryer	24	(27)	5	(5)	3	(3)
Rotary dryer	80	(88)	14	(15)	9	(10)
Expansion furnace	302	(333)	71	(78)	71	(78)
TOTAL	17,071	(18,818)	4,522	(4,985)	3,800	(4,189)
ROUNDED TOTAL	17,100	(18,800)	4,500	(5,000)	3,800	(4,200)

[a] Baseline.

[b] Based on control device inlet parameters for wet scrubbers instead of baghouses to represent the worst case scenario.

[c] Only one fluid bed dryer (a new unit) is known to be used in this industry.

TABLE 7-18. FIFTH YEAR (1988-1993) ANNUAL PARTICULATE EMISSIONS FROM DRYERS AND CALCINERS

Industry/facility	Particulate emissions, Mg/yr (tons/yr)					
	RA I[a]		RA II		RA III	
Alumina						
Flash calciner	704	(776)	188	(207)	188	(207)
Rotary calciner	2,857	(3,149)	601	(663)	601	(663)
Ball clay						
Rotary dryer (indirect)	8	(9)	2	(2)	1	(1)
Vibrating-grate dryer (indirect)	88	(97)	27	(30)	17	(19)
Bentonite						
Fluid bed dryer	14	(15)	5	(6)	4	(4)
Rotary dryer	139	(153)	62	(68)	39	(43)
Diatomite						
Flash dryer	119	(131)	60	(66)	37	(41)
Rotary dryer	28	(31)	8	(9)	5	(6)
Rotary calciner	91	(100)	36	(40)	36	(40)
Feldspar						
Fluid bed dryer	15	(17)	5	(5)	3	(3)
Rotary dryer	55	(61)	8	(9)	5	(6)
Fire clay						
Rotary dryer	80	(88)	21	(23)	14	(15)
Vibrating-grate dryer	19	(21)	11	(12)	7	(8)
Rotary calciner	53	(58)	13	(14)	13	(14)
Fuller's earth						
Fluid bed dryer	18	(20)	11	(12)	6	(7)
Rotary dryer	230	(253)	92	(101)	57	(63)
Rotary calciner	107	(118)	28	(31)	28	(31)
Gypsum						
Rotary dryer	584	(644)	155	(171)	97	(107)
Flash calciner	273	(301)	73	(80)	73	(80)
Kettle calciner	303	(334)	81	(89)	81	(89)
Industrial sand						
Fluid bed dryer	627	(691)	120	(132)	74	(82)
Rotary dryer	731	(806)	75	(83)	47	(52)
Kaolin						
Rotary dryer	224	(247)	60	(66)	37	(41)
Spray dryer	1,167	(1,286)	292	(322)	182	(201)
Flash calciner	3	(3)	2	(2)	2	(2)
Multiple hearth furnace	124	(137)	42	(46)	42	(46)
Rotary calciner	2	(2)	1	(1)	1	(1)
Lightweight aggregate[b]						
Rotary calciner	911	(1,004)	405	(446)	405	(446)
Magnesium compounds						
Multiple hearth furnace	174	(192)	44	(48)	44	(48)
Rotary calciner	166	(183)	47	(52)	47	(52)
Perlite						
Rotary dryer	42	(46)	34	(37)	21	(23)
Expansion furnace	220	(242)	67	(74)	67	(74)
Roofing granules						
Fluid bed dryer	13	(14)	4	(4)	3	(3)
Rotary dryer	146	(161)	58	(64)	36	(40)

(continued)

TABLE 7-18. FIFTH YEAR (1988-1993) ANNUAL PARTICULATE EMISSIONS FROM DRYERS AND CALCINERS

Industry/facility	Particulate emissions, Mg/yr (tons/yr)					
	RA I[a]		RA II		RA III	
Alumina						
Flash calciner	704	(776)	188	(207)	188	(207)
Rotary calciner	2,857	(3,149)	601	(663)	601	(663)
Ball clay						
Rotary dryer (indirect)	8	(9)	2	(2)	1	(1)
Vibrating-grate dryer (indirect)	88	(97)	27	(30)	17	(19)
Bentonite						
Fluid bed dryer	14	(15)	5	(6)	4	(4)
Rotary dryer	139	(153)	62	(68)	39	(43)
Diatomite						
Flash dryer	119	(131)	60	(66)	37	(41)
Rotary dryer	28	(31)	8	(9)	5	(6)
Rotary calciner	91	(100)	36	(40)	36	(40)
Feldspar						
Fluid bed dryer	15	(17)	5	(5)	3	(3)
Rotary dryer	55	(61)	8	(9)	5	(6)
Fire clay						
Rotary dryer	80	(88)	21	(23)	14	(15)
Vibrating-grate dryer	19	(21)	11	(12)	7	(8)
Rotary calciner	53	(58)	13	(14)	13	(14)
Fuller's earth						
Fluid bed dryer	18	(20)	11	(12)	6	(7)
Rotary dryer	230	(253)	92	(101)	57	(63)
Rotary calciner	107	(118)	28	(31)	28	(31)
Gypsum						
Rotary dryer	584	(644)	155	(171)	97	(107)
Flash calciner	273	(301)	73	(80)	73	(80)
Kettle calciner	303	(334)	81	(89)	81	(89)
Industrial sand						
Fluid bed dryer	627	(691)	120	(132)	74	(82)
Rotary dryer	731	(806)	75	(83)	47	(52)
Kaolin						
Rotary dryer	224	(247)	60	(66)	37	(41)
Spray dryer	1,167	(1,286)	292	(322)	182	(201)
Flash calciner	3	(3)	2	(2)	2	(2)
Multiple hearth furnace	124	(137)	42	(46)	42	(46)
Rotary calciner	2	(2)	1	(1)	1	(1)
Lightweight aggregate[b]						
Rotary calciner	911	(1,004)	405	(446)	405	(446)
Magnesium compounds						
Multiple hearth furnace	174	(192)	44	(48)	44	(48)
Rotary calciner	166	(183)	47	(52)	47	(52)
Perlite						
Rotary dryer	42	(46)	34	(37)	21	(23)
Expansion furnace	220	(242)	67	(74)	67	(74)
Roofing granules						
Fluid bed dryer	13	(14)	4	(4)	3	(3)
Rotary dryer	146	(161)	58	(64)	36	(40)

(continued)

TABLE 7-18. (continued)

	Particulate emissions, Mg/yr (tons/yr)					
ndustry/facility	RA I[a]		RA II		RA III	
alc						
Flash dryer	392	(432)	74	(82)	46	(51)
Rotary dryer	13	(14)	4	(4)	2	(2)
Rotary calciner	163	(180)	34	(38)	34	(38)
itanium dioxide						
Flash dryer	11	(12)	4	(4)	3	(3)
Fluid bed dryer[c]	0	(0)	0	(0)	0	(0)
Rotary dryer (direct)	38	(42)	10	(11)	6	(7)
Rotary dryer (indirect)	34	(37)	2	(2)	1	(1)
Spray dryer	206	(227)	69	(76)	43	(47)
Rotary calciner	50	(55)	50	(55)	50	(55)
Vermiculite						
Fluid bed dryer	15	(17)	3	(3)	2	(2)
Rotary dryer	52	(57)	9	(10)	5	(6)
Expansion furnace	198	(218)	46	(51)	46	(51)
TOTAL	11,504	(12,681)	3,040	(3,351)	2,559	(2,821)
ROUNDED TOTAL	11,500	(12,700)	3,000	(3,400)	2,600	(2,800)

[a] Baseline.
[b] Based on control device inlet parameters for wet scrubbers instead of baghouses to represent the worst case scenario.
[c] Only one fluid bed dryer (a new unit) is known to be used in this industry.

TABLE 7-19. ENVIRONMENTAL IMPACT OF DELAYED STANDARD--PARTICULATE EMISSION REDUCTION IN 1993

Regulatory	Proposal in 1985[a]		Proposal in 1988[a]	
Alternative	Mg/yr[b]	tons/yr	Mg/yr	tons/yr
II	12,500	13,800	8,400	9,300
III	13,200	14,600	9,000	9,900

[a] Baseline emissions in 1993 for the two cases are 17,100 Mg/yr (18,800 tons/yr) and 11,500 Mg/yr (12,700 tons/yr), respectively.

[b] Metric and English units may not convert exactly because values were rounded independently.

7.7 REFERENCES FOR CHAPTER 7

1. Memo from Strait, R., MRI, to 7702-L Project File. Calculations for BID Chapter 7. April 10, 1985.

2. P. Gutfreund and L. Mahoney, Systems Applications, Inc. Dispersion Modeling Analyses of Particulate Control Regulatory Alternatives for Stack Releases From Dryers and Calciners in the Mineral Industries. Prepared for U. S. Environmental Protection Agency, Research Triangle Park, North Carolina. November 5, 1984.

3. Environmental Protection Agency General Regulations on Standards of Performance for New Stationary Sources. Environment Reporter. January 22, 1982. pp. 121:1518-121:1526.

4. U. S. Environmental Protection Agency. Municipal Environmental Research Laboratory. Process Design Manual: Sludge Treatment and Disposal. Publication No. EPA-625/1-79-011. September 1979. p. 9-15.

5. U. S. Environmental Protection Agency. Municipal Environmental Research Laboratory. Process Design Manual: Land Application of Municipal Sludge. Publication No. EPA-625/1-83-016. October 1983. p. 4-3.

6. Environmental Protection Agency Regulations for Hazardous Waste Management. Code of Federal Regulations. Title 40, Chapter I, Parts 260, 261. July 1, 1984. Environment Reporter. March 20, 1984. pp. 161:1801-161:1871.

8. COST ANALYSIS OF CONTROL OPTIONS

8.1 INTRODUCTION

This chapter presents the cost impacts associated with the implementation of three regulatory alternatives for the control of particulate matter emissions from new, modified, or reconstructed mineral dryer and calciner process units. Capital and annualized costs of pollution control equipment were developed and used to evaluate the incremental cost effectiveness of RA II over the baseline alternative, RA I, and RA III over RA II. The average cost effectiveness of RA III over RA I and the cost effectiveness of RA I, RA II, and RA III over the uncontrolled conditions were also calculated. As discussed in Chapter 6, RA I represents the emission limit required by SIP's, RA II represents an emission limit of 90 mg/dscm (0.04 gr/dscf) for dryers and calciners, and RA III represents an emission limit of 57 mg/dscm (0.025 gr/dscf) for dryers and 90 mg/dscm (0.04 gr/dscf) for calciners. The capital cost of pollution control equipment was also compared with the capital cost of mineral dryer and calciner process units. All costs were based on January 1984 dollars. Control device costs are based on "study" estimates (±30 percent accuracy) and process unit costs are based on "order-of-magnitude" estimates (greater than ±30 percent accuracy). The economic impacts of each regulatory alternative on mineral dryer and calciner operators are presented in Chapter 9. Documentation of the calculations made for Chapter 8 is presented in Reference 1.

8.2 COST ANALYSIS FOR NEW FACILITIES

New facilities include any new dryer or calciner installed at a new plant. Capital and annualized costs of pollution control equipment were based on model facility parameters developed from industry information. The model facility parameters were presented in Chapter 6.

8.2.1 Basis for Estimating Capital and Annualized Costs of Pollution Control Equipment

The costs of using BH's, WS's, and dry ESP's to achieve the recommended emission limit of each regulatory alternative were evaluated. Data sources used to calculate capital and annualized costs of these pollution control devices and their associated equipment are listed in Table 8-1. Factors used to calculate the capital and annualized control costs are listed in Tables 8-2 and 8-3, respectively.

Land costs were not included as a factor because the typical plant site usually includes enough land for the company to add a new dryer or calciner and the associated pollution control equipment.

8.2.2 Capital Costs of Pollution Control Equipment for Each Regulatory Alternative

Tables 8-4a, 8-4b, and 8-4c show the purchased equipment, installation, and total capital cost of pollution control equipment used on the typical-size model facility in each mineral industry for RA I, RA II, and RA III, respectively. As indicated by the total capital cost factors in Table 8-2, BH installation costs are about 17 percent greater than BH purchased equipment costs and ESP installation costs are about 22 percent greater than ESP purchased equipment costs. However, WS installation costs are about 9 percent less than WS purchased equipment costs. Table 8-4d summarizes the total capital cost of pollution control equipment for each of the regulatory alternatives.

Tables 8-4a through 8-4c also present the gas flow rates and the control equipment design parameters upon which the costs were based. Net cloth areas were the most critical variable influencing BH capital costs. However, net cloth areas were held constant for each regulatory alternative because EPA-approved emission test results for BH's on existing facilities indicated that existing BH's could meet the recommended emission limits for RA II and RA III (See Chapter 4, Section 4.3). Therefore, BH capital costs remained constant for all three alternatives. The most critical variable influencing WS capital costs was the operating pressure drops. When necessary, the pressure drops were increased to meet the more stringent emission limits of RA II and RA III compared to the pressure drops needed to meet the baseline level of control. In cases where pressure drops for RA II or RA III are less than or equal to 6 kPa (25 in. w.c.), WS capital costs for RA II and RA III may be less than or equal to the WS capital cost for RA I. This occurred when radial-tip fan costs and damper costs for RA II and RA III decreased enough to offset increases in the other purchased equipment costs. Radial-tip fan costs and damper costs decreased with increases in pressure drops because smaller fan wheel diameters are used to generate higher pressure drops up to 6 kPa (25 in. w.c.).[2] For ESP's, SCA's were the most critical variable influencing capital costs. Specific collection areas were increased to meet the more stringent emission limits of RA II and RA III compared to the SCA's needed to meet the baseline level of control.

8.2.3 Annualized Costs of Pollution Control Equipment for Each Regulatory Alternative

Tables 8-5a, 8-5b, and 8-5c summarize the costs of utilities; operator, supervisor, and maintenance labor; overhead; product recovery or waste disposal; and capital charges that comprise the total annualized costs of pollution control equipment for RA I, RA II, and RA III, respectively. Table 8-5d summarizes the total annualized costs of pollution control equipment for the three regulatory alternatives. The critical variables influencing BH annualized costs were operating time, bag lifes, labor costs, and product recovery credits. Wet scrubber annualized costs were influenced most by operating time, pressure drops, labor costs, and waste disposal costs. Electrostatic precipitator annualized costs were influenced by operating time, SCA's, labor costs, and product recovery credits.

Product recovery credits for the different industries varied with the amount of particulate matter captured and the product values used to calculate the credits. Table 8-6 lists prices used to calculate product recovery credits for control devices on dryers and calciners in the different industries.[3-13] The price of the dried or calcined product was used to calculate credits for particulate matter recovered from BH's and ESP's. These prices were based on average annual prices reported by the U.S. BOM to account for price fluctuations rather than on a January 1984 price.

Product recovery credits were calculated for all BH's and ESP's except for BH's used on lightweight aggregate rotary calciners, perlite rotary dryers, and vermiculite fluid bed dryers. Particulate matter captured by BH's used on lightweight aggregate rotary calciners, perlite rotary dryers, and vermiculite fluid bed dryers is disposed of as waste. Therefore, a dust disposal charge of $5.51/Mg ($5.00/ton) was used to estimate the cost of hauling the waste to a landfill. Product recovery credits were also calculated for WS's used on titanium dioxide flash dryers, indirect rotary dryers, and rotary calciners. Product recovery prices were discounted from the final product price by 35 percent for flash dryers and 40 percent for rotary calciners. The raw ore price was used to calculate product recovery credits for direct and indirect rotary dryers.[14] Waste disposal costs were calculated for WS's used in the other mineral industries. Most of the industries typically pump WS wastewater to a settling pond located at the plant site.[15-20] Therefore, the costs of a pump, motor, and pipe needed to transport the wastewater to a settling pond were added to the capital cost of the WS and the pump electricity cost was added to the annualized cost of the WS.

8.2.4 Cost Effectiveness of Pollution Control

The incremental and average cost-effectiveness values of the regulatory alternatives are summarized in Table 8-7. Incremental cost effectiveness was calculated by dividing the incremental annualized cost of RA II over RA I (and RA III over RA II) by the additional amount of particulate matter removed by RA II over RA I (and RA III over RA II). Average cost effectiveness was calculated by dividing the additional annualized cost of RA III over RA I by the additional amount of particulate matter removed by RA III over RA I. The cost effectiveness of the regulatory alternatives versus the uncontrolled process units is summarized in Table 8-8. These cost-effectiveness values were calculated by dividing the annualized control cost of each regulatory alternative by the amount of particulate matter removed under each regulatory alternative for each model facility.

8.2.5 Five-Year Projection of Nationwide Capital and Annualized Pollution Control Costs for Each Regulatory Alternative

Table 8-9 presents projections of capital and annualized pollution control costs for each regulatory alternative in 1990. Production projections for 1990 are based on the number of affected facilities expected in the fifth year. The number of affected facilities was calculated by dividing incremental production in the fifth year by the design production capacity of the typical-size facility for each industry. The number of affected facilities was rounded and multiplied by the capital and annualized cost of pollution control equipment calculated for each typical-size facility for each regulatory alternative.

Two total capital and annualized cost figures are listed for each regulatory alternative at the bottom of Table 8-9. The first total includes the cost of a BH and the second total includes the cost of a WS for those facilities that are typically controlled by either control device. Capital costs for the second total decreased from the first total by about $4.8 million for RA I and $4.0 million for RA II and RA III. Annualized costs for the second total increased from the first total by about $0.5 million for RA I and $0.2 million for RA II and RA III.

8.3 COST ANALYSIS OF MODEL FACILITY PROCESS UNITS

8.3.1 Basis for Estimating Capital Costs of Process Unit Equipment

Capital costs of mineral dryers and calciners included the cost of the process unit, a cyclone, and the auxiliary equipment required for their operation. Data sources used to calculate capital costs of process unit equipment are listed in Table 8-10.

Except for direct and indirect rotary dryers and kettle calciners; rocess unit, auxiliary equipment, and installation capital costs were btained from vendors.[21-36] Capital costs of rotary dryers were estimated ing a regression equation developed from data provided by industry ponses to EPA information requests.[37-40] Capital costs of kettle ciners were based on gypsum industry information.[41] Factors used to culate capital costs of new dryers and calciners are listed in

Table 8-11. Capital costs of process units for the typical-size model facility in each industry are listed in Table 8-12.

8.3.2 Comparison of Capital Costs of Pollution Control Equipment to Capital Costs of Uncontrolled Process Units

Capital costs of pollution control equipment are compared to the capital costs of uncontrolled process units in Table 8-13 by expressing pollution control equipment costs as a percentage of typical-size process unit costs. The purpose of the comparison is to show the cost of pollution control equipment under the baseline case (RA I) relative to the cost of the process unit and to show how these relative costs change for RA II and RA III.

The relative capital cost change between RA I and RA II ranged from a decrease of 2 percent to an increase of 29 percent and averaged 2 percent. The relative cost change between RA I and RA III ranged from a decrease of 2 percent to an increase of 42 percent and averaged 2 percent. The relative cost change between RA II and RA III ranged from a decrease of 1 percent to an increase of 13 percent and averaged 0 percent.

8.4 COST ANALYSIS FOR MODIFIED/RECONSTRUCTED FACILITIES

Under the provisions of 40 CFR 60.14 and 60.15, an existing facility must comply with the NSPS if it is modified or reconstructed. However, the modification and reconstruction provisions should not cause many calciners and dryers in the 17 mineral industries to become affected facilities because most of the physical and operational changes made to existing calciners and dryers are considered routine maintenance. Calciners and dryers at existing plants are more likely to become affected facilities when they are replaced by new process units at the end of their useful lives. Owners and operators of modified, reconstructed, or replaced facilities controlled by wet scrubbers or ESP's will probably incur retrofit costs if the design operating parameters of the wet scrubber or ESP must be increased to achieve the emission limit of the NSPS. However, the cost of retrofitting wet scrubbers or ESP's would be similar to the cost of installing wet scrubbers or ESP's on new facilities because site-specific factors that might normally increase retrofit costs (e.g., availability of land and configuration of equipment) typically are not limiting factors at mineral processing plants. If site-specific factors are limiting at a plant, the capital cost of retrofitting wet scrubbers or ESP's may be greater than the cost of wet scrubbers and ESP's installed on new facilities (e.g., more ductwork). However, the annualized cost of retrofitting wet scrubbers or ESP's would not differ significantly from the annualized costs of wet scrubbers and ESP's installed on new facilities. Owners and operators of modified, reconstructed, or replaced facilities controlled by fabric filters should not incur retrofit costs because the emission limits of the NSPS can be achieved by increasing the operation and maintenance of fabric filters.

8.5 OTHER COST CONSIDERATIONS

8.5.1 Other Air Pollution Costs

Other air pollution costs considered in this analysis were the capital and annualized costs of control equipment for new facilities to meet existing SIP regulations. These costs were used as the baseline control costs in RA I to analyze the cost effectiveness of RA II and RA III. No other air pollution regulations apply directly to controlling particulate matter emissions from mineral dryer and calciner process units. However, NSPS are being developed for other process equipment used in nonmetallic mineral industries. This equipment may either precede or follow the dryer and calciner process units being considered in this analysis and includes crushers, grinding mills (including air separators, classifiers, and conveyors), screens, bucket elevators, belt conveyors, bagging operations, storage bins, and enclosed truck and rail car loading stations. Industries considered in this analysis that may be affected by the standards for nonmetallic mineral industries include ball clay, bentonite, diatomite, feldspar, fire clay, fuller's earth, gypsum, industrial sand, kaolin, perlite, talc, and vermiculite.[42] New source performance standards have been promulgated for equipment used to process ores of metallic minerals. However, this equipment also precedes or follows the dryer and calciner process units and includes crushing, ore storage, and product loadout units. Alumina and titanium dioxide are the only industries considered in this analysis that are affected by the metallic mineral NSPS.[43]

8.5.2 Continuous Opacity Monitors

Continuous opacity monitoring using a transmissometer is an effective means to ensure that dry control devices are properly operated and maintained to achieve the maximum emission reduction for which they were designed. Therefore, the owner or operator of an affected facility controlled by a BH or an ESP may be required to install a continuous opacity monitor to demonstrate compliance under this NSPS. The capital costs associated with installing a transmissometer are estimated to be $31,500. The capital costs include the cost of equipment, installation, and training and certifying an operator. The annualized costs associated with operating and maintaining a transmissometer are estimated to be $10,700. The annualized costs include the cost of operator and maintenance labor, electricity, capital recovery, and data reduction.[44]

Requiring an owner or operator of an affected facility to install a transmissometer to improve operation and maintenance practices of the control device will increase the cost effectiveness of the regulatory alternatives. The annualized cost of the transmissometer was added to the annualized cost of RA III to analyze the impact that the additional cost of a transmissometer would have on the average cost effectiveness of RA III over RA I. Results of this analysis indicate that the average industry-wide cost effectiveness would increase for calciners by $990/Mg ($900/ton) and for dryers by $430/Mg ($390/ton) as a result of using continuous opacity monitors.[44]

8.5.3 Water Pollution Control Act

Standards of performance for point sources specify zero discharge of wastewater to navigable waters. Wet scrubbers were the only control devices considered that generate wastewater at the plant site. Industries using wet scrubbers include diatomite, feldspar, fire clay, fuller's earth, industrial sand, kaolin, lightweight aggregate, roofing granules, titanium dioxide, and vermiculite. Plants in these industries typically discharge wastewater from the scrubber into a settling pond at the plant site and recycle the clarified water to the scrubber. Therefore, no discharges to navigable waters occur, and no additional water treatment costs are incurred that are attributable to the development of this NSPS.

8.5.4 Resource Conservation and Recovery Act

The three regulatory alternatives considered in this analysis are not expected to increase costs to the mineral industries under RCRA because the pollution control equipment used to achieve the emission limits of the regulatory alternatives will not generate wastes that are considered hazardous under the provisions of RCRA.

8.5.5 Occupational Safety and Health Administration Act

Mineral processing plants considered in this analysis are subject to the Occupational Safety and Health Administration's (OSHA's) general industrial health and safety standards. These standards include regulations covering noise exposure; fixed machinery and hand tools; electrical installations; floor and stair conditions; and lunchroom, toilet, and first aid provisions. Data were not obtained to evaluate the cost of complying with these regulations. However, the pollution control equipment associated with the regulatory alternatives should result in minimal OSHA-related compliance costs. Therefore, no costs of complying with OSHA regulations were included in this analysis.

8.5.6 Resource Requirements Imposed on Regional, State, and Local Agencies

The owner or operator of a new, modified, or reconstructed facility is responsible for applying to the State for a permit to construct and operate the facility. Regional, State, and local regulatory agencies are responsible for reviewing the applications and enforcing the regulations. The regulatory alternatives considered in this analysis should not create major resource requirements for the regulatory agencies because it is expected that affected facilities will be distributed throughout the United States (not clustered in a few States) and because the agencies have developed the resources to regulate particulate matter emissions from mineral dryer and calciner process units under the authority of SIP's.

TABLE 8-1. CAPITAL AND ANNUALIZED COST DATA SOURCES FOR POLLUTION CONTROL EQUIPMENT

Cost item	Source	Date	Ref.
A. Capital costs			
1. Baghouse (BH)	EPA/OAQPS/EAB	Dec. 1977	45
2. Wet scrubber (WS)	EPA/OAQPS/EAB	Dec. 1977	46
3. Dry electrostatic precipitator (ESP)	EPA/OAQPS/EAB	Dec. 1977	47
4. Auxiliary equipment (ductwork, fan system, stack, and WS waste disposal equipment)	EPA/OAQPS/EAB	Dec. 1977	48
5. Cost factors	EPA/OAQPS/EAB	Dec. 1977	49
6. Cost indexes	EPA/OAQPS/EAB Bureau of Labor Statistics (BLS) Chemical Engr.	Dec. 1977 April 1984 June 1984	50 51 52
B. Annualized costs			
1. Electricity	EPA/OAQPS/EAB	Dec. 1977	53
2. Industrial power index	BLS	April 1984	54
3. Water	American Water Works Association	May 1984	55
4. Labor			
a. Wage rate	BLS	April, May 1984	56,57
b. Operator, supervisor, and maintenance	EPA/OAQPS/EAB	Dec. 1977	58
3. Overhead and materials	EPA/OAQPS/EAB	Dec. 1977	59
4. Dust disposal	EPA/OAQPS/EAB	Dec. 1977	60
5. Capital charges	EPA/OAQPS/EAB	Dec. 1977	61

TABLE 8-2. POLLUTION CONTROL EQUIPMENT CAPITAL COST FACTORS FOR NEW FACILITIES

Cost item	Cost factor BH	 WS	 ESP
A. Direct costs			
1. Purchased equipment	----------- A ----------		
a. Control device			
b. Auxiliary equipment (ductwork, fan system, and stack)	----------- B ----------		
c. Instruments and controls	------ 0.10 (A+B) ------		
d. Taxes	------ 0.03 (A+B) ------		
e. Freight	------ 0.05 (A+B) ------		
f. Total (1a through 1e)	------ 0.18 (A+B) ------		
g. Purchased equipment cost factor, C = 1.18 (A+B)	C	C	C
2. Installation			
a. Foundation and supports	0.04C	0.06C	0.04C
b. Erection and handling	0.50C	0.40C	0.50C
c. Electrical	0.08C	0.01C	0.08C
d. Piping	0.01C	0.05C	0.01C
e. Insulation	0.07C	0.03C	0.02C
f. Painting	0.02C	0.01C	0.02C
g. Total (2a through 2f)	0.72C	0.56C	0.67C
B. Indirect costs			
1. Installation			
a. Engineering and supervision	0.10C	0.10C	0.20C
b. Construction and field expenses	0.20C	0.10C	0.20C
c. Construction fee	0.10C	0.10C	0.10C
d. Startup	0.01C	0.01C	0.01C
e. Performance test	0.01C	0.01C	0.01C
f. Total (1a through 1e)	0.42C	0.32C	0.52C
2. Contingencies	0.03C	0.03C	0.03C
TOTAL CAPITAL COST FACTOR	1.17C	0.91C	1.22C

TABLE 8-3. POLLUTION CONTROL EQUIPMENT ANNUALIZED COST FACTORS FOR NEW FACILITIES

Cost item	Cost factor BH	 WS	 ESP
A. Direct operating cost			
1. Operating labor			
a. Operator	2 h/ shift	2 h/ shift	0.5 h shift
b. Supervisor	15% of operator labor		
2. Maintenance labor			
a. Maintenance	1-1.25 h/ shift	1 h/ shift	0.5 h shift
b. Materials	100% of maintenance labor		
c. Wage rate			
-Alumina	$12.78/h		
-Magnesium compounds and Titanium dioxide	$12.11/h		
-Roofing granules	$9.29/h		
-Ball clay, Bentonite, Diatomite, Feldspar, Fire clay, Fuller's earth, Gypsum, Industrial sand, Kaolin, Lightweight aggregate, Perlite, Talc, and Vermiculite	$9.44/h		
3. Utilities			
a. Electricity	$1.55 x10^{-7}/J[a] ($0.0558/kWh)		
	$0.18/1,000 ℓ[b] ($0.68/1,000 gal)		
4. Dust disposal	$5.51/Mg[c] ($5.00/ton)		
B. Indirect operating costs			
1. Overhead	80% of operator + supervisor + maintenance labor costs		
2. Property tax	1% of capital costs		
3. Insurance	1% of capital costs		
4. Administration	2% of capital costs		
5. Capital recovery	11.746% of capital cost[d]	16.275% of capital cost[e]	11.746% of capital cost[d]

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[a] $/J = dollars per joule.

[b] $/1,000 ℓ = dollars per 1,000 liters.

[c] $/Mg = dollars per megagram.

[d] Based on 20 year life and 10 percent interest.

[e] Based on 10 year life and 10 percent interest.

TABLE 8-4a. CAPITAL COSTS OF POLLUTION CONTROL EQUIPMENT FOR REGULATORY ALTERNATIVE I (January 1984 Dollars)

Industry/facility	Typical facility size[a]	Gas flow, acfm	Control device	Design parameter	Purchased equipment cost, $000	Installation cost, $000	Total, $000
Alumina							
Flash calciner	L	116,000	ESP	SCA = 180[b]	452	552	1,004
Rotary calciner	S	98,000	ESP	SCA = 280[b]	463	564	1,027
Ball clay							
Rotary dryer (indirect)	M	17,000	BH	A/C = 3:1[c]	180	210	390
Vibrating-grate dryer (indirect)	M	25,000	BH	A/C = 5.6:1	163	191	354
Bentonite							
Fluid bed dryer	M	50,000	BH	A/C = 3:1	427	499	926
Fluid bed dryer	M	50,000	ESP	SCA = 174	426	519	945
Rotary dryer	M	30,000	BH	A/C = 3.5:1	248	291	539
Diatomite							
Flash dryer	S	22,000	WS	ΔP = 6[d]	75	69	144
Rotary dryer	M	15,000	BH	A/C = 4:1	141	164	305
Rotary calciner	L	30,000	BH	A/C = 2:1	300	352	652
Rotary calciner	L	30,000	WS	ΔP = 8	89	80	169
Feldspar							
Fluid bed dryer	M	10,000	BH	A/C = 4.5:1	104	122	226
Fluid bed dryer	L	17,000	BH	A/C = 4.5:1	145	170	315
Rotary dryer	L	21,000	WS	ΔP = 3	76	69	145
Fire clay							
Rotary dryer	M	18,000	BH	A/C = 4.5:1	148	173	321
Rotary dryer	M	18,000	WS	ΔP = 3	71	64	135
Vibrating-grate dryer	M	62,000	WS	ΔP = 3	155	141	296
Rotary calciner	M	40,000	WS	ΔP = 6	97	89	186
Fuller's earth							
Fluid bed dryer	L	124,000	BH	A/C = 4.5:1	714	835	1,549
Rotary dryer	S	20,000	BH	A/C = 4:1	165	193	358
Rotary dryer	S	20,000	WS	ΔP = 5	69	63	132
Rotary calciner	M	30,000	BH	A/C = 2:1	302	354	656
Gypsum							
Rotary dryer	M	12,500	BH	A/C = 4:1	124	145	269
Flash calciner	M	4,100	BH	A/C = 2:1	69	81	150
Kettle calciner	M	4,100	BH	A/C = 2:1	69	81	150
Industrial sand							
Fluid bed dryer	M	30,000	WS	ΔP = 3	95	86	181
Rotary dryer	S	11,000	WS	ΔP = 3	55	50	105
Kaolin							
Rotary dryer	M	17,000	BH	A/C = 3.5:1	161	188	349
Spray dryer	M	35,000	BH	A/C = 3:1	322	376	698
Spray dryer	L	60,000	BH	A/C = 3:1	505	591	1,096
Flash calciner	S	[e]	BH	A/C = 2:1	260	304	564
Multiple hearth furnace	S	12,000	WS	ΔP = 8	52	48	100
Rotary calciner	S	24,000	BH	A/C = 2:1	268	314	582
Rotary calciner	S	24,000	WS	ΔP = 10	87	79	166
Lightweight aggregate							
Rotary calciner	M	68,000	BH	A/C = 5:1	314	367	681
Rotary calciner	M	100,000	WS	ΔP = 10	204	185	389

(continued)

TABLE 8-4a. (continued)

Industry/facility	Typical facility size[a]	Gas flow, acfm	Control device	Design parameter	Purchased equipment cost, $000	Installation cost, $000	Total, $000
Magnesium compounds							
Multiple hearth furnace							
Mg(OH)$_2$ feed	L	70,000	ESP	SCA = 250	371	453	824
Magnesite feed	M	e	BH	A/C = 1.4:1	351	411	762
Rotary calciner							
Mg(OH)$_2$ feed	S	50,000	ESP	SCA = 200	307	374	681
Magnesite feed	L	e	BH	A/C = 1.65:1	446	522	968
Perlite							
Rotary dryer	M	40,000	BH	A/C = 4:1	285	333	618
Expansion furnace	S	6,000	BH	A/C = 2:1	84	99	183
Roofing granules							
Fluid bed dryer	M	25,000	WS	ΔP = 3	83	76	159
Rotary dryer	S	20,000	WS	ΔP = 3	74	68	142
Rotary dryer	M	30,000	WS	ΔP = 3	93	85	178
Talc							
Flash dryer	S	8,000	BH	A/C = 3:1	108	127	235
Rotary dryer	M	10,000	BH	A/C = 3:1	128	151	279
Rotary calciner	S	20,000	BH	A/C = 2:1	220	256	476
Titanium dioxide							
Flash dryer	L	e	WS	ΔP = 20	215	195	410
Fluid bed dryer	L	34,000	BH	A/C = 4.1:1	250	292	542
Fluid bed dryer	L	34,000	WS	ΔP = 10	101	91	192
Rotary dryer (direct)	L	13,000	BH	A/C = 4:1	127	148	275
Rotary dryer (indirect)	M	2,850	WS	ΔP = 3	39	35	74
Spray dryer	M	30,000	BH	A/C = 4:1	227	266	493
Rotary calciner	S	e	WS	ΔP = e	117	106	223
Rotary calciner	M	e	WS	ΔP = e	208	188	396
Vermiculite							
Fluid bed dryer	L	35,000	BH	A/C = 6:1	196	229	425
Rotary dryer	M	20,000	WS	ΔP = 3	73	66	139
Expansion furnace	S	5,000	BH	A/C = 2:1	48	56	104

[a] S = small, M = medium, L = large.
[b] Specific collection area, ft²/1,000 acfm.
[c] Air-to-cloth ratio, ft³/min per ft².
[d] Pressure drop, in. w.c.
[e] Confidential data.

TABLE 8-4b. CAPITAL COSTS OF POLLUTION CONTROL EQUIPMENT FOR REGULATORY ALTERNATIVE II (January 1984 Dollars)

Industry/facility	Typical facility size[a]	Gas flow, acfm	Control device	Design parameter	Purchased equipment cost, $000	Installation cost, $000	Total, $000
Alumina							
Flash calciner	L	116,000	ESP	SCA = [b]	496	604	1,100
Rotary calciner	S	98,000	ESP	SCA = 380[c]	514	628	1,142
Ball clay							
Rotary dryer (indirect)	M	17,000	BH	A/C = 3:1[d]	180	210	390
Vibrating-grate dryer (indirect)	M	25,000	BH	A/C = 5.6:1	163	191	354
Bentonite							
Fluid bed dryer	M	50,000	BH	A/C = 3:1	427	499	926
Fluid bed dryer	M	50,000	ESP	SCA = 300	486	593	1,079
Rotary dryer	M	30,000	BH	A/C = 3.5:1	248	291	539
Diatomite							
Flash dryer	S	22,000	WS	$\Delta P = 14$[e]	78	71	149
Rotary dryer	M	15,000	BH	A/C = 4:1	141	164	305
Rotary calciner	L	30,000	BH	A/C = 2:1	300	352	652
Rotary calciner	L	30,000	WS	$\Delta P = 23$	93	84	177
Feldspar							
Fluid bed dryer	M	10,000	BH	A/C = 4.5:1	104	122	226
Fluid bed dryer	L	17,000	BH	A/C = 4.5:1	145	170	315
Rotary dryer	L	21,000	WS	$\Delta P = 4$	75	69	144
Fire clay							
Rotary dryer	M	18,000	BH	A/C = 4.5:1	148	173	321
Rotary dryer	M	18,000	WS	$\Delta P = 10$	68	62	130
Vibrating-grate dryer	M	62,000	WS	$\Delta P = 3$	155	141	296
Rotary calciner	M	40,000	WS	$\Delta P = 19$	111	101	212
Fuller's earth							
Fluid bed dryer	L	124,000	BH	A/C = 4.5:1	714	835	1,549
Rotary dryer	S	20,000	BH	A/C = 4:1	165	193	358
Rotary dryer	S	20,000	WS	$\Delta P = 8$	69	62	131
Rotary calciner	M	30,000	BH	A/C = 2:1	302	354	656
Gypsum							
Rotary dryer	M	12,500	BH	A/C = 4:1	124	145	269
Flash calciner	M	4,100	BH	A/C = 2:1	69	81	150
Kettle calciner	M	4,100	BH	A/C = 2:1	69	80	150
Industrial sand							
Fluid bed dryer	M	30,000	WS	$\Delta P = 3$	95	86	181
Rotary dryer	S	11,000	WS	$\Delta P = 3$	55	50	105
Kaolin							
Rotary dryer	M	17,000	BH	A/C = 3.5:1	161	188	349
Spray dryer	M	35,000	BH	A/C = 3:1	322	376	698
Spray dryer	L	60,000	BH	A/C = 3:1	505	591	1,096
Flash calciner	S	b	BH	A/C = 2:1	260	304	564
Multiple hearth furnace	S	12,000	WS	$\Delta P = 23$	51	46	97
Rotary calciner	S	24,000	BH	A/C = 2:1	268	314	582
Rotary calciner	S	24,000	WS	$\Delta P = 24$	84	76	160
Lightweight aggregate							
Rotary calciner	M	68,000	BH	A/C = 5:1	314	367	681
Rotary calciner	M	100,000	WS	$\Delta P = 23$	261	237	498

(continued)

TABLE 8-4b. (continued)

Industry/facility	Typical facility size[a]	Gas flow, acfm	Control device	Design parameter	Purchased equipment cost, $000	Installation cost, $000	Total, $000
Magnesium compounds							
Multiple hearth furnace							
$Mg(OH)_2$ feed	L	70,000	ESP	SCA = 400	440	538	978
Magnesite feed	M	b	BH	A/C = 1.4:1	351	411	762
Rotary calciner							
$Mg(OH)_2$ feed	S	50,000	ESP	SCA = 300	341	416	757
Magnesite feed	L	b	BH	A/C = 1.65:1	446	522	968
Perlite							
Rotary dryer	M	40,000	BH	A/C = 4:1	285	333	618
Expansion furnace	S	6,000	BH	A/C = 2:1	84	99	183
Roofing granules							
Fluid bed dryer	M	25,000	WS	ΔP = 3	83	76	159
Rotary dryer	S	20,000	WS	ΔP = 3	74	68	142
Rotary dryer	M	30,000	WS	ΔP = 3	93	85	178
Talc							
Flash dryer	S	8,000	BH	A/C = 3:1	108	127	235
Rotary dryer	M	10,000	BH	A/C = 3:1	128	151	279
Rotary calciner	S	20,000	BH	A/C = 2:1	220	256	476
Titanium dioxide							
Flash dryer	L	b	WS	ΔP = 34	250	227	477
Fluid bed dryer	L	34,000	BH	A/C = 4.1:1	250	292	542
Fluid bed dryer	L	34,000	WS	ΔP = 34	112	101	213
Rotary dryer (direct)	L	13,000	BH	A/C = 4:1	127	148	275
Rotary dryer (indirect)	M	2,850	WS	ΔP = 10	38	34	72
Spray dryer	M	30,000	BH	A/C = 4:1	227	266	493
Rotary calciner	S	b	WS	ΔP = b	117	106	223
Rotary calciner	M	b	WS	ΔP = b	208	188	396
Vermiculite							
Fluid bed dryer	L	35,000	BH	A/C = 6:1	196	229	425
Rotary dryer	M	20,000	WS	ΔP = 3	73	66	139
Expansion furnace	S	5,000	BH	A/C = 2:1	48	56	104

[a] S = small, M = medium, L = large.
[b] Confidential data.
[c] Specific collection area, ft²/1,000 acfm.
[d] Air-to-cloth ratio, ft³/min per ft².
[e] Pressure drop, in. w.c.

TABLE 8-4c. CAPITAL COSTS OF POLLUTION CONTROL EQUIPMENT FOR REGULATORY ALTERNATIVE III (January 1984 Dollars)

Industry/facility	Typical facility size[a]	Gas flow, acfm	Control device	Design parameter	Purchased equipment cost, $000	Installation cost, $000	Total, $000
Alumina							
Flash calciner	L	116,000	ESP	SCA = b	496	604	1,100
Rotary calciner	S	98,000	ESP	SCA = 380[c]	514	628	1,142
Ball clay							
Rotary dryer (indirect)	M	17,000	BH	A/C = 3:1[d]	180	210	390
Vibrating-grate dryer (indirect)	M	25,000	BH	A/C = 5.6:1	163	191	354
Bentonite							
Fluid bed dryer	M	50,000	BH	A/C = 3:1	427	499	926
Fluid bed dryer	M	50,000	ESP	SCA = 350	512	625	1,137
Rotary dryer	M	30,000	BH	A/C = 3.5:1	248	291	539
Diatomite							
Flash dryer	S	22,000	WS	ΔP = 25[e]	92	84	176
Rotary dryer	M	15,000	BH	A/C = 4:1	141	164	305
Rotary calciner	L	30,000	BH	A/C = 2:1	300	352	652
Rotary calciner	L	30,000	WS	ΔP = 23	93	84	177
Feldspar							
Fluid bed dryer	M	10,000	BH	A/C = 4.5:1	104	122	226
Fluid bed dryer	L	17,000	BH	A/C = 4.5:1	145	170	315
Rotary dryer	L	21,000	WS	ΔP = 10	75	69	144
Fire clay							
Rotary dryer	M	18,000	BH	A/C = 4.5:1	148	173	321
Rotary dryer	M	18,000	WS	ΔP = 14	67	61	128
Vibrating-grate dryer	M	62,000	WS	ΔP = 3	155	141	296
Rotary calciner	M	40,000	WS	ΔP = 19	111	101	212
Fuller's earth							
Fluid bed dryer	L	124,000	BH	A/C = 4.5:1	714	835	1,549
Rotary dryer	S	20,000	BH	A/C = 4:1	165	193	358
Rotary dryer	S	20,000	WS	ΔP = 11	68	62	130
Rotary calciner	M	30,000	BH	A/C = 2:1	302	354	656
Gypsum							
Rotary dryer	M	12,500	BH	A/C = 4:1	124	145	269
Flash calciner	M	4,100	BH	A/C = 2:1	69	81	150
Kettle calciner	M	4,100	BH	A/C = 2:1	69	81	150
Industrial sand							
Fluid bed dryer	M	30,000	WS	ΔP = 3	95	86	181
Rotary dryer	S	11,000	WS	ΔP = 3	55	50	105
Kaolin							
Rotary dryer	M	17,000	BH	A/C = 3.5:1	161	188	349
Spray dryer	M	35,000	BH	A/C = 3:1	322	376	698
Spray dryer	L	60,000	BH	A/C = 3:1	505	591	1,096
Flash calciner	S	b	BH	A/C = 2:1	260	304	564
Multiple hearth furnace	S	12,000	WS	ΔP = 23	51	46	97
Rotary calciner	S	24,000	BH	A/C = 2:1	268	314	582
Rotary calciner	S	24,000	WS	ΔP = 24	84	76	160
Lightweight aggregate							
Rotary calciner	M	68,000	BH	A/C = 5:1	314	367	681
Rotary calciner	M	100,000	WS	ΔP = 23	261	237	498

(continued)

TABLE 8-4c. (continued)

Industry/facility	Typical facility size[a]	Gas flow, acfm	Control device	Design parameter	Purchased equipment cost, $000	Installation cost, $000	Total, $000
Magnesium compounds							
Multiple hearth furnace							
$Mg(OH)_2$ feed	L	70,000	ESP	SCA = 400	440	538	978
Magnesite feed	M	b	BH	A/C = 1.4:1	351	411	762
Rotary calciner							
$Mg(OH)_2$ feed	S	50,000	ESP	SCA = 300	341	416	757
Magnesite feed	L	b	BH	A/C = 1.65:1	446	522	968
Perlite							
Rotary dryer	M	40,000	BH	A/C = 4:1	285	333	618
Expansion furnace	S	6,000	BH	A/C = 2:1	84	99	183
Roofing granules							
Fluid bed dryer	M	25,000	WS	ΔP = 3	83	76	159
Rotary dryer	S	20,000	WS	ΔP = 3	74	68	142
Rotary dryer	M	30,000	WS	ΔP = 3	93	85	178
Talc							
Flash dryer	S	8,000	BH	A/C = 3:1	108	127	235
Rotary dryer	M	10,000	BH	A/C = 3:1	128	151	279
Rotary calciner	S	20,000	BH	A/C = 2:1	220	256	476
Titanium dioxide							
Flash dryer	L	b	WS	ΔP = b	290	265	555
Fluid bed dryer	L	34,000	BH	A/C = 4.1:1	250	292	542
Fluid bed dryer	L	34,000	WS	ΔP = 43	136	123	259
Rotary dryer (direct)	L	13,000	BH	A/C = 4:1	127	148	275
Rotary dryer (indirect)	M	2,850	WS	ΔP = 17	38	35	73
Spray dryer	M	30,000	BH	A/C = 4:1	227	266	493
Rotary calciner	S	b	WS	ΔP = b	117	106	223
Rotary calciner	M	b	WS	ΔP = b	208	188	396
Vermiculite							
Fluid bed dryer	L	35,000	BH	A/C = 6:1	196	229	425
Rotary dryer	M	20,000	WS	ΔP = 4	72	66	138
Expansion furnace	S	5,000	BH	A/C = 2:1	48	56	104

[a] S = small, M = medium, L = large.
[b] Confidential data.
[c] Specific collection area, $ft^2/1,000$ acfm.
[d] Air-to-cloth ratio, ft^3/min per ft^2.
[e] Pressure drop, in. w.c.

TABLE 8-4d. TOTAL CAPITAL COSTS OF POLLUTION CONTROL EQUIPMENT FOR EACH REGULATORY ALTERNATIVE (January 1984 Dollars)

Industry/facility	Typical facility size^a	Control device	RA I, $000			RA II, $000			RA III, $000		
			S	M	L	S	M	L	S	M	L
Alumina											
Flash calciner	L	ESP	--	--	1,004	--	--	1,100	--	--	1,100
Rotary calciner	S	ESP	1,027	1,153	1,331	1,142	1,307	1,532	1,142	1,307	1,532
Ball clay											
Rotary dryer (indirect)	M	BH	--	390	--	--	390	--	--	390	--
Vibrating-grate dryer (indirect)	M	BH	--	354	594	--	354	594	--	354	594
Bentonite											
Fluid bed dryer	M	BH	--	926	--	--	926	--	--	926	--
Fluid bed dryer	M	ESP	--	945	--	--	1,079	--	--	1,137	--
Rotary dryer	M	BH	392	539	818	392	539	818	392	539	818
Diatomite											
Flash dryer	S	WS	144	--	207	149	--	228	176	--	250
Rotary dryer	M	BH	--	305	--	--	305	--	--	305	--
Rotary calciner	L	BH	373	--	652	373	--	652	373	--	652
Rotary calciner	L	WS	116	--	169	111	--	177	111	--	177
Feldspar											
Fluid bed dryer	M,L	BH	--	226	315	--	226	315	--	226	315
Rotary dryer	L	WS	75	113	145	74	111	144	72	106	144
Fire clay											
Rotary dryer	M	BH	234	321	398	234	321	398	234	321	398
Rotary dryer	M	WS	109	135	165	103	130	157	104	128	154
Vibrating-grate dryer	M	WS	--	296	--	--	296	--	--	296	--
Rotary calciner	M	WS	139	186	--	154	212	--	154	212	--
Fuller's earth											
Fluid bed dryer	L	BH	--	--	1,549	--	--	1,549	--	--	1,549
Rotary dryer	S	BH	358	490	694	358	490	694	358	490	694
Rotary dryer	S	WS	132	161	214	131	165	211	130	161	211
Rotary calciner	M	BH	316	656	847	316	656	847	316	656	847
Gypsum											
Rotary dryer	M	BH	--	269	322	--	269	322	--	269	322
Flash calciner	M	BH	--	150	--	--	150	--	--	150	--
Kettle calciner	M	BH	--	150	--	--	150	--	--	150	--

(continued)

TABLE 8-4d. (continued)

Industry/facility	Typical facility size[a]	Control device	RA I, $000			RA II, $000			RA III, $000		
			S	M	L	S	M	L	S	M	L
Industrial sand											
Fluid bed dryer	M	WS	124	181	326	124	181	326	124	181	326
Rotary dryer	S	WS	105	142	198	105	142	198	105	142	198
Kaolin											
Rotary dryer	M	BH	--	349	--	--	349	--	--	349	--
Spray dryer	M,L	BH	--	698	1,096	--	698	1,096	--	698	1,096
Flash calciner	S	BH	564	--	--	564	--	--	564	--	--
Multiple hearth furnace	S	WS	100	--	--	97	--	--	97	--	--
Rotary calciner	S	BH	582	--	--	582	--	--	582	--	--
Rotary calciner	S	WS	166	--	--	160	--	--	160	--	--
Lightweight aggregate											
Rotary calciner	M	BH	475	681	857	475	681	857	475	681	857
Rotary calciner	M	WS	263	389	588	299	498	763	299	498	763
Magnesium compounds											
Multiple hearth furnace											
$Mg(OH)_2$ feed	L	ESP	479	704	824	525	819	978	525	819	978
Magnesite feed	M	BH	--	762	1,125	--	762	1,125	--	762	1,125
Rotary calciner											
$Mg(OH)_2$ feed	S	ESP	681	804	--	757	919	--	757	919	--
Magnesite feed	L	BH	--	--	968	--	--	968	--	--	968
Perlite											
Rotary dryer	M	BH	--	618	915	--	618	915	--	618	915
Expansion furnace	S	BH	183	--	--	183	--	--	183	--	--
Roofing granules											
Fluid bed dryer	M	WS	--	159	--	--	159	--	--	159	--
Rotary dryer	S,M	WS	142	178	219	142	178	219	142	178	219
Talc											
Flash dryer	S	BH	235	--	--	235	--	--	235	--	--
Rotary dryer	M	BH	--	279	694	--	279	694	--	279	694
Rotary calciner	S	BH	476	--	--	476	--	--	476	--	--

(continued)

TABLE 8-4d. (continued)

Industry/facility	Typical facility size[a]	Control device	RA I, $000			RA II, $000			RA III, $000		
			S	M	L	S	M	L	S	M	L
Titanium dioxide											
Flash dryer	L	WS	--	--	410	--	--	477	--	--	555
Fluid bed dryer	L	BH	--	--	542	--	--	542	--	--	542
Fluid bed dryer	L	WS	--	--	192	--	--	213	--	--	259
Rotary dryer (direct)	L	BH	125	183	275	125	183	275	125	183	275
Rotary dryer (indirect)	M	WS	--	74	--	--	72	--	--	73	--
Spray dryer	M	BH	265	493	735	265	493	735	265	493	735
Rotary calciner	S,M	WS	223	396	--	223	396	--	223	396	--
Vermiculite											
Fluid bed dryer	L	BH	--	--	425	--	--	425	--	--	425
Rotary dryer	M	WS	--	139	144	--	139	144	--	138	142
Expansion furnace	S	BH	104	--	--	104	--	--	104	--	--

[a] S = small, M = medium, L = large.

TABLE 8-5a. ANNUALIZED COSTS OF POLLUTION CONTROL EQUIPMENT REGULATORY ALTERNATIVE I (January 1984 Dollars)

Industry/facility	Typical facility size[a]	Control device	Utilities, $000	Operator, supervisor, and maintenance labor,[b] $000	Overhead, $000	Product recovery credit,[c] $000	Capital charges, $000	Total,[d] $000
Alumina								
Flash calciner	L	ESP	20	20	11	-1,478	158	-1,269
Rotary calciner	S	ESP	24	20	11	-977	162	-760
Ball clay								
Rotary dryer (indirect)	M	BH	3	32	10	-15	61	91
Vibrating-grate dryer (indirect)	M	BH	5	33	12	-37	56	69
Bentonite								
Fluid bed dryer	M	BH	18	112	20	-140	146	156
Fluid bed dryer	M	ESP	10	14	8	-148	149	33
Rotary dryer	M	BH	9	79	19	-70	85	122
Diatomite								
Flash dryer	S	WS	22	41	25	--	29	117
Rotary dryer	M	BH	2	36	13	-118	48	-19
Rotary calciner	L	BH	12	69	20	-325	103	-121
Rotary calciner	L	WS	24	33	20	--	35	112
Feldspar								
Fluid bed dryer	M	BH	2	50	15	-18	35	84
Fluid bed dryer	L	BH	3	68	15	-31	49	104
Rotary dryer	L	WS	10	26	16	--	30	82
Fire clay								
Rotary dryer	M	BH	3	30	9	-11	51	82
Rotary dryer	M	WS	5	15	9	--	28	57
Vibrating-grate dryer	M	WS	12	10	6	--	60	88
Rotary calciner	M	WS	32	41	25	--	38	136
Fuller's earth								
Fluid bed dryer	L	BH	36	93	20	-340	244	53
Rotary dryer	S	BH	8	52	23	-69	57	71
Rotary dryer	S	WS	15	38	23	--	28	104
Rotary calciner	M	BH	12	76	25	-90	103	126
Gypsum								
Rotary dryer	M	BH	4	60	17	-6	43	118
Flash calciner	M	BH	1	39	17	-18	24	63
Kettle calciner	M	BH	1	39	17	-138	24	-57
Industrial sand								
Fluid bed dryer	M	WS	18	32	20	--	37	107
Rotary dryer	S	WS	2	9	6	--	21	[illegible]
Kaolin								
Rotary dryer	M	BH	3	29	9	-45	56	[illegible]
Spray dryer	M	BH	15	74	25	-186	110	[illegible]
Spray dryer	L	BH	29	88	25	-319	173	[illegible]
Flash calciner	S	BH	15	52	25	-1,454	89	-1,2[illegible]
Multiple hearth furnace	S	WS	11	41	25	--	19	[illegible]
Rotary calciner	S	BH	10	75	25	-213	91	[illegible]
Rotary calciner	S	WS	30	41	25	--	34	[illegible]

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TABLE 8-5a. (continued)

Industry/facility	Typical facility size[a]	Control device	Utilities, $000	Operator, supervisor, and maintenance labor,[b] $000	Overhead, $000	Product recovery credit,[c] $000	Capital charges, $000	Total,[d] $000
Lightweight aggregate								
Rotary calciner	M	BH	27	84	25	147[e]	108	391
Rotary calciner	M	WS	85	41	25	--	78	229
Magnesium compounds								
Multiple hearth furnace								
$Mg(OH)_2$ feed	L	ESP	21	19	10	-1,138	130	-958
Magnesite feed	M	BH	13	66	32	-700	120	-469
Rotary calciner								
$Mg(OH)_2$ feed	S	ESP	13	19	10	-429	108	-279
Magnesite feed	L	BH	29	78	32	-995	152	-704
Perlite								
Rotary dryer	M	BH	9	72	9	6[e]	97	193
Expansion furnace	S	BH	1	16	5	-15	28	35
Roofing granules								
Fluid bed dryer	M	WS	9	20	12	--	33	74
Rotary dryer	S	WS	11	30	18	--	29	88
Rotary dryer	M	WS	17	30	18	--	36	101
Talc								
Flash dryer	S	BH	4	42	17	-45	37	55
Rotary dryer	M	BH	3	54	23	-89	45	36
Rotary calciner	S	BH	7	79	25	-151	75	35
Titanium dioxide								
Flash dryer	L	WS	114	52	32	-4,890	83	-4,609
Fluid bed dryer	L	BH	14	93	28	-643	86	-422
Fluid bed dryer	L	WS	32	46	28	-643	39	-498
Rotary dryer (direct)	L	BH	7	77	32	-316	43	-157
Rotary dryer (indirect)	M	WS	2	52	32	-72	15	29
Spray dryer	M	BH	14	95	32	-2,847	77	-2,629
Rotary calciner	S	WS	50	52	32	-962	46	-782
Rotary calciner	M	WS	99	52	32	-1,929	80	-1,666
Vermiculite								
Fluid bed dryer	L	BH	18	41	15	13[e]	68	155
Rotary dryer	M	WS	4	13	8	--	28	53
Expansion furnace	S	BH	1	19	9	-41	16	4

[a] S = small, M = medium, L = large.
[b] Includes materials costs.
[c] Product recovery credits are presented as negative costs.
[d] Negative values indicate that product recovery credits are greater than total annualized costs. Total values may not add exactly because of independent rounding.
[e] Product not recovered. Cost incurred from waste disposal.

TABLE 8-5b. ANNUALIZED COSTS OF POLLUTION CONTROL EQUIPMENT REGULATORY ALTERNATIVE II (January 1984 Dollars)

Industry/facility	Typical facility size[a]	Control device	Utilities, $000	Operator, supervisor, and maintenance labor,[b] $000	Overhead, $000	Product recovery credit,[c] $000	Capital charges, $000	Total,[d] $000
Alumina								
Flash calciner	L	ESP	24	20	11	-1,520	174	-1,291
Rotary calciner	S	ESP	31	20	11	-1,016	180	-774
Ball clay								
Rotary dryer (indirect)	M	BH	3	37	10	-16	62	96
Vibrating-grate dryer (indirect)	M	BH	5	38	13	-38	56	74
Bentonite								
Fluid bed dryer	M	BH	18	135	21	-142	146	178
Fluid bed dryer	M	ESP	15	14	8	-150	170	57
Rotary dryer	M	BH	9	95	20	-71	84	137
Diatomite								
Flash dryer	S	WS	31	41	25	--	30	127
Rotary dryer	M	BH	2	41	14	-121	48	-16
Rotary calciner	L	BH	12	81	21	-330	103	-113
Rotary calciner	L	WS	39	33	20	--	37	129
Feldspar								
Fluid bed dryer	M	BH	2	59	16	-19	35	93
Fluid bed dryer	L	BH	3	81	16	-32	49	117
Rotary dryer	L	WS	11	26	16	--	30	83
Fire clay								
Rotary dryer	M	BH	3	36	10	-12	50	87
Rotary dryer	M	WS	9	15	9	--	27	60
Vibrating-grate dryer	M	WS	12	10	6	--	60	88
Rotary calciner	M	WS	51	41	25	--	43	160
Fuller's earth								
Fluid bed dryer	L	BH	36	112	21	-343	244	70
Rotary dryer	S	BH	8	59	25	-70	57	79
Rotary dryer	S	WS	19	38	23	--	27	107
Rotary calciner	M	BH	12	89	26	-93	104	1[illegible]
Gypsum								
Rotary dryer	M	BH	4	71	19	-6	41	129
Flash calciner	M	BH	1	45	19	-18	23	70
Kettle calciner	M	BH	1	45	19	-139	23	-51
Industrial sand								
Fluid bed dryer	M	WS	20	32	20	--	34	10[illegible]
Rotary dryer	S	WS	2	9	6	--	21	[illegible]
Kaolin								
Rotary dryer	M	BH	3	34	10	-46	55	[illegible]
Spray dryer	M	BH	15	86	26	-192	110	[illegible]
Spray dryer	L	BH	29	104	26	-329	171	[illegible]
Flash calciner	S	BH	15	59	26	-1,455	89	-1,[illegible]
Multiple hearth furnace	S	WS	18	41	25	--	19	[illegible]
Rotary calciner	S	BH	10	87	26	-216	94	[illegible]
Rotary calciner	S	WS	44	41	25	--	32	[illegible]

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TABLE 8-5b. (continued)

Industry/facility	Typical facility size[a]	Control device	Utilities, $000	Operator, supervisor, and maintenance labor,[b] $000	Overhead, $000	Product recovery credit,[c] $000	Capital charges, $000	Total,[d] $000
Lightweight aggregate								
Rotary calciner	M	BH	27	98	26	148[e]	108	407
Rotary calciner	M	WS	124	41	25	--	101	291
Magnesium compounds								
Multiple hearth furnace								
$Mg(OH)_2$ feed	L	ESP	28	19	10	-1,174	154	-963
Magnesite feed	M	BH	13	74	34	-714	120	-473
Rotary calciner								
$Mg(OH)_2$ feed	S	ESP	16	19	10	-440	120	-275
Magnesite feed	L	BH	29	90	34	-1,018	152	-713
Perlite								
Rotary dryer	M	BH	9	88	10	6[e]	97	210
Expansion furnace	S	BH	1	19	5	-16	29	38
Roofing granules								
Fluid bed dryer	M	WS	9	20	12	--	33	74
Rotary dryer	S	WS	11	30	18	--	29	88
Rotary dryer	M	WS	17	30	18	--	36	101
Talc								
Flash dryer	S	BH	4	48	19	-47	36	60
Rotary dryer	M	BH	3	62	24	-91	44	42
Rotary calciner	S	BH	7	92	26	-156	75	44
Titanium dioxide								
Flash dryer	L	WS	153	52	32	-4,978	96	-4,645
Fluid bed dryer	L	BH	14	109	30	-670	86	-431
Fluid bed dryer	L	WS	58	46	28	-670	43	-495
Rotary dryer (direct)	L	BH	7	88	34	-325	43	-153
Rotary dryer (indirect)	M	WS	4	52	32	-88	15	15
Spray dryer	M	BH	14	110	34	-2,906	78	-2,670
Rotary calciner	S	WS	50	52	32	-962	46	-782
Rotary calciner	M	WS	99	52	32	-1,929	80	-1,666
Vermiculite								
Fluid bed dryer	L	BH	18	47	16	14[e]	68	163
Rotary dryer	M	WS	4	13	8	--	29	54
Expansion furnace	S	BH	1	21	10	-42	15	5

[a] S = small, M = medium, L = large.
[b] Includes materials costs.
[c] Product recovery credits are presented as negative costs.
[d] Negative values indicate that product recovery credits are greater than total annualized costs.
Total values may not add exactly because of independent rounding.
[e] Product not recovered. Cost incurred from waste disposal.

TABLE 8-5c. ANNUALIZED COSTS OF POLLUTION CONTROL EQUIPMENT REGULATORY ALTERNATIVE III (January 1984 Dollars)

Industry/facility	Typical facility size[a]	Control device	Utilities, $000	Operator, supervisor, and maintenance labor,[b] $000	Overhead, $000	Product recovery credit,[c] $000	Capital charges, $000	Total,[d] $000
Alumina								
Flash calciner	L	ESP	24	20	11	-1,520	174	-1,291
Rotary calciner	S	ESP	31	20	11	-1,016	180	-774
Ball clay								
Rotary dryer (indirect)	M	BH	3	38	10	-16	61	96
Vibrating-grate dryer (indirect)	M	BH	5	39	13	-38	56	75
Bentonite								
Fluid bed dryer	M	BH	18	136	22	-143	146	179
Fluid bed dryer	M	ESP	16	14	8	-151	180	67
Rotary dryer	M	BH	9	95	20	-71	85	138
Diatomite								
Flash dryer	S	WS	42	41	25	--	36	144
Rotary dryer	M	BH	2	42	14	-121	48	-15
Rotary calciner	L	BH	12	81	21	-330	103	-113
Rotary calciner	L	WS	39	33	20	--	37	129
Feldspar								
Fluid bed dryer	M	BH	2	59	16	-19	36	94
Fluid bed dryer	L	BH	3	82	16	-32	49	118
Rotary dryer	L	WS	18	26	16	--	29	89
Fire clay								
Rotary dryer	M	BH	3	36	10	-12	51	88
Rotary dryer	M	WS	11	15	9	--	26	61
Vibrating-grate dryer	M	WS	12	10	6	--	60	88
Rotary calciner	M	WS	51	41	25	--	43	160
Fuller's earth								
Fluid bed dryer	L	BH	36	112	21	-344	244	69
Rotary dryer	S	BH	8	60	25	-71	58	80
Rotary dryer	S	WS	22	38	23	--	27	110
Rotary calciner	M	BH	12	89	26	-93	104	138
Gypsum								
Rotary dryer	M	BH	4	71	19	-6	42	130
Flash calciner	M	BH	1	45	19	-18	23	70
Kettle calciner	M	BH	1	45	19	-139	23	-51
Industrial sand								
Fluid bed dryer	M	WS	18	32	20	--	37	107
Rotary dryer	S	WS	2	9	6	--	21	[illegible]
Kaolin								
Rotary dryer	M	BH	3	34	10	-46	55	[illegible]
Spray dryer	M	BH	15	87	27	-193	110	[illegible]
Spray dryer	L	BH	29	105	27	-330	172	[illegible]
Flash calciner	S	BH	15	59	26	-1,455	89	-1,[illegible]
Multiple hearth furnace	S	WS	18	41	25	--	19	[illegible]
Rotary calciner	S	BH	10	87	26	-216	92	[illegible]
Rotary calciner	S	WS	44	41	25	--	32	[illegible]

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TABLE 8-5c. (continued)

Industry/facility	Typical facility size[a]	Control device	Utilities, $000	Operator, supervisor, and maintenance labor,[b] $000	Overhead, $000	Product recovery credit,[c] $000	Capital charges, $000	Total,[d] $000
Lightweight aggregate								
Rotary calciner	M	BH	27	98	26	148[e]	108	407
Rotary calciner	M	WS	124	41	25	--	101	291
Magnesium compounds								
Multiple hearth furnace								
$Mg(OH)_2$ feed	L	ESP	28	19	10	-1,174	154	-963
Magnesite feed	M	BH	13	74	34	-714	120	-473
Rotary calciner								
$Mg(OH)_2$ feed	S	ESP	16	19	10	-440	120	-275
Magnesite feed	L	BH	29	90	34	-1,018	152	-713
Perlite								
Rotary dryer	M	BH	9	88	10	6[e]	97	210
Expansion furnace	S	BH	1	19	5	-16	29	38
Roofing granules								
Fluid bed dryer	M	WS	9	20	12	--	33	74
Rotary dryer	S	WS	11	30	18	--	29	88
Rotary dryer	M	WS	17	30	18	--	36	101
Talc								
Flash dryer	S	BH	4	49	19	-48	36	60
Rotary dryer	M	BH	3	63	25	-92	44	43
Rotary calciner	S	BH	7	92	26	-156	75	44
Titanium dioxide								
Flash dryer	L	WS	173	52	32	-4,997	112	-4,628
Fluid bed dryer	L	BH	14	110	30	-672	85	-433
Fluid bed dryer	L	WS	65	46	28	-672	52	-481
Rotary dryer (direct)	L	BH	7	89	34	-326	43	-153
Rotary dryer (indirect)	M	WS	5	52	32	-89	15	15
Spray dryer	M	BH	14	112	34	-2,917	78	-2,679
Rotary calciner	S	WS	50	52	32	-962	46	-782
Rotary calciner	M	WS	99	52	32	-1,929	80	-1,666
Vermiculite								
Fluid bed dryer	L	BH	18	48	16	14[e]	68	164
Rotary dryer	M	WS	5	13	8	--	28	54
Expansion furnace	S	BH	1	21	15	-42	15	5

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[a] S = small, M = medium, L = large.
[b] Includes materials costs.
[c] Product recovery credits are presented as negative costs.
[d] Negative values indicate that product recovery credits are greater than total annualized costs. Total values may not add exactly because of independent rounding.
[e] Product not recovered. Cost incurred from waste disposal.

TABLE 8-5d. TOTAL ANNUALIZED COSTS OF POLLUTION CONTROL EQUIPMENT FOR EACH REGULATORY ALTERNATIVE (January 1984 Dollars)

Industry/facility	Typical facility size[a]	Control device	RA I, $000			RA II, $000			RA III, $000		
			S	M	L	S	M	L	S	M	L
Alumina											
Flash calciner	L	ESP	--	--	-1,269[b]	--	--	-1,291	--	--	-1,291
Rotary calciner	S	ESP	-760	-954	-1,217	-774	-969	-1,234	-774	-969	-1,234
Ball clay											
Rotary dryer (indirect)	M	BH	--	91	--	--	96	--	--	96	--
Vibrating-grate dryer (indirect)	M	BH	--	69	86	--	74	93	--	75	93
Bentonite											
Fluid bed dryer	M	BH	--	156	--	--	178	--	--	179	--
Fluid bed dryer	M	ESP	--	33	--	--	57	--	--	67	--
Rotary dryer	M	BH	104	122	143	115	137	162	116	138	163
Diatomite											
Flash dryer	S	WS	117	--	145	127	--	168	144	--	193
Rotary dryer	M	BH	--	-19	--	--	-16	--	--	-15	--
Rotary calciner	L	BH	-23	--	-121	-16	--	-113	-16	--	-113
Rotary calciner	L	WS	89	--	112	97	--	129	97	--	129
Feldspar											
Fluid bed dryer	M,L	BH	--	84	104	--	93	117	--	94	118
Rotary dryer	L	WS	49	65	82	49	65	83	50	68	89
Fire clay											
Rotary dryer	M	BH	66	82	91	70	87	97	70	88	97
Rotary dryer	M	WS	50	57	65	51	60	68	52	61	68
Vibrating-grate dryer	M	WS	--	88	--	--	88	--	--	88	--
Rotary calciner	M	WS	113	136	--	128	160	--	128	160	--
Fuller's earth											
Fluid bed dryer	L	BH	--	--	53	--	--	70	--	--	69
Rotary dryer	S	BH	71	68	66	79	77	76	80	78	77
Rotary dryer	S	WS	104	117	138	107	123	144	110	125	151
Rotary calciner	M	BH	101	126	142	110	138	156	110	138	156
Gypsum											
Rotary dryer	M	BH	--	118	125	--	129	136	--	130	137
Flash calciner	M	BH	--	63	--	--	70	--	--	70	--
[illegible]	M	BH	--	-57	--	--	-51	--	--	-51	--

(continued)

TABLE 8-5d. (continued)

Industry/facility	Typical facility size[a]	Control device	RA I, $000			RA II, $000			RA III, $000		
			S	M	L	S	M	L	S	M	L
Industrial sand											
Fluid bed dryer	M	WS	44	107	160	44	107	160	44	107	160
Rotary dryer	S	WS	38	47	86	38	47	86	38	47	86
Kaolin											
Rotary dryer	M	BH	--	52	--	--	56	--	--	56	--
Spray dryer	M,L	BH	--	38	-4	--	45	3	--	46	3
Flash calciner	S	BH	-1,273	--	--	-1,266	--	--	-1,266	--	--
Multiple hearth furnace	S	WS	96	--	--	103	--	--	103	--	--
Rotary calciner	S	BH	-12	--	--	-1	--	--	-1	--	--
Rotary calciner	S	WS	130	--	--	142	--	--	142	--	--
Lightweight aggregate											
Rotary calciner	M	BH	288	391	489	303	407	508	303	407	508
Rotary calciner	M	WS	174	229	295	207	291	382	207	291	382
Magnesium compounds											
Multiple hearth furnace											
$Mg(OH)_2$ feed	L	ESP	-157	-658	-958	-156	-661	-963	-156	-661	-963
Magnesite feed	M	BH	--	-469	-797	--	-473	-808	--	-473	-808
Rotary calciner											
$Mg(OH)_2$ feed	S	ESP	-279	-468	--	-275	-461	--	-275	-461	--
Magnesite feed	L	BH	--	--	-704	--	--	-713	--	--	-713
Perlite											
Rotary dryer	M	BH	--	193	268	--	210	290	--	210	290
Expansion furnace	S	BH	35	--	--	38	--	--	38	--	--
Roofing granules											
Fluid bed dryer	M	WS	--	74	--	--	74	--	--	74	--
Rotary dryer	S,M	WS	88	101	94	88	101	94	88	101	94
Talc											
Flash dryer	S	BH	55	--	--	60	--	--	60	--	--
Rotary dryer	M	BH	--	36	-86	--	42	-79	--	43	-79
Rotary calciner	S	BH	35	--	--	44	--	--	44	--	--

(continued)

TABLE 8-5d. (continued)

Industry/facility	Typical facility size[a]	Control device	RA I, $000			RA II, $000			RA III, $000		
			S	M	L	S	M	L	S	M	L
Titanium dioxide											
Flash dryer	L	WS	--	--	-4,609	--	--	-4,645	--	--	-4,628
Fluid bed dryer	L	BH	--	--	-422	--	--	-431	--	--	-433
Fluid bed dryer	L	WS	--	--	-498	--	--	-495	--	--	-481
Rotary dryer (direct)	L	BH	49	-29	-157	55	-24	-153	57	-23	-153
Rotary dryer (indirect)	M	WS	--	29	--	--	15	--	--	15	--
Spray dryer	M	BH	-984	-2,629	-4,261	-995	-2,670	-4,331	-998	-2,679	-4,347
Rotary calciner	S,M	WS	-782	-1,666	--	-782	-1,666	--	-782	-1,666	--
Vermiculite											
Fluid bed dryer	L	BH	--	--	155	--	--	163	--	--	164
Rotary dryer	M	WS	--	53	54	--	53	54	--	54	55
Expansion furnace	S	BH	4	--	--	5	--	--	5	--	--

[a] S = small, M = medium, L = large.

[b] Negative values indicate that product recovery credits are greater than total annualized costs.

TABLE 8-6. PRODUCT VALUES USED TO CALCULATE PRODUCT RECOVERY CREDITS FOR POLLUTION CONTROL EQUIPMENT

Industry/facility[a]	Control device	Product Value $/Mg	Product Value $/ton
Alumina			
Calciners	ESP	297.00	269.00
Ball clay			
Dryers	BH	36.38	33.00
Bentonite			
Dryers	BH	43.00	39.00
Diatomite			
Dryers	BH	197.00	179.00
Calciners	BH	197.00	179.00
Feldspar			
Dryers	BH	36.00	33.00
Fire clay			
Dryers	BH	17.60	16.00
Fuller's earth			
Dryers	BH	54.00	49.00
Calciners	BH	54.00	49.00
Gypsum			
Dryers	BH	9.00	8.00
Calciners	BH	24.00	22.00
Kaolin			
Dryers	BH	86.00	78.00
Calciners	BH	132.10	120.00
Magnesium compounds			
Multiple hearth furnaces	ESP, BH	398.00	362.00
Rotary calciners	ESP, BH	236.00	214.00
Perlite			
Calciners	BH	181.90	165.00
Talc			
Dryers	BH	111.20	100.90
Calciners	BH	111.20	100.90

(continued)

TABLE 8-6. (continued)

Industry/facility[a]	Control device	Product Value $/Mg	 $/ton
<u>Titanium dioxide</u>			
Flash dryer	WS	931.00	845.00
Fluid bed dryer	BH	1,433.00	1,300.00
Fluid bed dryer	WS	330.00	300.00
Rotary dryer (direct)	BH	330.00	300.00
Rotary dryer (indirect)	WS	330.00	300.00
Spray dryer	BH	1,433.00	1,300.00
Rotary calciner	WS	687.00	633.00
<u>Vermiculite</u>			
Calciners	BH	257.00	233.00

[a] Particulate matter controlled by wet scrubbers is disposed as waste for all industries except titanium dioxide. The titanium dioxide industry recycles scrubber-controlled particulate matter from dryers and calciners to the process. Particulate matter controlled by BH's on lightweight aggregate calciners and perlite dryers is disposed as waste.

TABLE 8-7. COST EFFECTIVENESS OF REGULATORY ALTERNATIVES[a]
$/Mg of Particulate Removed
($/ton of Particulate Removed)

Industry/facility	Typical facility size[b]	Control device	RA II vs. RA I[c]			RA III vs. RA I[d]			RA III vs. RA II[c]		
			S	M	L	S	M	L	S	M	L
Alumina											
Flash calciner	L	ESP	--	--	-150[e,f]	--	--	-150	--	--	g
			--	--	(-140)	--	--	(-140)	--	--	g
Rotary calciner	S	ESP	-110	-100	-90	-110	-100	-90	g	g	g
			(-100)	(-90)	(-80)	(-100)	(-90)	(-80)	g	g	g
Ball clay											
Rotary dryer (indirect)	M	BH	--	420	--	--	410	--	--	280	--
			--	(380)	--	--	(370)	--	--	(250)	--
Vibrating-grate dryer	M	BH	--	220	140	--	200	130	--	130	40
(indirect)			--	(200)	(130)	--	(180)	(120)	--	(120)	(40)
Bentonite											
Fluid bed dryer	M	BH	--	440	--	--	360	--	--	40	--
			--	(400)	--	--	(330)	--	--	(40)	--
Fluid bed dryer	M	ESP	--	440	--	--	510	--	--	780	--
			--	(400)	--	--	(460)	--	--	(710)	--
Rotary dryer	M	BH	830	740	560	680	590	440	200	110	60
			(750)	(670)	(510)	(620)	(540)	(400)	(180)	(100)	(50)
Diatomite											
Flash dryer	S	WS	540	--	670	1,100	--	1,100	2,300	--	2,000
			(490)	--	(610)	(970)	--	(930)	(2,100)	--	(1,800)
Rotary dryer	M	BH	--	210	--	--	200	--	--	100	--
			--	(190)	--	--	(180)	--	--	(90)	--
Rotary calciner	L	BH	560	--	320	560	--	320	g	--	g
			(510)	--	(290)	(510)	--	(290)	g	--	g
Rotary calciner	L	WS	1,100	--	1,200	4,200	--	4,800	--	--	g
			(1,000)	--	(1,100)	(3,800)	--	(4,400)	--	--	g
Feldspar											
Fluid bed dryer	M,L	BH	--	630	530	--	590	500	--	360	200
			--	(570)	(480)	--	(540)	(450)	--	(330)	(180)
Rotary dryer	L	WS	0	10	20	70	80	110	960	1,100	1,400
			(0)	(10)	(20)	(60)	(70)	(100)	(870)	(1,000)	(1,300)
Fire clay											
Rotary dryer	M	BH	420	340	240	410	320	230	350	210	140
			(380)	(310)	(220)	(370)	(290)	(210)	(320)	(190)	(130)
Rotary dryer	M	WS	110	180	140	190	220	100	770	480	-200
			(100)	(160)	(130)	(170)	(200)	(90)	(700)	(440)	(-180)

(continued)

TABLE 8-7. (continued)

Industry/facility	Typical facility size[b]	Control device	RA II vs. RA I[c]			RA III vs. RA I[d]			RA III vs. RA II[c]		
			S	M	L	S	M	L	S	M	L
Fire clay (continued)											
Vibrating-grate dryer	M	WS	-- --	h h	-- --	-- --	h h	-- --	-- --	h h	-- --
Rotary calciner	M	WS	300 (270)	300 (270)	-- --	300 (270)	300 (270)	-- --	g g	g g	-- --
Fuller's earth											
Fluid bed dryer	L	BH	-- --	-- --	350 (320)	-- --	-- --	230 (210)	-- --	-- --	10 (10)
Rotary dryer	S	BH	370 (340)	300 (270)	240 (220)	340 (310)	250 (230)	200 (180)	200 (180)	110 (100)	60 (50)
Rotary dryer	S	WS	140 (130)	190 (170)	130 (120)	240 (220)	220 (200)	230 (210)	640 (580)	340 (310)	660 (600)
Rotary calciner	M	BH	450 (410)	240 (220)	220 (200)	450 (410)	240 (220)	220 (200)	g g	g g	g g
Gypsum											
Rotary dryer	M	BH	-- --	560 (510)	420 (380)	-- --	530 (480)	400 (360)	-- --	320 (290)	240 (220)
Flash calciner	M	BH	-- --	1,700 (1,500)	-- --	-- --	1,700 (1,500)	-- --	-- --	g g	-- --
Kettle calciner	M	BH	-- --	1,200 (1,100)	-- --	-- --	1,200 (1,100)	-- --	-- --	g g	-- --
Industrial sand											
Fluid bed dryer	M	WS	h h	h h	h h	h h	h h	h h	h h	h h	h h
Rotary dryer	S	WS	h h	h h	h h	h h	h h	h h	h h	h h	h h
Kaolin											
Rotary dryer	M	BH	-- --	300 (270)	-- --	-- --	260 (240)	-- --	-- --	150 (140)	-- --
Spray dryer	M,L	BH	-- --	110 (100)	70 (60)	-- --	110 (100)	60 (50)	-- --	70 (60)	0 (0)
Flash calciner	S	BH	660 (600)	-- --	-- --	660 (600)	-- --	-- --	g g	-- --	-- --
Multiple hearth furnace	S	WS	470 (430)	-- --	-- --	470 (430)	-- --	-- --	g g	-- --	-- --
Rotary calciner	S	BH	430 (390)	-- --	-- --	430 (390)	-- --	-- --	g g	-- --	-- --
Rotary calciner	S	WS	480 (440)	-- --	-- --	480 (440)	-- --	-- --	g g	-- --	-- --

(continued)

TABLE 8-7. (continued)

Industry/facility	Typical facility size[b]	Control device	RA II vs. RA I[c]			RA III vs. RA I[d]			RA III vs. RA II[c]		
			S	M	L	S	M	L	S	M	L
Lightweight aggregate											
Rotary calciner	M	BH	360	280	240	360	280	240	g	g	g
			(330)	(250)	(220)	(330)	(250)	(220)	g	g	g
Rotary calciner	M	WS	810	1,000	1,100	810	1,000	1,100	g	g	g
			(740)	(900)	(970)	(740)	(900)	(970)			
Magnesium compounds											
Multiple hearth furnace											
$Mg(OH)_2$ feed	L	ESP	20	-30	-40	20	-30	-40	g	g	g
			(20)	(-30)	(-40)	(20)	(-30)	(-40)	g	g	g
Magnesite feed	M	BH	--	120	190	--	120	190	g	g	g
			--	(110)	(170)	--	(110)	(170)	g	g	g
Rotary calciner											
$Mg(OH)_2$ feed	S	ESP	90	90	--	90	90	--	g	g	g
			(80)	(80)	--	(80)	(80)	--	g	g	g
Magnesite feed	L	BH	--	--	100	--	--	100	g	g	g
			--	--	(90)	--	--	(90)	g	g	g
Perlite											
Rotary dryer	M	BH	--	5,500	4,400	--	2,300	1,900	--	80	30
			--	(5,000)	(4,000)	--	(2,100)	(1,700)	--	(70)	(30)
Expansion furnace	S	BH	1,300	--	--	1,300	--	--	g	--	--
			(1,200)	--	--	(1,200)	--	--	g	--	--
Roofing granules											
Fluid bed dryer	M	WS	--	h	--	--	h	--	--	h	--
			--	h	--	--	h	--	--	h	--
Rotary dryer	S,M	WS	h	h	h	h	h	h	h	h	h
			h	h	h	h	h	h	h	h	h
Talc											
Flash dryer	S	BH	280	--	--	290	--	--	460	--	--
			(250)	--	--	(260)	--	--	(420)	--	--
Rotary dryer	M	BH	--	290	90	--	290	80	--	290	0
			--	(260)	(80)	--	(260)	(70)	--	(260)	(0)
Rotary calciner	S	BH	170	--	--	170	--	--	g	--	--
			(150)	--	--	(150)	--	--	g	--	--
Titanium dioxide											
Flash dryer	L	WS	--	--	-370	--	--	-170	--	--	840
			--	--	(-340)	--	--	(-150)	--	--	(760)
Fluid bed dryer	L	BH	--	--	-110	--	--	-110	--	--	-130
			--	--	(-100)	--	--	(-100)	--	--	(-120)

(continued)

TABLE 8-7. (continued)

Industry/facility	Typical facility size[b]	Control device	RA II vs. RA I[c]			RA III vs. RA I[d]			RA III vs. RA II[c]		
			S	M	L	S	M	L	S	M	L
Titanium dioxide (continued)											
Fluid bed dryer	L	WS	-- --	-- --	30 (30)	-- --	-- --	200 (180)	-- --	-- --	1,900 (1,700)
Rotary dryer (direct)	L	BH	1,200 (1,100)	400 (360)	140 (130)	1,300 (1,200)	420 (380)	140 (130)	2,100 (1,900)	580 (530)	120 (110)
Rotary dryer (indirect)	M	WS	-- --	-300 (-270)	-- --	-- --	-280 (-250)	-- --	-- --	680 (620)	-- --
Spray dryer	M	BH	-670 (-610)	-1,000 (-910)	-1,100 (-970)	-700 (-640)	-1,000 (-940)	-1,100 (-1,000)	-880 (-800)	-1,200 (-1,100)	-1,300 (-1,200)
Rotary calciner	S,M	WS	h h	h h	-- --	h h	h h	-- --	g g	g g	-- --
Vermiculite											
Fluid bed dryer	L	BH	-- --	-- --	100 (90)	-- --	-- --	100 (90)	-- --	-- --	130 (120)
Rotary dryer	M	WS	-- --	i i	i i	-- --	20 (20)	10 (10)	-- --	280 (250)	140 (130)
Expansion furnace	S	BH	260 (240)	-- --	-- --	260 (240)	-- --	-- --	g g	-- --	-- --

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[a] The source will choose the most cost effective method of control when an option of more than one control device exists.

[b] S = small, M = medium, L = large.

[c] Incremental cost effectiveness.

[d] Average cost effectiveness.

[e] Metric and English units may not convert exactly because values were rounded independently.

[f] Negative values occur when product recovery credits are greater than the annualized cost of pollution control equipment for the more stringent regulatory alternative.

[g] No additional costs are incurred for calciners under RA III because the emission outlet concentration for both RA II and RA III is 90 mg/dscm (0.04 gr/dscf).

[h] No additional costs are incurred because the same pressure drop is used for RA I, RA II, and RA III.

[i] No additional costs are incurred because the same pressure drop is used for RA I and RA II.

TABLE 8-8. COST EFFECTIVENESS OF REGULATORY ALTERNATIVES VERSUS UNCONTROLLED CONDITIONS
$/Mg of Particulate Removed
($/ton of Particulate Removed)

Industry/facility	Typical facility size^{a}	Control device	RA I vs. Uncontrolled			RA II vs. Uncontrolled			RA III vs. Uncontrolled		
			S	M	L	S	M	L	S	M	L
Alumina											
Flash calciner	L	ESP	-- --	-- --	-250^{b,c} (-230)	-- --	-- --	-250 (-230)	-- --	-- --	-250 (-230)
Rotary calciner	S	ESP	-230 (-210)	-240 (-220)	-240 (-220)	-230 (-210)	-230 (-210)	-230 (-210)	-230 (-210)	-230 (-210)	-230 (-210)
Ball clay											
Rotary dryer (indirect)	M	BH	-- --	220 (200)	-- --	-- --	220 (200)	-- --	-- --	220 (200)	-- --
Vibrating-grate dryer (indirect)	M	BH	-- --	70 (60)	40 (40)	-- --	70 (60)	40 (40)	-- --	70 (60)	40 (40)
Bentonite											
Fluid bed dryer	M	BH	-- --	40 (40)	-- --	-- --	60 (50)	-- --	-- --	60 (50)	-- --
Fluid bed dryer	M	ESP	-- --	10 (10)	-- --	-- --	20 (20)	-- --	-- --	20 (20)	-- --
Rotary dryer	M	BH	100 (90)	80 (70)	60 (50)	110 (100)	90 (80)	60 (50)	100 (90)	90 (80)	60 (50)
Diatomite											
Flash dryer	S	WS	70 (60)	-- --	50 (40)	70 (60)	-- --	60 (50)	80 (70)	-- --	60 (50)
Rotary dryer	M	BH	-- --	-30 (-30)	-- --	-- --	-20 (-20)	-- --	-- --	-20 (-20)	-- --
Rotary calciner	L	BH	-30 (-30)	-- --	-80 (-70)	-20 (-20)	-- --	-70 (-60)	-20 (-20)	-- --	-70 (-60)
Rotary calciner	L	WS	130 (120)	-- --	80 (70)	140 (130)	-- --	90 (80)	140 (130)	-- --	90 (80)
Feldspar											
Fluid bed dryer	M,L	BH	-- --	170 (150)	120 (110)	-- --	180 (160)	130 (120)	-- --	180 (160)	130 (120)
Rotary dryer	L	WS	390 (350)	120 (110)	80 (70)	360 (330)	110 (100)	80 (70)	360 (330)	120 (110)	80 (70)

(continued)

TABLE 8-8. (continued)

Industry/facility	Typical facility size[a]	Control device	RA I vs. Uncontrolled S	RA I vs. Uncontrolled M	RA I vs. Uncontrolled L	RA II vs. Uncontrolled S	RA II vs. Uncontrolled M	RA II vs. Uncontrolled L	RA III vs. Uncontrolled S	RA III vs. Uncontrolled M	RA III vs. Uncontrolled L
Fire clay											
Rotary dryer	M	BH	160 (150)	130 (120)	100 (90)	180 (160)	130 (120)	110 (100)	180 (160)	130 (120)	110 (100)
Rotary dryer	M	WS	130 (120)	90 (80)	80 (70)	130 (120)	90 (80)	80 (70)	130 (120)	90 (80)	80 (70)
Vibrating-grate dryer	M	WS	-- --	60 (50)	-- --	-- --	60 (50)	-- --	-- --	60 (50)	-- --
Rotary calciner	M	WS	30 (30)	20 (20)	-- --	50 (40)	30 (30)	-- --	50 (40)	30 (30)	-- --
Fuller's earth											
Fluid bed dryer	L	BH	-- --	-- --	10 (10)	-- --	-- --	10 (10)	-- --	-- --	10 (10)
Rotary dryer	S	BH	60 (50)	30 (30)	20 (20)	70 (60)	40 (40)	20 (20)	70 (60)	40 (40)	20 (20)
Rotary dryer	S	WS	80 (70)	70 (60)	40 (40)	80 (70)	70 (60)	60 (50)	90 (80)	70 (60)	60 (50)
Rotary calciner	M	BH	150 (140)	80 (70)	70 (60)	170 (150)	80 (70)	70 (60)	170 (150)	80 (70)	70 (60)
Gypsum											
Rotary dryer	M	BH	-- --	180 (160)	140 (130)	-- --	190 (170)	140 (130)	-- --	190 (170)	140 (130)
Flash calciner	M	BH	-- --	90 (80)	-- --	-- --	90 (80)	-- --	-- --	90 (80)	-- --
Kettle calciner	M	BH	-- --	-10 (-10)	-- --	-- --	-10 (-10)	-- --	-- --	-10 (-10)	-- --
Industrial sand											
Fluid bed dryer	M	WS	140 (130)	60 (50)	30 (30)	140 (130)	60 (50)	30 (30)	140 (130)	60 (50)	30 (30)
Rotary dryer	S	WS	200 (180)	140 (130)	70 (60)	190 (170)	120 (110)	60 (50)	190 (170)	120 (110)	60 (50)

(continued)

TABLE 8-8. (continued)

Industry/facility	Typical facility size[a]	Control device	RA I vs. Uncontrolled			RA II vs. Uncontrolled			RA III vs. Uncontrolled		
			S	M	L	S	M	L	S	M	L
Kaolin											
Rotary dryer	M	BH	--	100	--	--	100	--	--	110	--
			--	(90)	--	--	(90)	--	--	(100)	--
Spray dryer	M,L	BH	--	20	0	--	20	0	--	20	0
			--	(20)	(0)	--	(20)	(0)	--	(20)	(0)
Flash calciner	S	BH	-120	--	--	-110	--	--	-110	--	--
			(-110)	--	--	(-100)	--	--	(-100)	--	--
Multiple hearth furnace	S	WS	150	--	--	170	--	--	170	--	--
			(140)	--	--	(150)	--	--	(150)	--	--
Rotary calciner	S	BH	-10	--	--	0	--	--	0	--	--
			(-10)	--	--	(0)	--	--	(0)	--	--
Rotary calciner	S	WS	80	--	--	90	--	--	90	--	--
			(70)	--	--	(80)	--	--	(80)	--	--
Lightweight aggregate											
Rotary calciner	M	BH	20	10	10	20	10	10	20	10	10
			(20)	(10)	(10)	(20)	(10)	(10)	(20)	(10)	(10)
Rotary calciner	M	WS	10	10	10	10	10	10	10	10	10
			(10)	(10)	(10)	(10)	(10)	(10)	(10)	(10)	(10)
Magnesium compounds											
Multiple hearth furnace											
$Mg(OH)_2$ feed	L	ESP	-230	-320	-340	-230	-320	-330	-230	-320	-330
			(-210)	(-290)	(-310)	(-210)	(-290)	(-300)	(-210)	(-290)	(-300)
Magnesite feed	M	BH	--	-260	-290	--	-260	-290	--	-260	-290
			--	(-240)	(-260)	--	(-240)	(-260)	--	(-240)	(-260)
Rotary calciner											
$Mg(OH)_2$ feed	S	ESP	-150	-180	--	-140	-170	--	-140	-170	--
			(-140)	(-160)	--	(-130)	(-150)	--	(-130)	(-150)	--
Magnesite feed	L	BH	--	--	-170	--	--	-170	--	--	-170
			--	--	(-150)	--	--	(-150)	--	--	(-150)
Perlite											
Rotary dryer	M	BH	--	170	140	--	190	150	--	190	150
			--	(150)	(130)	--	(170)	(140)	--	(170)	(140)
Expansion furnace	S	BH	420	--	--	440	--	--	440	--	--
			(380)	--	--	(400)	--	--	(400)	--	--

(continued)

TABLE 8-8. (continued)

Industry/facility	Typical facility size[a]	Control device	RA I vs. Uncontrolled			RA II vs. Uncontrolled			RA III vs. Uncontrolled		
			S	M	L	S	M	L	S	M	L
Roofing granules											
Fluid bed dryer	M	WS	-- --	80 (70)	-- --	-- --	80 (70)	-- --	-- --	70 (60)	-- --
Rotary dryer	S,M	WS	70 (60)	60 (50)	60 (50)	70 (60)	60 (50)	60 (50)	70 (60)	60 (50)	60 (50)
Talc											
Flash dryer	S	BH	130 (120)	-- --	-- --	140 (130)	-- --	-- --	140 (130)	-- --	-- --
Rotary dryer	M	BH	-- --	40 (40)	-30 (-30)	-- --	60 (50)	-30 (-30)	-- --	60 (50)	-30 (-30)
Rotary calciner	S	BH	20 (20)	-- --	-- --	30 (30)	-- --	-- --	30 (30)	-- --	-- --
Titanium dioxide											
Flash dryer	L	WS	-- --	-- --	-880 (-800)	-- --	-- --	-870 (-790)	-- --	-- --	-860 (-780)
Fluid bed dryer	L	BH	-- --	-- --	-220 (-200)	-- --	-- --	-220 (-200)	-- --	-- --	-210 (-190)
Fluid bed dryer	L	WS	-- --	-- --	-250 (-230)	-- --	-- --	-240 (-220)	-- --	-- --	-240 (-220)
Rotary dryer (direct)	L	BH	260 (240)	-70 (-60)	-170 (-150)	300 (270)	-40 (-40)	-150 (-140)	300 (270)	-40 (-40)	-150 (-140)
Rotary dryer (indirect)	M	WS	-- --	130 (120)	-- --	-- --	60 (50)	-- --	-- --	60 (50)	-- --
Spray dryer	M	BH	-1,200 (-1,100)	-1,300 (-1,200)	-1,300 (-1,200)	-1,200 (-1,100)	-1,300 (-1,200)	-1,300 (-1,200)	-1,200 (-1,100)	-1,300 (-1,200)	-1,300 (-1,200)
Rotary calciner[d]	S,M	WS	-590 (-540)	-620 (-570)	-- --	-590 (-540)	-620 (-570)	-- --	-590 (-540)	-620 (-570)	-- --
Vermiculite											
Fluid bed dryer	L	BH	-- --	-- --	100 (90)	-- --	-- --	100 (90)	-- --	-- --	100 (90)
Rotary dryer	M	WS	-- --	120 (110)	110 (100)	-- --	110 (100)	110 (100)	-- --	110 (100)	110 (100)
Expansion furnace	S	BH	20 (20)	-- --	-- --	30 (30)	-- --	-- --	30 (30)	-- --	-- --

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[a] S = small, M = medium, L = large.

[b] Metric and English units may not convert exactly because values were rounded independently.

[c] Negative values occur when product recovery credits are greater than the annualized cost of pollution control equipment.

[d] Cost-effectiveness values are constant for RA I, RA II, and RA III because the same pressure drop and mass inlet and outlet concentration is used for all three alternatives

TABLE 8-9. FIVE-YEAR PROJECTION OF NATIONWIDE CAPITAL AND ANNUALIZED CONTROL COSTS OF EACH REGULATORY ALTERNATIVE

Industry/facility	Typical facility size[a]	Control device	Pollution control equipment capital cost in 1990			Pollution control equipment annualized cost in 1990		
			RA I, $000	RA II, $000	RA III, $000	RA I, $000	RA II, $000	RA III, $000
Alumina								
Flash calciner	L	ESP	3,012	3,300	3,300	-3,807[b]	-3,873	-3,873
Rotary calciner	S	ESP	15,405	17,130	17,130	-11,400	-11,610	-11,610
Ball clay								
Rotary dryer (indirect)	M	BH	0	0	0	0	0	0
Vibrating-grate dryer (indirect)	M	BH	354	354	354	69	74	75
Bentonite								
Fluid bed dryer	M	BH, ESP[c]	0	0	0	0	0	0
Rotary dryer	M	BH	1,617	1,617	1,617	366	411	414
Diatomite								
Flash dryer	S	WS	432	447	528	351	381	432
Rotary dryer	M	BH	305	305	305	-19	-16	-15
Rotary calciner	L	BH	1,304	1,304	1,304	-242	-226	-226
Rotary calciner	L	WS	338	354	354	224	258	258
Feldspar								
Fluid bed dryer	M, L	BH	0	0	0	0	0	0
Rotary dryer	L	WS	0	0	0	0	0	0
Fire clay								
Rotary dryer	M	BH	321	321	321	82	87	88
Rotary dryer	M	WS	135	130	128	57	60	61
Vibrating-grate dryer	M	WS	0	0	0	0	0	0
Rotary calciner	M	WS	0	0	0	0	0	0
Fuller's earth								
Fluid bed dryer	L	BH	0	0	0	0	0	0
Rotary dryer	S	BH	2,506	2,506	2,506	497	553	560
Rotary dryer	S	WS	924	917	910	728	749	770
Rotary calciner	M	BH	1,312	1,312	1,312	252	276	276
Gypsum								
Rotary dryer	M	BH	3,497	3,497	3,497	1,534	1,677	1,690
Flash calciner	M	BH	4,950	4,950	4,950	2,079	2,310	2,310
Kettle calciner	M	BH	4,050	4,050	4,050	-1,539	-1,377	-1,377
Industrial sand								
Fluid bed dryer	M	WS	724	724	724	428	428	428
Rotary dryer	S	WS	840	840	840	304	304	304
Kaolin								
Rotary dryer	M	BH	1,047	1,047	1,047	156	168	168
Spray dryer	M, L	BH	7,479	7,479	7,479	216	279	288
Flash calciner	S	BH	0	0	0	0	0	0
Multiple hearth furnace	S	WS	600	582	582	576	618	618
Rotary calciner	S	BH	0	0	0	0	0	0
Rotary calciner	S	WS	0	0	0	0	0	0
Lightweight aggregate								
Rotary calciner	M	BH	4,767	4,767	4,767	2,730	2,849	2,849
Rotary calciner	M	WS	2,723	3,485	3,486	1,603	2,037	2,037
gnesium compounds								
Multiple hearth furnace	M, L	BH, ESP[d]	801	897	897	-775	-779	-779
Rotary calciner	S, L	BH, ESP[d]	911	926	926	-619	-625	-625

(continued)

TABLE 8-9. (continued)

Industry/facility	Typical facility size[a]	Control device	Pollution control equipment capital cost in 1990 RA I, $000	RA II, $000	RA III, $000	Pollution control equipment annualized cost in 1990 RA I, $000	RA II, $000	RA III, $000
Perlite								
Rotary dryer	M	BH	618	618	618	194	210	210
Expansion furnace	S	BH	2,379	2,379	2,379	455	494	494
Roofing granules								
Fluid bed dryer	M	WS	0	0	0	0	0	0
Rotary dryer	S, M	WS	745	745	745	455	455	455
Talc								
Flash dryer	S	BH	2,350	2,350	2,350	550	600	600
Rotary dryer	M	BH	0	0	0	0	0	0
Rotary calciner	S	BH	1,428	1,428	1,428	105	132	132
Titanium dioxide								
Flash dryer	L	WS	0	0	0	0	0	0
Fluid bed dryer	L	BH	0	0	0	0	0	0
Fluid bed dryer	L	WS	0	0	0	0	0	0
Rotary dryer (direct)	L	BH	275	275	275	-157	-153	-153
Rotary dryer (indirect)	M	WS	74	72	73	29	15	15
Spray dryer	M	BH	1,972	1,972	1,972	-10,516	-10,680	-10,716
Rotary calciner	S, M	WS	676	676	676	-2,148	-2,148	-2,148
Vermiculite								
Fluid bed dryer	L	BH	0	0	0	0	0	0
Rotary dryer	M	WS	139	139	138	53	53	54
Expansion furnace	S	BH	936	936	936	36	45	45
TOTAL[e]			67,826	69,945	70,026	-19,705	-19,068	-19,017
TOTAL[f]			63,048	65,934	66,006	-20,208	-19,274	-19,200

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[a] S = small, M = medium, L = large. For facilities with two typical sizes, projections were based on a weighted average of the number of affected facilities projected for each typical size.

[b] Negative values indicate that product recovery credits are greater than total annualized costs.

[c] The projection was based on BH costs because BH's were more cost effective than ESP's.

[d] Baghouses are used to control facilities processing magnesite feed and ESP's are used to control facilities processing $Mg(OH)_2$ feed. Therefore, projections were based on a weighted average of the cost of BH's and ESP's and the number of affected facilities projected for each typical size.

[e] Total includes diatomite rotary calciner, fire clay rotary dryer, fuller's earth rotary dryer, kaolin rotary calciner, and lightweight aggregate rotary calciner BH costs and not WS costs.

[f] Total includes diatomite rotary calciner, fire clay rotary dryer, fuller's earth rotary dryer, kaolin rotary calciner, and lightweight aggregate rotary calciner WS costs and not BH costs.

TABLE 8-10. CAPITAL COST DATA SOURCES FOR MINERAL DRYER AND CALCINER PROCESS UNITS

Cost item	Source	Date	Ref.
1. Process units, auxiliary equipment and insulation	EPA/OAQPS/EAB	Dec. 1977	48
	Gypsum NSPS BID	Nov. 1980	40
	Industry	1983	36-39
	Vendors	June 1984	20-35
2. Cyclones, auxiliary equipment, and insulation	EPA/OAQPS/EAB	Dec. 1977	61
3. Cost factors	EPA/OAQPS/EAB	Dec. 1977	48

TABLE 8-11. DRYER AND CALCINER PROCESS UNIT CAPITAL COST FACTORS FOR NEW FACILITIES

Cost item	Cost factor
A. Direct costs	
1. Purchased equipment for process unit	
a. Process unit	A
b. Auxiliary equipment (burner, instruments and controls, structural supports, taxes, and freight)	B
c. Total (C = A+B)	C
2. Installation for process unit, D = installation cost factor for foundation and support, erection and handling, electrical, piping, insulation, and painting costs	(D)(C)
3. Purchased equipment for cyclone	
a. Cyclone	E
b. Auxiliary equipment (ductwork and elbows, structural supports, dust hopper, and scroll)	F
c. Instruments and controls	0.10 (E+F)
d. Taxes	0.03 (E+F
e. Freight	0.05 (E+
f. Total (3c through 3e)	0.18 (E+F
g. Purchased equipment cost factor, G = 1.18 (E+F)	G
4. Installation for cyclone	
a. Foundation and supports	0.04 (
b. Erection and handling	0.14 (
c. Piping	0.02 (
d. Painting	0.01 (
e. Site preparation	0.05 (
f. Total (5a through 5e)	0.26 (
B. Indirect costs	
1. Installation for process unit	[illegible]
2. Installation for cyclone	
a. Engineering and supervision	0.10(
b. Construction and field expenses	0.10(
c. Construction fee	0.10(
d. Contingencies	0.03(
e. Total (2a through 2c)	0.33(
TOTAL CAPITAL COST FACTOR	(D)(C)+0.[illegible]

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[a] Indirect installation costs of process units were included in the dir installation cost factor for process units.

TABLE 8-12. CAPITAL COSTS OF PROCESS UNITS (January 1984 Dollars)

try/facility	Typical facility size^a	Capital cost, $000
ina		
sh calciner	L	4,023
ary calciner	S	2,105
clay		
ary dryer (indirect)	M	344
rating-grate dryer (indirect)	M	895
nite		
id bed dryer	M	456
ary dryer	M	368
ite		
sh dryer	S	585
ary dryer	M	201
ary calciner	L	1,498
ar		
id bed dryer	M	254
id bed dryer	L	351
ry dryer	L	330
lay		
ry dryer	M	327
ating-grate dryer	M	1,511
ry calciner	M	1,825
's earth		
d bed dryer	L	640
ry dryer	S	177
ry calciner	M	2,024
ry dryer	M	442
h calciner	M	1,283
le calciner	M	864
rial sand		
d bed dryer	M	739
y dryer	S	440
y dryer	M	266
dryer	M	686
dryer	L	1,128
calciner	S	927
ple hearth furnace	S	430
y calciner	S	1,251

(continued)

TABLE 8-12. (continued)

Industry/facility	Typical facility size[a]	Capital cost, $000
Lightweight aggregate		
Rotary calciner	M	2,275
Magnesium compounds		
Multiple hearth furnace		
$Mg(OH)_2$ feed	L	907
Magnesite feed	M	526
Rotary calciner		
$Mg(OH)_2$ feed	S	1,244
Magnesite feed	L	1,857
Perlite		
Rotary dryer	M	315
Expansion furnace	S	194
Roofing granules		
Fluid bed dryer	M	425
Rotary dryer	S	238
Rotary dryer	M	520
Talc		
Flash dryer	S	157
Rotary dryer	M	197
Rotary calciner	S	1,165
Titanium dioxide		
Flash dryer	L	882
Fluid bed dryer	M	457
Rotary dryer (direct)	L	229
Rotary dryer (indirect)	M	209
Spray dryer	M	407
Rotary calciner	S	1,112
Rotary calciner	M	1,241
Vermiculite		
Fluid bed dryer	L	537
Rotary dryer	M	208
Expansion furnace	S	192

[a] S = small, M = medium, L = large.

TABLE 8-13. COMPARISON OF CAPITAL COSTS OF POLLUTION CONTROL EQUIPMENT TO CAPITAL COSTS OF UNCONTROLLED PROCESS UNITS (January 1984 Dollars)

Industry/facility	Typical facility size[a]	Control device	Pollution control equipment cost (percent of facility cost)		
			RA I	RA II	RA III
Alumina					
Flash calciner	L	ESP	24	26	26
Rotary calciner	S	ESP	48	53	53
Ball clay					
Rotary dryer (indirect)	M	BH	111	111	111
Vibrating-grate dryer (indirect)	M	BH	39	39	39
Bentonite					
Fluid bed dryer	M	BH	213	213	213
Fluid bed dryer	M	ESP	217	248	261
Rotary dryer	M	BH	143	143	143
Diatomite					
Flash dryer	S	WS	24	24	29
Rotary dryer	M	BH	148	148	148
Rotary calciner	L	BH	43	43	43
Rotary calciner	L	WS	11	12	12
Feldspar					
Fluid bed dryer	M	BH	88	88	88
Fluid bed dryer	L	BH	88	88	88
Rotary dryer	L	WS	43	43	43
Fire clay					
Rotary dryer	M	BH	96	96	96
Rotary dryer	M	WS	40	39	38
Vibrating-grate dryer	M	WS	20	20	20
Rotary calciner	M	WS	10	12	12
Fuller's earth					
Fluid bed dryer	L	BH	229	229	229
Rotary dryer	S	BH	195	195	195
Rotary dryer	S	WS	72	71	71
Rotary calciner	M	BH	32	32	32
Gypsum					
Rotary dryer	M	BH	60	60	60
Flash calciner	M	BH	12	12	12
Kettle calciner	M	BH	17	17	17
Industrial sand					
Fluid bed dryer	M	WS	24	24	24
Rotary dryer	S	WS	24	24	24
Kaolin					
Rotary dryer	M	BH	129	129	129
Spray dryer	M	BH	100	100	100
Spray dryer	L	BH	96	96	96
Flash calciner	S	BH	60	60	60
Multiple hearth furnace	S	WS	23	23	23
Rotary calciner	S	BH	46	46	46
Rotary calciner	S	WS	13	13	13
Lightweight aggregate					
Rotary calciner	M	BH	29	29	29
Rotary calciner	M	WS	17	21	21

(continued)

TABLE 8-13. (continued)

Industry/facility	Typical facility size[a]	Control device	Pollution control equipment cost (percent of facility cost)		
			RA I	RA II	RA III
Magnesium compounds					
Multiple hearth furnace					
Mg(OH)$_2$ feed	L	ESP	89	105	105
Magnesite feed	M	BH	142	142	142
Rotary calciner					
Mg(OH)$_2$ feed	S	ESP	54	60	60
Magnesite feed	L	BH	52	52	52
Perlite					
Rotary dryer	M	BH	190	190	190
Expansion furnace	S	BH	93	93	93
Roofing granules					
Fluid bed dryer	M	WS	37	37	37
Rotary dryer	S	WS	59	59	59
Rotary dryer	M	WS	34	34	34
Talc					
Flash dryer	S	BH	145	145	145
Rotary dryer	M	BH	139	139	139
Rotary calciner	S	BH	41	41	41
Titanium dioxide					
Flash dryer	L	WS	44	51	60
Fluid bed dryer	L	BH	119	119	119
Fluid bed dryer	L	WS	42	47	57
Rotary dryer (direct)	L	BH	118	118	118
Rotary dryer (indirect)	M	WS	35	34	35
Spray dryer	M	BH	119	119	119
Rotary calciner	S	WS	20	20	20
Rotary calciner	M	WS	32	32	32
Vermiculite					
Fluid bed dryer	L	BH	78	78	78
Rotary dryer	M	WS	66	66	65
Expansion furnace	S	BH	54	54	54

[a] S = small, M = medium, L = large.

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9. ECONOMIC IMPACT

The purpose of this chapter is to describe current economic parameters and anticipated economic effects resulting from setting a New Source Performance Standard for each of the 17 mineral industries. The information provided earlier in Chapter 8 (Cost of Pollution Control) and below in Section 9.1 (Industry Economic Profile) forms the basis for formal analyses of the economic effects of the pollution control regulatory alternatives on the various mineral industries. These analyses are presented in Section 9.2 and Section 9.3. The references for Chapter 9 are provided in Section 9.4.

9.1 INDUSTRY ECONOMIC PROFILE

The 17 mineral industries are listed in alphabetical order in Table 9-1. For each industry, the major product uses are listed in the order of their importance for the industry. Note that a number of industries share common end product uses, and thus compete with one another in some cases. Major economic characteristics for each industry such as production, imports, price, number of firms, employment, and growth rates, are presented in summary form in Table 9-2. In Table 9-2 the six industries that are in the clay "family" are grouped together because some economic information is only available for the group as a whole and not for each of the six clay industries individually. A brief discussion of each industry is provided below. More detailed economic profile information, such as company names, plant locations, historical prices, and historical production, can be found in the docket. Unless noted otherwise, tons represent short tons (2,000 pounds).

TABLE 9-1. MINERAL INDUSTRIES: PRODUCT USES

Mineral Industry (SIC)[a]	Product uses
1. Alumina (1051, 3334)	Aluminum metal, abrasives, refractories, chemicals
2. Ball clay (1455)	Pottery, sanitary ware, tile, china/dinner ware
3. Bentonite (1452)	Drilling mud, iron ore pelletizing, foundry sand
4. Diatomite (1499)	Filtration media, fillers
5. Feldspar (1459)	Glassmaking, pottery, porcelain enamel
6. Fire clay (1453)	Refractories, mortars
7. Fuller's earth (1454)	Pet waste, oil and grease absorbents
8. Gypsum (1492, 3275)	Wallboard, building and specialty plasters
9. Industrial sand (1446)	Glass, foundry sand
10. Kaolin (1455)	Paper coating, paint
11. Lightweight aggregate (1499)	Concrete block, precast and prestressed concrete products
12. Magnesium compounds (3295)	Refractories, livestock feed additives, chemicals, pharmaceuticals, fertilizers, construction materials, electrical heating rods, fluxes, petroleum additives
13. Perlite (1499, 3295)	Soil conditioners, loose-fill insulation, construction fillers
14. Roofing granules (3295)	Coated and uncoated roofing shingles
15. Talc (1496)	Ceramics, paint, plastics
16. Titanium dioxide (2816)	Paint finishes, paper
17. Vermiculite (1499, 3295)	Soil conditioner, lightweight concrete aggregates, loose-fill insulation

[a] Standard Industrial Classification.

STATISTICS[a]

Mineral Industry	Annual Production 1978-1983 10^3 Mg (10^3 tons)	Avg. Annual Imports 1978-1983 10^3 Mg (10^3 tons)	Price \$ per Mg (\$ per ton) 1983	No. of Firms (no. of plants) 1983	Employment 1983	Projected growth: annual percent
Alumina	5,976[b] (6,588)	3,572 (3,938)	228; 203; 352[c] (207; 184; 319)	5 (6)	400	1981-1990: 6.3
Clays	42,400 (46,748)	28 (31)	Varies with product	383 (1,000)	2,000	1982-1990: 2-4
Ball clay	779 (859)	d	38.13[f] (34.59)	4 (5)	d	d
Bentonite	3,638 (4,011)	d	42.64 (38.69)	12 (24)	d	d
Fire clay	1,854 (2,045)	d	18.70 (16.97)	10 (10)	d	d
Fuller's earth	1,477 (1,629)	d	11.02-77.02 (10.00-69.89)	5 (5)	d	d
Kaolin	6,566 (7,239)	d	87.91 (79.76)	12 (13)	d	d
LWA[e]	4,579 (5,049)	d	4.54 (4.12)	32 (39)	d	d
Diatomite	602 (663)	minimal	215 (195)	7 (9)	900	1982-1990: 2.0
Feldspar	628 (693)	minimal	36 (33)	11 (12)	450	1981-1990: 2.0
Gypsum (crude)	11,509 (12,689)	6,962 (7,676)	9.92 (9.00)	14 (69)	5,300	1981-1990: 3.3

(continued)

TABLE 9-2. (continued)

Mineral Industry	Avg. Annual Production 1978-1983 10^3 Mg (10^3 tons)	Avg. Annual Imports 1978-1983 10^3 Mg (10^3 tons)	Price \$ per Mg (\$ per ton) 1983	No. of Firms (no. of plants) 1983	Employment 1983	Projected growth: annual percent
Industrial sand	26,732 (29,473)	minimal	13.17 (11.95)	120 (195)	1,500	1979-1990: 1.5
Magnesium compounds	701 (773)	49 (54)	245 (222)	10[f] (13)	900	1978-1990: 1.8
Perlite	535 (590)	16[g] (18)	35.84 (32.50)	42 (70)	150	1982-1990: 3.0
Roofing granules	4,743[h,i] (5,230)	Not Available	39.00 35.00	4[j] (16)	Not Available	1979-1990: 2.0
Talc	1,148 (1,266)	21 (23)	Varies with product	21[k] (35)	800	1979-1990: 2.0
Titanium dioxide	650 (717)	112 (124)	1,650 (1,500)	6 (13)	4,200	1980-1990: 2.0
Vermiculite	296 (326)	23 (25)	107[l] (97)	15 (46)	300	1982-1990: 2.0

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[a] Conversion factors used for metric units as follows: 1.102 short tons = 1 megagram (Mg)
1 short ton = .907 Mg

[b] Average production for 1978-1982.
[c] Prices for calcined, heavy hydrated and granular activated alumina.
[d] Included with clays.
[e] Not limited solely to clay.
[f] 1982 data.
[g] Average imports for 1982 and 1983 only.
[h] Average production for 1978 through 1981.
[i] Uncoated granules
[illegible]

9.1.1 Alumina

Alumina (Al_2O_3) is a white powdery material that is chemically extracted from bauxite. Deposits of bauxite are widespread globally, although the major deposits are confined to a belt extending 20° north and south of the equator.[1] Over two-thirds of the world's bauxite reserves are in four areas: Guinea (27 percent), Australia (21 percent), Brazil (11 percent), and Jamaica (9 percent). United States bauxite reserves are less than 0.2 percent of the world total. In 1981, imports supplied about 90 percent of the U.S. bauxite requirements, and 36 percent of the alumina requirements.[2]

The main use of alumina is in the production of primary aluminum metal. Alumina is also used in refractories and chemicals. The alumina products used by the refractories industry are tabular alumina, calcined alumina, and calcium aluminate cement. In addition to these products, other chemical products made from alumina include activated alumina, gallium, and hydrated alumina.

The Bayer process has been the standard commercial method for refining bauxite to alumina for the past 90 years. Although it has been improved and modified to treat different types of bauxites, the basic elements of the process remain unchanged. Bauxite is the only ore used in the commercial production of alumina. Bauxite ores have an average alumina content of 40 to 60 percent. About 2 Mg (2.2 tons) of bauxite are required to produce 1 Mg (1.1 ton) of alumina, and almost 2 Mg (2.2 tons) of alumina are required to produce 1 Mg (1.1 ton) of aluminum metal.

During 1982 and 1983 prices of calcined, heavy hydrated, and ranular activated alumina remained steady at $228, $203, and $352/Mg $207, $184, and $319/short ton), respectively.[3]

In 1982, eight U.S. refineries processed an estimated 92 percent all domestic and imported bauxite into alumina, and approximately 90 rcent of the alumina was used to produce aluminum metal. Reacting to k markets and prices, domestic bauxite mines operated at less than percent of capacity, and output declined 54 percent from the 1981 put. The market remained weak in 1983 with domestic bauxite mines and alumina plants operating at 35 to 40 percent of capacity, and mine production declining 4 percent from the 1982 output. Production of alumina declined significantly in 1982 compared with 1981. Annual production of alumina averaged 6 $\times 10^6$ Mg (6.6 $\times 10^6$ tons) during the 5-year period from 1978 through 1982. Imports of alumina in 1983 increased 27 percent from the 1982 total.

Possible alternative domestic raw materials for making alumina include clays, anorthosite, alunite, coal wastes, and oil shales. Potential resources of aluminum in nonbauxitic materials in the United States are abundant and could meet domestic aluminum requirements. However, since no plants have been built to treat such materials and optimum processes have not been determined, this technology is not likely to appear in the short-term.

Three major companies operating six refineries control approximately 80 percent of the total alumina output. With the exception of the Virgin Islands facility, U.S. refineries are located in Arkansas, Louisiana, and Texas. The three dominant companies are highly integrated.

The demand for primary aluminum metal in 1983 increased slightly as the markets recovered from the low levels of 1980 through 1982. Domestic bauxite production in 1983 was 0.66 $\times 10^6$ Mg (0.73 $\times 10^6$ tons) and is expected to increase to 0.73 $\times 10^6$ Mg (0.8 $\times 10^6$ tons) in 1984. Apparent consumption of bauxite and alumina (in aluminum equivalent) in 1983 is estimated at 4.2 $\times 10^6$ Mg (4.6 $\times 10^6$ tons) and is expected to increase to 4.4 $\times 10^6$ Mg (4.8 $\times 10^6$ tons) in 1984. From a 1981 base, apparent aluminum metal demand is projected to grow at about 6.3 percent a year through 1990.[4] However, increasing imports in the more processed form of aluminum metal will result in a somewhat lower annual rate of increase in demand for domestic alumina.

There are some changes in capacity that are occurring in the alumina industry. Aluminum Company of America is currently constructing a specialty alumina plant at Vidalia, Louisiana, that will produce primarily activated alumina with some production of tabular alumina to be used in the petrochemical industry. This plant is expected to begin operating in 1984. Reynolds Metals Company scheduled the phaseout of the Hurricane Creek, Arkansas plant in 1984.

9.1.2 The Clay Industries

Clay is a soil material that is composed mainly of fine particles of hydrous aluminum silicates and other minerals. The United States is a major world producer of high-quality clays. About 99 percent of the clay used in the U.S. comes from domestic mines, and about 7 percent of the total U.S. production is exported. In 1983, 33 firms supplied about one-half of the total output, and approximately 350 firms provided the remainder. Together these companies operated about 1,000 mines.

Most of the active clay mines in the United States are in Wyoming, Texas, Missouri, and Georgia. The major producers of the individual clays are located in the following states: ball clay in Tennessee, bentonite in Wyoming, common clay and shale in Texas, fire clay in Missouri, fuller's earth in Georgia and Florida, and kaolin in Georgia.

Increases in unit value were reported for all clays in 1982 because of increased labor, fuel, and material costs. In 1983, the total quantity of clays sold or used by domestic producers increased 14 percent from 1982. This increase in production reverses a downward trend that had occurred since 1978. Average annual production during the 6-year period 1978 to 1983 was 42.4 $x10^6$ Mg (46.8 $x10^6$ tons). It is estimated that in 1984 domestic mine production will be 39 $x10^6$ Mg (43 $x10^6$ tons). Most clay producers operated at 50 to 70 percent of apacity during 1983. Imports have declined since 1979, and averaged 8,000 Mg (31,000 tons) during the 6-year period 1978 through 1983.

World and U.S. resources of commercial clays are extremely large. r example, resources of kaolin in Georgia are estimated at between 5 to 9 $x10^9$ Mg (5 to 10 $x10^9$ tons). Therefore, development of y substitutes is not a high research priority. Clay substitutes and ernatives, such as talc and whiting, are sometimes used for filler extender applications.

Average prices for most clays are expected to rise slowly, reflecting higher quality requirements for the specialty clays and increasing costs associated with land acquisition, land rehabilitation, and environmental and energy factors.

According to the U.S. Bureau of Mines, demand for individual types of clay is expected to increase from a 1982 base at an annual rate of 2 to 4 percent through 1990.[5] The growth of the energy-intensive clay-based industries could be impeded by higher energy costs and lower construction rates. Characterization of the six specific clays investigated in this study follows.

9.1.2.1 Ball Clay. Ball clay is a fine-grained, sedimentary clay composed primarily (>70 percent) of the clay mineral kaolinite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$). Pottery manufacture, which uses the highest percentage of ball clay produced, consumed nearly one-fourth of the total output. The average unit value for ball clay reported by domestic producers rose between 1981 and 1982 to \$38.13/Mg (\$34.59/ton), an increase of \$1.81/Mg (\$1.64/ton).[6] Ball clay production declined significantly in 1982 to 0.58 $x10^6$ Mg (0.64 $x10^6$ tons) compared with 1981 production of 0.77 $x10^6$ Mg (0.85 $x10^6$ tons), but production is estimated to have increased in 1983 to 0.77 $x10^6$ Mg (0.85 $x10^6$ tons). Average annual production for the 6-year period 1978 through 1983 was 0.78 $x10^6$ Mg (0.86 $x10^6$ tons).

Ball clay exports in 1982 amounted to 0.13 $x10^6$ Mg (0.14 $x10^6$ tons) valued at \$5.2 million, compared with 0.19 $x10^6$ Mg (0.21 $x10^6$ tons) worth \$6.6 million in 1981. Unit value of the exports increased 15 percent to \$39.42/Mg (\$35.77/ton). Shipments were made to 29 countries; major recipients were Mexico (58 percent) and Canada (31 percent).

Ball clay imports, largely from Canada and the United Kingdom, decreased 29 percent to 6,600 Mg (7,300 tons) valued at \$856,000 in 1981 to 4,700 Mg (5,200 tons) valued at \$368,000 in 1982. The ball clay industry is not highly integrated. The industry mines, processes, and packages the material but has no involvement with final product applications.

The demand for ball clay is projected to keep pace with that expected for the clay industry in general, that is, to grow from a 1982 base by an annual average rate of 2 to 4 percent through 1990. Any industry growth that occurs is expected to take place in Tennessee or Kentucky. Increased production capacities, modernization, and/or construction of new plants slowed during 1982. Adequate reserves and present process technology ensure that domestic production can meet future increases in demand.

9.1.2.2 Bentonite. Bentonite is a clay consisting essentially of smectite minerals of the montmorillonite group. Bentonite can be classified according to its swelling capacities when wet. Bentonite with sodium as the dominant or the abundant exchangeable ion typically has very high-swelling capacities and forms gel-like masses when wet. Calcium is more abundant than other ions in the low-swelling bentonite that swells little more than common clay. The major use of bentonite is for drilling mud.

Average annual production of bentonite during the 6-year period from 1978 through 1983 was 3.6 $x10^6$ Mg (4 $x10^6$ tons). Production has generally declined during this period. Bentonite production in the U.S. for 1982 decreased 34 percent in tonnage and 31 percent in value compared to 1981. Bentonite was exported to 71 countries in 1982. The major recipients were Canada (34 percent), Japan (12 percent), Singapore (7 percent), and Saudi Arabia and the Netherlands (6 percent each). Bentonite exports decreased from 0.78 $x10^6$ Mg (0.86 $x10^6$ tons) in 1981 to 0.61 $x10^6$ Mg (0.67 $x10^6$ tons) in 1982, a 22 percent decline; total value of exports decreased from $64.5 million in 1981 to $54.7 million in 1982. The unit value of exported bentonite increased from $82.50/Mg ($74.83/ton) in 1981 to $90.26/Mg ($81.91/ton) in 1982. This increase in unit value was attributed to a larger percentage of the higher cost drilling muds and foundry sand grades being shipped. Domestic bentonite producers in 1982 faced increased competition in foreign markets.

Bentonite imports in 1982 (98 percent chemically activated material) totaled 6,600 Mg (7,000 tons) valued at $2.8 million, compared with 9,100 Mg (10,000 tons) valued at $4.8 million in 1981. The chemically activated bentonite was imported from five countries.

The average price of bentonite in 1982 was $42.64/Mg ($38.69/ton).[7] Prices increased in 1982 compared to 1981. The average value of bentonite sold or used by producers increased 5 percent in 1982 compared with 1981. The bentonite industry does not have a high degree of vertical integration. Although the industry does mine, process, and package the bentonite product, it has little involvement with final product application in terms of drilling operations.

During 1982, all the major western and southern bentonite producers either cancelled or deferred ongoing expansions or modernizations. This situation was caused by the significant decline in oil-and gas-well drilling activities at mid-year, compounded by the continued depression in the steel and foundry industries.

The demand for bentonite is projected to increase from a 1982 base at an annual rate of 2 to 4 percent through 1990. With successful conversion to coal from oil and gas firing in dryers, the industry was continuing to explore the practicality of augmenting coal with wood chips as a fuel. Producers of low-swelling bentonite, as well as producers of high-swelling bentonite, prefer rotary dryers to fluid bed dryers and would use them to replace existing units.

9.1.2.3 Fire Clay. Fire clay is detrital material containing low percentages of iron oxide, lime, magnesia, and alkalies to enable the material to withstand temperatures of 1500°C (2700°F) or higher. Clays that are commonly called fire clay, and are generally used as refractories, are the flints, plastics, and bauxites.

Annual production of fire clay averaged 1.9 $\times 10^6$ Mg (2 $\times 10^6$ tons) during the 6-year period from 1978 through 1983 with an overall downward trend. The industry is dependent to a significant degree on basic manufacturing industries such as steel and aluminum. The reported average unit value for fire clay produced in the United States increased from $17.84/Mg ($16.18/ton) in 1981 to $18.70/Mg ($16.97/ton) in 1982.[8]

Fire clay was exported to 31 countries in 1982. Japan received 28 percent, while Mexico, Belgium, the Federal Republic of Germany, and Canada received 18 percent, 16 percent, 13 percent and 11 percent, respectively. Exports of fire clay decreased 38 percent in 1982 to 0.16 $\times 10^6$ Mg (0.18 $\times 10^6$ tons) valued at $13.6 million, compared to 0.26 $\times 10^6$ Mg (0.29 $\times 10^6$ tons) valued at $19.3 million in 1981. The price of exported fire clay increased 14 percent to $83.31/Mg ($75.56/ton), indicating a larger percentage of higher quality material shipped.

No imports of fire clay were reported in 1982. Domestic fire clay production was reported in 1982 from mines in 17 States. In order of decreasing volume, Missouri, Ohio, Pennsylvania, West Virginia, and Alabama accounted for 88 percent of the total domestic output.

Most fire clay companies are highly integrated operations capable of mining, processing, bagging, and shipping the finished product. Most companies dry the raw material, process it into firebrick and other refractory shapes, and calcine the bricks/shapes prior to shipping.

Specialty refractory products include gunning, ramming, or plastic mixes, granular materials, hydraulic-setting castables, and mortars. These products are generally made from the same raw materials as their brick counterparts. According to the U.S. Bureau of Mines, the demand for fire clay is expected to increase from a 1982 base at an annual rate of 2 to 4 percent through 1990.

9.1.2.4 Fuller's Earth. Fuller's earth is a nonplastic clay or claylike material, usually high in magnesia, that has specialized decolorizing and purifying properties. Major uses of fuller's earth include pet waste absorbent, medical, pharmaceutical, and cosmetic applications.

Production of fuller's earth has remained relatively constant over the 6-year period 1978 to 1983, averaging 1.5 $\times 10^6$ Mg (1.6 $\times 10^6$ tons) per year. Production in 1982 increased in quantity and value from 1981 levels.

The two major types of fuller's earth produced are attapulgite and montmorillonite. Prices for attapulgite reported by producers in 1982 ranged from \$54.55 to \$77.02/Mg (\$49.50 to \$69.89/ton); montmorillonite prices ranged from \$11.02 to \$68.65/Mg (\$10.00 to \$62.30/ton).[9]

In 1982, fuller's earth was exported to 42 countries; exports decreased 16 percent from 0.10 x10^6 Mg (0.11 x10^6 tons) in 1981 to 0.08 x10^6 Mg (0.09 x10^6 tons) in 1982. The unit value of exported fuller's earth decreased 2 percent to \$102.16/Mg (\$92.68/ton). The major recipients were: Canada (63 percent), the Netherlands (16 percent), the United Kingdom (6 percent,; and other countries (15 percent). Imports of fuller's earth declined from 196 Mg (216 tons) valued at \$55,000 in 1981 to 36 Mg (40 tons) valued at \$8,000 in 1982.

Capacity utilization of fuller's earth processing plants in 1982 was approximately 85 percent. Most companies/plants are highly integrated operations. The majority of the facilities have the capability to produce the products in their end-use state, i.e., adsorbents, drilling mud, etc. From a 1982 base, demand for fuller's earth is projected to increase at an annual rate of 2 to 4 percent through 1990.

9.1.2.5 Kaolin. Kaolin consists essentially of the mineral kaolinite, which is a hydrated aluminum silicate ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$). Two basically different processes, a dry process and a wet process, are used to produce a kaolin product. The dry process is simple and yields a lower cost and lower quality product than the wet process. The dry process accounts for 20 percent of total production, and the wet process accounts for 70 percent of total production. The remaining 10 percent is not processed in a dryer or calciner. It is estimated that 60 to 65 percent of the industry uses spray dryers. The remaining 35 to 40 percent that use the air-floated dry process utilize rotary and other types of dryers.

The major use of kaolin is for paper coating applications, utilizing nearly one-half of the total output. The production and value of calcined kaolin sold or used by U.S. producers reached a low point due to the recession of 1982 but improved in 1983. Annual kaolin production averaged 6.6 x10^6 Mg (7.2 x10^6 tons) during the 6-year period from 1978 through 1983. Recovery in the automotive and housing industry helped to boost kaolin sales in the last half of 1983 but the main source of improvement came from the paper industry. No significant new expansions were initiated in 1983. Capital investment was concentrated in streamlining existing operations, rather than in building new plants.

The average price in 1983 was $87.91/Mg ($79.76/ton), up slightly from the 1982 price of $85.33/Mg ($77.42/ton).

Exports of kaolin, as reported by the U.S. Department of Commerce, decreased 8 percent in 1982 to 1.18 $\times 10^6$ Mg (1.30 $\times 10^6$ tons) valued at $147 million, compared to a value of $156 million in 1981. Kaolin, including calcined material was exported to 68 countries. The major recipients were Japan (34 percent), Canada (15 percent), the Netherlands (14 percent), Italy (8 percent), and Mexico (5 percent).

Imports of kaolin decreased 31 percent in 1982 to 8,500 Mg (9,400 tons) valued at $800,000. The United Kingdom supplied about 94 percent and Canada supplied about 6 percent. The demand for kaolin is expected to increase from a 1982 base at an annual rate of 2 to 4 percent through 1990.

9.1.2.6 Lightweight Aggregate. Lightweight aggregate (LWA) is produced by sintering either flyash or claylike materials (i.e., clay, shale, or slate) to produce an expanded and relatively low-density product. Lightweight aggregate is used in concrete in place of sand, gravel, or stone. Other uses are roofing granules, acoustical plaster, insulating fills, and landscaping materials. Substitutes for the more common raw materials (clay, shale, and slate) in the production of LWA are perlite, vermiculite, natural pumice, and blast furnace slag.

Average annual production of lightweight aggregate during the 6-year period 1978 through 1983 was 4.6 $\times 10^6$ Mg (5.0 $\times 10^6$ tons). During this time production generally declined. Domestic production of LWA decreased 18 percent in 1982 to 3.6 $\times 10^6$ Mg (4.0 $\times 10^6$ tons) valued at $25 million, compared with 4.4 $\times 10^6$ Mg (4.9 $\times 10^6$ tons) valued at $31 million in 1981.[10]

There is no import or export of LWA because of the high transportation cost. Neither the raw materials nor the products can be shipped profitably beyond approximately a 485-km (300-mile) radius of a plant. Also, most countries have local deposits of clays and/or shales that are adequate for manufacturing structural clay products, cement clinker, and LWA, and thus they have no need to import such materials.

A typical LWA production facility obtains raw material from mining/quarrying sites located near the plant. The LWA produced is sold to companies that further process the aggregate into other products, therefore most plants are not vertically integrated operations. Only one company (Solite Corporation) is known to use its aggregate in the production of end products. Other companies may do so to a lesser extent.

In 1978, the predominant end use of LWA according to the U.S. Bureau of Mines was concrete block products, utilizing over 60 percent of LWA production. The next major use was in structural concrete, followed by highway surfacing.

The LWA industry faces varying degrees of competition from several substitutes, including construction sand and gravel, crushed stone, pumice, and to a lesser degree perlite and vermiculite. Some of these are closer substitutes than others, depending on the end product application. Thus, LWA, crushed stone, pumice, perlite and the others are not perfect substitutes competing "head-to-head" with each other in every application. But, to varying degrees, there are substitutes available for LWA, and these must be considered in any economic analysis. For example, in end uses where weight savings are important, such as in bridge deckings and high-rise buildings, lightweight aggregate has a significant competitve advantage.

Capacity expansions at existing plants, construction of new plants and merger activity all slowed during 1982. The construction industry, which is the largest consumer of heavy clay products, has experienced a slow rebound in growth in recent years.

The demand for LWA products is tied directly to the availability and cost of transportation and raw materials connected with the building and construction industries. The fluctuations in these industries, together with the availability of substitute products, makes it difficult to forecast growth in the LWA industry.

9.1.3 Diatomite

The major processed diatomite products are powders and aggregates of variable sizes and grades that are uncalcined (natural), straight-calcined, or flux-calcined. All domestic commercial diatomite originates in the Western States, but the major markets are in the East. Because the majority of diatomite powders are packaged in 23-kg (50-lb) bags, transportation costs are a substantial portion of the total cost.

The United States is the world's largest diatomite producer, followed by the U.S.S.R. and France.[11] Total value of sales declined in 1982 to \$108 million, compared with \$113 million in 1981. However, production increased in 1983 to 0.57 x10^6 Mg (0.63 x10^6 tons), compared to 0.56 x10^6 Mg (0.61 x10^6 tons) in 1982. Average annual production during the 6-year period from 1978 through 1983 was 0.60 x10^6 Mg (0.66 x10^6 tons). Prices increased during this period, reaching \$215/Mg (\$195/ton) in 1983.[12]

Principal uses of diatomite have not changed over the years with the majority (68 percent) used in filtration media, and the remaining 32 percent used in industrial fillers, insulation, and other uses.

Exports of diatomite reached a peak in 1980, and declined in 1981 and 1982. In 1982, exports declined 13 percent to 0.13 x10^6 Mg (0.14 x10^6 tons), compared with 0.15 x10^6 Mg (0.16 x10^6 tons) in 1981. The quantity of diatomite exported in 1982 represented 23 percent of U.S. production, which has changed very little in recent years. Exports increased slightly in 1983 to 0.13 x10^6 Mg 0.15 x10^6 tons). Imports of diatomite, which are relatively small, clined in 1982 to 229 Mg (252 tons), compared with 349 Mg (385 tons) 1981.

Many alternate materials can be substituted for diatomite; however, the unique properties of diatomite ensure a continuing acceptance for many applications. Expanded perlite, asbestos, and silica sand compete for filtration purposes, although in most instances diatomite is a superior material. Alternate filler materials include talc, ground silica sand, ground mica, clay, perlite, vermiculite, and ground limestone. For thermal insulation, materials such as brick, clay, asbestos, mineral wool, expanded perlite, and exfoliated vermiculite can be used. World resources of crude diatomite are adequate for the foreseeable future.

During 1983, seven companies operating nine processing facilities produced diatomite. California was the principal producing State. The diatomite industry does not have a high degree of vertical integration. Although the industry does mine, process, and package the material, it has no involvement with final product applications.

From a 1982 base, demand for diatomite is expected to increase at an annual rate of about 2 percent through 1990.[13] Industry growth is expected to take place primarily in California and Nevada.

9.1.4 Feldspar

Feldspar flotation concentrates can be classified as either soda, potash, or "mixed" feldspar, depending on the relative amounts of sodium oxide (Na_2O) and potassium oxide (K_2O) present. Feldspar-silica mixtures (sandspar) can either be a naturally occurring material, such as sand deposits, or a processed mixture obtained from flotation.

Feldspar production declined between 1979 and 1982, but is estimated to increase slightly in 1983. Average annual production during the 6-year period from 1978 through 1983 was 0.63×10^6 Mg (0.69×10^6 tons). The average price for feldspar in 1983 was $36/Mg ($33/ton).[14]

In 1982, U.S. exports classified as feldspar, leucite, and nepheline syenite decreased 23 percent to approximately 9,800 Mg (10,800 tons) valued at $989,000, compared with 12,700 Mg (14,000 tons) valued at $1,110,000 in 1981. It is estimated that exports declined again in 1983. Chief recipients of the exported material were Mexico (41 percent), Canada (21 percent), the Dominican Republic (8 percent), and Venezuela (8 percent).[15] The remaining 22 percent was shared among 17 other countries.

Most feldspar is ground and sized by the feldspar producers, although some manufacturers of pottery, soaps, and enamels purchase feldspar for grinding to preferred specifications in their own mills. A substantial portion of the material classified as feldspar-silica mixtures is used in glassmaking without additional processing after it is mined.

It was estimated that in 1983 the end-use distribution of domestic feldspar was: glassmaking (55 percent), pottery (41 percent), and porcelain enamel and miscellaneous applications (4 percent). Imported nepheline syenite is the major alternative material in the glass making process. However, imports of nepheline syenite declined 8 percent from 1981 to 1982. Feldspar can also be replaced in some of its end uses by feldspar-silica mixtures, clays, talc, pyrophyllite, spodumene, or electric-furnace slag. It is estimated that resources of feldspar are immense, although not always conveniently accessible from the principal centers of consumption.

Feldspar is mined in six States with North Carolina, Connecticut, and Georgia providing 90 percent of the 1983 output. The other producing states are California, Oklahoma, and South Dakota. In 1982, 11 U.S. companies operating 16 mines and 12 plants produced feldspar. Most companies operate mining, processing, and packaging facilities. However, there is no integration between feldspar producers and the commercial application for their product.

From a 1981 base, demand for feldspar is expected to increase at an annual rate of about 2 percent through 1990.[16] An increase in housing construction in 1983 resulted in improved markets for some end use markets for feldspar. However, competition from plastic bottles kept the output of glass containers level. One possible area for growth lies in the ceramic tile market because the United States is considered the world's largest undeveloped ceramic tile market. It is estimated that in 1984 domestic mine production of feldspar will be 0.65×10^6 Mg (0.72×10^6 tons) and U.S. apparent consumption will be 0.64×10^6 Mg (0.71×10^6 tons).

9.1.5 Gypsum

The gypsum industry processes mined gypsum ore into various finished materials such as cement retarder, agricultural fertilizer (land plaster), industrial and building plasters, gypsum wallboard, and various specialty plasters. Calcined gypsum, referred to by the trade term stucco, can be mixed with water and other additives and formed into wallboard, or mixed with various retarders or accelerators and sold as plaster. Gypsum used as a retarder in portland cement manufacture or as an agricultural fertilizer is not calcined but is upgraded from raw ore by crushing, screening, and, in the case of agricultural fertilizer, grinding and drying.

The United States is the world's leading producer of gypsum, accounting for 13 percent of the total world output.[17] In 1983 the gypsum industry recovered from its depressed level in 1982 with an increase in output of crude gypsum of 16 percent, resulting in 11.1 $\times 10^6$ Mg (12.2 $\times 10^6$ tons) of crude gypsum valued at $110 million. Average annual production of crude gypsum during the 6-year period from 1978 through 1983 was 11.6 $\times 10^6$ Mg (12.7 $\times 10^6$ tons). Calcined gypsum production also increased in 1983 to 12.1 $\times 10^6$ Mg (13.4 $\times 10^6$ tons) representing a 19 percent increase over 1982.

In 1983 the available capacity of operating gypsum wallboard plants increased to 1.8 $\times 10^9$ m^2 (19.5 $\times 10^9$ ft^2) per year. Sales of gypsum wallboard products were 1.54 $\times 10^9$ m^2 (16.6 $\times 10^9$ ft^2) an increase of 27 percent compared with 1982, representing a capacity utilization of 85 percent.[18] One existing plant was dismantled in 1983, one new plant came onstream, and two other plants remained dormant.

About 80 percent of all gypsum is calcined. Most of the gypsum that is calcined is used in the production of wallboard. With housing starts showing a dramatic improvement in 1983, calcined gypsum consumption increased significantly and posted a 28 percent increase during the first 10 months of 1983. Calcined gypsum is also used as a base for building and industrial plasters, but demand in this sector remained essentially unchanged. The remaining 20 percent of the gypsum market is uncalcined gypsum, used in the cement industry, as a soil additive in agriculture, and as an inert filler. During the first 10 months of 1983 usage of uncalcined gypsum trailed 1982 by 9 percent, with only the filler segment of the market showing any gain.

Exports are an insignificant part of the gypsum industry. Imports of crude gypsum represent approximately 40 percent of the crude gypsum consumed. Imports increased 24 percent in 1983 compared with 1982. Average annual imports during 1978 through 1983 were 7 x10^6 Mg (7.7 x10^6 tons). Most of the imports are from Canada (representing 68 percent of the tonnage), from Mexico (20 percent) and from Spain (12 percent).

In 1983 the total supply of crude gypsum, was 19.0 x10^6 Mg (20.9 x10^6 tons), of which 15.1 x10^6 Mg (16.6 x10^6 tons) was calcined for gypsum products, and the remaining 3.9 x10^6 Mg (4.3 x10^6 tons) was used mainly as cement retarder or as agricultural land plaster. The calcined gypsum was sold as prefabricated products or as industrial or building plaster.

Other construction materials may be substituted for gypsum, especially lime, lumber, cement, steel, or masonry. However, there is no practical substitute for gypsum in portland cement. By-product gypsum is presently substituting for crude gypsum in special agricultural applications and may, in time, be utilized in place of crude gypsum for cement set-retarding and manufacturing wallboard.

Domestic resources are adequate but are unevenly distributed. There are no gypsum deposits on the Eastern seaboard of the United States, and large imports from Canada augment the domestic supply of crude ore in these industrial demand areas. Large deposits occur in the Great Lakes region, Mid-continent region, California, and in other States. Foreign resources are adequate but are not evenly distributed.

The outlook for gypsum is tied to the housing industry. It is expected that housing starts will be sufficient to maintain operating capacity for calcined gypsum. In terms of other markets, it is anticipated that both the cement and agricultural markets will experience increases in demand.

From a 1981 base, demand for gypsum is expected to increase at an annual rate of about 3.3 percent through 1990.[19] It is estimated that in 1984 domestic mine production of gypsum will be 11.4 $\times 10^6$ Mg (12.6 $\times 10^6$ tons) and U.S. apparent consumption will be 19 $\times 10^6$ Mg (21 $\times 10^6$ tons).

9.1.6 Industrial Sand

Industrial sand is naturally occurring unconsolidated or poorly consolidated rock particles that pass through a 4.8 mm sieve (No. 4 mesh) and are retained on a 74 μm sieve (No. 200 mesh). Industrial sands are often called silica sands and are primarily composed of the mineral quartz (SiO_2). The quartz content is typically greater than 95 percent, with some ores containing more than 99 percent. Deposits of quartz-rich sand and sandstones, from which most of the industrial sand is derived, are found throughout the United States, but primarily in the East and Midwest and in California and Nevada.

Dryers reduce the moisture content of the sand from about 4 to 9 percent down to about 0 to 0.5 percent. The majority of dryers used in the industry are either rotary or fluid bed. Selection of industrial sand dryers in the future, i.e., rotary versus fluid bed, will be determined by both energy costs and cooler requirements.

The total U.S. sand and gravel industry is divided into two parts, construction sand and gravel, and industrial sand and gravel. By production volume, the industrial sand and gravel industry represents only a small part, about 4 to 5 percent, of the total sand and gravel industry. Product utilization of industrial sand produced or sold in 1983 was: glassmaking (43 percent), foundry sand (25 percent), abrasive sand (10 percent), hydraulic fracturing sand (6 percent), and other uses (16 percent).

Most of the glass sand produced in 1982 was consumed in the South (33 percent) and the North Central States (32 percent), while most of the foundry sand was used in the North Central States (69 percent), and a significantly smaller amount was used in the South (22 percent). Of the other end uses, most of the abrasive sand was used in the South (77 percent), and most of the hydraulic fracturing sand was used in the South (53 percent) and the North Central States (41 percent).

The average price of industrial sand in 1983 was $13.17/Mg ($11.95/ton).[20] There was virtually no change in price from 1982 to 1983. The highest price sand in 1982 was industrial sand used as fillers, followed by fiberglass sand, and hydraulic fracturing sand.

Exports of industrial sand decreased 28 percent in 1982 to 742,000 Mg (818,000 tons) valued at $26.3 million of which 71 percent went to Canada and 20 percent went to Mexico.[21] Only minor quantities of industrial sand are imported. Although imports increased dramatically in percentage terms in 1982 (with most of the imports coming from Australia), the total quantity remained insignificant relative to domestic production and imports declined in 1983.

Of the total industrial sand and gravel produced in 1982, 68 percent was transported by truck from the plant or pit to the site of the first point of sale or use, 29 percent was transported by rail, and 3 percent by waterway. Because most of the producers have not kept records nor reported data regarding the distance which industrial sand was shipped, or the cost per ton-mile of the shipments, such information is not available.

Silica sand is the major material used for glassmaking and for foundry and molding sands; alternative raw materials for these uses are ircon, olivine, staurolite, and chromite sands.

Sand and gravel resources of the world are large. However, due
geographic distribution, environmental restrictions, and quality
quirements for some uses, extraction is sometimes uneconomic. The
t important commercial sources of sand and gravel have been river
d plains, river channels, and glacial deposits. Marine deposits
d become important in the future. Quartz-rich sand and sandstones,
ain source of industrial silica sand, occur throughout the world.

In 1982 the North Central States led the nation in the production
dustrial sand and gravel with 38 percent of the total, followed by
uth with 36 percent, the West with 14 percent, and the Northeast
percent. A comparison between 1981 and 1982 shows the produc-
the North Central area declined in 1982 by 14 percent with the
d the West showing an increase in production.

The large plants produce a disproportionately large share of the total production for the industry. The largest number of operations producing industrial sand and gravel are smaller than 0.27 $\times 10^6$ Mg/yr (0.30 $\times 10^6$ tons/yr). However, most of the total production came from operations larger than 0.27 $\times 10^6$ Mg/yr (0.30 $\times 10^6$ tons/yr); 50 operations, representing only 26 percent of the total number of operations, produced 73 percent of the total tonnage.

In 1983, the five leading States in the production of industrial sand were Illinois, Michigan, Texas, California, and New Jersey. Combined production from these five States made up about 51 percent of the national total.

Most industrial sand plants consist of mining, processing, and packaging operations. However, there is no vertical integration between industrial sand producers and the commercial application of the product.

It was estimated that 1984 production and apparent consumption was 27 $\times 10^6$ Mg (30 $\times 10^6$ tons). From a 1979 base, demand for industrial sand and gravel is expected to increase at an annual rate of 1.5 percent through 1990.[22]

9.1.7 Magnesium Compounds

The United States is a major world producer of magnesium compounds. Natural brine solutions, such as sea, lake, and wellwaters are the primary source of domestically produced magnesium compounds. Magnesium compounds are also produced from natural magnesite in Nevada. The magnesium compounds produced are mainly magnesia, magnesium hydroxide, magnesium sulfate, and precipitated magnesium carbonate. Only magnesia producing plants use dryers and calciners, and, therefore, this study is concentrated only on magnesia producing plants. However, in some cases data are only available for magnesium compounds as a group.

Domestic production of caustic-calcined and other magnesias fell in 1982 to 0.51 $\times 10^6$ Mg (0.56 $\times 10^6$ tons) compared with 0.69 $\times 10^6$ Mg (0.76 $\times 10^6$ tons) in 1981. It is estimated that production also declined slightly in 1983. Average annual production during the 6-year period 1978 through 1983 was 0.70 $\times 10^6$ Mg (0.77 $\times 10^6$ tons). The major portion of magnesium compounds was used in the production of basic refractories, which are used in high temperature metallurgical furnaces for making iron and steel. The remainder was used to prepare caustic-calcined, specified magnesias, and other magnesium compounds which are used for animal feeds, construction materials, fluxes and other uses.

United States exports of crude and processed magnesium compounds declined significantly in 1982 compared with 1981. Exports are estimated to remain approximately the same in 1983.

Total imports of crude and processed magnesite declined significantly in 1982 compared with 1981. Additional magnesium compounds valued at almost $8 million were also imported. Imports rose in 1983. Annual imports averaged 47,000 Mg (52,000 tons) during the 6-year period 1978 through 1983.

Alumina and silica can be substituted for magnesia in refractories. The size of the resources from which magnesium compounds may be recovered range from large, to virtually unlimited, and are globally widespread. Identified world resources of magnesite total 11 $\times 10^9$ Mg (12 $\times 10^9$ tons), and resources of brucite total several million tons. Resources of dolomite, forsterite, and magnesium-bearing evaporite minerals are enormous: magnesia-bearing brines are estimated to constitute a resource in billions of megagrams, and magnesium hydroxide can be recovered from seawater at places along world coastlines where salinity is highest.

Three companies accounted for almost 80 percent of the magnesia production.[23] Estimates are that in 1983 the magnesium compounds industry operated at almost three-fifths of capacity. Some companies are highly integrated and include operations from raw material production through processing and packaging. Some companies buy magnesium hydroxide slurry for production of magnesia. Most companies sell their magnesia, while a few companies use it internally for production of chemicals or refractories.

It is estimated that in 1984 domestic magnesium compound production from all sources will be 0.51 $\times 10^6$ Mg (0.56 $\times 10^6$ tons) and U.S. apparent consumption will be 0.52 $\times 10^6$ Mg (0.58 $\times 10^6$ tons). From a

1978 base, demand for nonmetallic-magnesium is expected to increase at an annual rate of about 1.8 percent through 1990.[24]

9.1.8 Perlite

Perlite is a glassy volcanic rock with an "onion skin" fracture. It is characterized by an expansion of up to 20 times its original volume when heated. Both perlite ore (crude perlite) and the expanded product (expanded perlite) are typically referred to by the collective term "perlite." Crude perlite containing approximately 10 percent moisture is dried in a rotary dryer. All perlite that is mined must be dried before further processing. Approximately 80 percent of the dried perlite is expanded.

The United States is the world's largest producer and consumer of perlite. Production has been declining since 1979 with output during the 5-year period 1978 through 1982 averaging 0.54 $\times 10^6$ Mg (0.59 $\times 10^6$ tons).

Expanded perlite has a variety of industrial and construction uses. Uses related to the construction industry, particularly formed products, account for 65 percent of total usage. The remaining uses are for filter aids and horticultural products.

Alternate materials that compete with perlite in the various use categories include vermiculite, expanded clay, shale and slag, volcanic cinders, formed concrete, mineral wood, diatomite, asbestos, and plastic foams. The domestic resources of perlite can be estimated conservatively at 635 $\times 10^6$ Mg (700 $\times 10^6$ tons). According to the U.S. Bureau of Mines, available information from other perlite-producing countries is insufficient to permit a reliable estimate of foreign resources.

In 1983, 12 companies produced crude ore from 14 mines. Five companies supplied 88 percent of total production. Crude ore was produced in seven Western States. New Mexico continued to be the major producing State, accounting for 79 percent of the crude ore mined in the U.S. Processed perlite was expanded by 42 companies at 70 plants.[illegible] The expansion plants are located in 32 states, and are therefore more widely dispersed than the crude ore plants.

The supply of perlite from domestic reserves is expected to adequately meet future requirements. It is estimated that in 1984 domestic production of processed perlite will be 0.48 $\times 10^6$ Mg (0.53 $\times 10^6$ tons) and apparent consumption will be 0.47 $\times 10^6$ Mg (0.52 $\times 10^6$ tons). From a 1982 base, demand for perlite is expected to increase at an annual rate of about 3 percent through 1990.[26]

Industry growth in crude perlite production is expected primarily in Western States. Rotary dryers are the only type utilized for perlite drying, and any future growth is expected to be in rotary units. Both stationary vertical and horizontal rotary perlite expansion furnaces are in use at this time; however, the trend in the industry is toward the more fuel-efficient vertical units.

No significant changes are currently projected for supply-demand relationships within the perlite industry in the United States. One factor that could affect the domestic perlite industry is the cost of transporting perlite ore from the Western United States, where it is mined, to the Eastern seaboard, where large markets presently exist. If future transportation costs from foreign producers become less than shipping costs from New Mexico to the Eastern States, then perlite imports in that region are a real possibility.

9.1.9 Roofing Granules

Roofing granules are dried particles of rock or fired clay that are used as surfacing agents for asphalt roofing and shingles. The granules are usually coated with pigments and other materials and dried before being applied to the roofing. Uncoated roofing granules typically represent about 25 percent of the total annual roofing granules production.

Annual production, which had declined since 1978, averaged 4.7 $\times 10^6$ Mg (5.2 $\times 10^6$ tons), during the 4-year period from 1978 through 1981. Roofing granules are shipped by rail in covered hoppers or boxcars to asphalt roofing plants. Various colored roofing granules sell at different prices because of the varying costs of pigments and processing.

Two leading companies control approximately 60 percent of total roofing granules output. There are 16 plants located primarily in Arkansas, Wisconsin, and California. There are no by-products from roofing granule manufacture. All granules produced, coated or uncoated, are dried and sized before sale.

The demand for roofing granules is a function of the demand for asphalt roofing in housing construction. During the past 10 years, the compound annual growth rate for asphalt roofing was 2.5 percent. The growth rate projection for the next 5 years is 1.5 to 2 percent. Also, the Bureau of Mines projects a 2 percent annual growth rate to 1990 from a 1979 base for the crushed stone industry.

Ore capacity is not expected to increase. Present ore capacity is sufficient to meet the demand of roofing manufacturers. However, there has been some mention by one of the leading manufacturers about a new granule production facility in the Southeastern United States.

9.1.10 Talc

Grades of talc are most frequently identified with the end use, such as ceramics, paints, roofing, insecticides, and paper. The important properties include softness and smoothness, color, luster, high slip tendency, moisture content, oil and grease absorption, chemical inertness, fusion point, heat and electrical conductivity, and high dielectrical strength.

The United States is currently the world's largest producer of talc minerals.[27] Pyrophyllite is not chemically related to talc but has similar physical properties, which is the reason it is included with talc data. Production declined in 1983 to 0.94 $\times 10^6$ Mg (1.0 $\times 10^6$ tons) compared with the 1982 level of 1 $\times 10^6$ Mg (1.1 $\times 10^6$ tons). Average annual production during the 6-year period 1978 through 1983 was 1.1 $\times 10^6$ Mg (1.3 $\times 10^6$ tons).

United States exports of talc minerals had shown cyclical growth in earlier years but the tonnage exported in 1983 was the same as that in 1982, and the lowest since 1976. Mexico is the major importer of U.S. talc, accounting for 44 percent of the export tonnage in 1982, followed by Canada with 27 percent. Imports of talc, which are relatively small, decreased in 1983 compared with 1982. Most imported talc is from Italy and Canada.

Prices for crude or ground talc and pyrophyllite vary depending on the quality and method of processing. There are also regional price differences as evident by the price for 98% through 44 µm (325-mesh) (December 1982) as follows: Vermont, \$71/Mg (\$64/ton); New York \$81 to \$83/Mg (\$73 to \$75/ton); and Georgia, \$44/Mg (\$40/ton).[28]

The talc group is among the most versatile of the inorganic substances available to industry. Ground talc is used mainly in ceramics as well as in paints, roofing, paper, plastics, cosmetics, and rubber. Ground pyrophyllite is used in refractories, ceramics, insecticides and roofing.

In the ceramics market, talc and pyrophyllite compete with each other as well as with kaolin, fuller's earth, other inorganic fillers, and feldspar. Talc, mica, and other minerals compete for plastic (especially polypropylene) filling and reinforcing roles.

The United States is self-sufficient in its supplies of most grades of talc and related minerals. Domestic and world resources are estimated to be approximately five times the quantity of reserves.

Most companies are highly integrated operations. In 1983, there were 21 talc-producing companies in 11 States.[29] Vermont, Montana, Texas and New York produced 83 percent of the total.

From a 1979 base, demand for talc and related minerals is expected
o increase at an annual rate of about 2 percent through 1990.[30] It
s estimated that in 1984 domestic mine production of talc will be
2 x10 Mg (1.3 x10^{6} tons) and U.S. apparent consumption will be
9 x10 Mg (1.0 x10^{6} tons). The quantity of ore produced is a close
lection of demand, and, since producers customarily maintain only
or stocks of these minerals, current production usually differs only
htly from current consumption. Ore capacity is expected to
ase at an annualized rate of 2.6 percent through 1987.

Producers generally are not planning expansion of capacities in the present economic climate. However, Vermont Talc Company reports that the company's exploration program has proven substantial reserves in a newly developed open-pit mine, and engineering has been completed for a new froth flotation processing plant.

Research and development efforts in the talc industry have not produced significant new large markets in the U.S. in recent years in spite of some important product developments. Surface-modified talcs are available now for special plastic applications. Further research efforts could result in substantial growth of talc as a functional additive as well as an inert filler in plastics.

9.1.11 Titanium Dioxide

The two major processes used to produce titanium dioxide (TiO_2) pigments are the chloride process and the sulfate process. For the chloride process, mineral rutile (95 percent TiO_2) is the preferred raw material. The final product is usually a rutile pigment. The sulfate process uses ilmenite (37 to 65 percent TiO_2) or a titanium slag (70 percent TiO_2) as the raw material. A rutile pigment can be produced by the sulfate process, but more frequently an anatase pigment, which has facial angles different from rutile pigment, is produced.

Because it is a continuous process, the chloride process is inherently simpler than the sulfate process. The chloride process requires fewer steps and creates less waste material because it uses feed materials with a higher TiO_2 content and a lower iron content than does the sulfate process. The sulfate process produces four times as much waste as the chloride process. Chloride processors are increasing the use of lower grade feed materials but at the expense of creating more iron chloride or iron oxide waste material. The sulfate process has the advantage of low raw materials cost.

The 1979 cost of constructing new chloride process pigment plants was about $1,100 to $1,653/Mg ($1,000 to $1,500/ton) of annual capacity. Sulfate process plants cost $276/Mg ($250/ton) less at that time. The operating costs of chloride plants, which may be operated continuously and are more easily automated, are reportedly 30 percent lower than those for sulfate plants.[31] However, technical problems during start-up of a new chloride plant may delay the 30 percent long-term operating cost advantage for several years after start-up. The cost of finishing TiO_2 pigment for market is about the same for both processes and comprises a significant portion of total production costs. Raw materials cost for sulfate process plants is appreciably lower than that for chloride process plants that use rutile ore as feed material.

Of the 1981 production of titanium dioxide, 74 percent was produced by the chloride process and 26 percent by the sulfate process. Of the chloride production, 92 percent was rutile pigment and 8 percent was anatase pigment. Of the sulfate production, 11 percent was rutile pigment and 89 percent was anatase pigment. The rutile is used primarily in paints and finishes, while the anatase is used primarily in the paper industry. Production of titanium dioxide decreased significantly in 1982 from 1981 but is estimated to have recovered in 1983. Annual production averaged 0.65 $\times 10^6$ Mg (0.72 $\times 10^6$ tons) during the 5-year period 1978 through 1982.[32]

Imports of titanium dioxide have been increasing since 1980 with the main sources being the Federal Republic of Germany (30 percent); Canada (14 percent); France (13 percent); Spain (11 percent); and others (32 percent). Average annual imports from 1978 to 1982 were 112,000 Mg (124,000 tons).

Prices for titanium pigment have remained stable from 1981 through 1983. However, in 1983 the list price was being discounted by pproximately 20 percent. In 1983 the price for titanium dioxide rutile pigment was \$1.65/kg (\$0.75/lb).[33] Major uses of titanium igment are in paints, paper, and plastics.

A number of materials such as zinc oxide, talc, clay, silica, d alumina can be used in place of TiO_2 pigment, but use of such terials will result in production of pigments of lower quality with pect to brightness or will cause higher costs to be incurred.

In 1983, titanium dioxide pigment was produced by 6 companies 13 plants in 8 states. Titanium dioxide plants operated at 75 per- of capacity in 1981. There are no by-products associated with

TiO_2 pigment production. Titanium tetrachloride ($TiCl_4$) is a co-product for at least one major producer.

The titanium industry is characterized by a moderately high degree of vertical integration from raw materials to semi-finished products. Several companies mine and utilize the ore minerals in producing titanium pigments. In 1979, NL Industries and E.I. duPont de Nemours & Company owned or controlled 32 percent of the worldwide titanium dioxide pigment production capacity. From a 1980 base, demand for TiO_2 is expected to increase at an annual rate of about 2 percent through 1990.[34]

9.1.12 Vermiculite

Vermiculite is mined by open-pit methods. Beneficiation methods, which vary with the source material, include screening, flotation, drying in a rotary or fluid bed dryer, and exfoliation (expansion) by exposure to high heat. All mined vermiculite is dried at the mine site prior to exfoliation. Approximately 84 percent of the mined vermiculite is expanded. Expansion increases the mineral volume by approximately 10 times. The expanding process is energy-intensive, and the expanded material is expensive to transport. Freight and energy costs are significant portions of the final user's costs. Transportation costs from the source to exfoliation plants near the point of end use limit the size of marketing areas as well as vermiculite's competitive position with regard to other mineral commodities.

Expanded perlite is a substitute for expanded vermiculite in lightweight concrete and plaster.[35] (Other more dense but less costly substitutes in these applications are expanded clay, shale, slate, or slag.) Alternate materials for loose-fill fireproofing insulation include fiberglass, perlite, and slag wool. In agriculture, substitutes include peat, perlite, sawdust, bark and other plant materials, and synthetic soil conditioners.

Estimated world production of vermiculite in 1982 was 0.51 $\times 10^6$ Mg (0.56 $\times 10^6$ tons), a small decrease from that of 1981.[36] The United States and the Republic of South Africa accounted for 92 percent of world production. More than 80 percent of worldwide production comes from five mines, while the balance comes from numerous small deposits.

Mine production of vermiculite has been decreasing since 1979 as well as apparent consumption of both the concentrate and exfoliated vermiculite. Average annual production during the 6-year period 1978 through 1983 was 0.30 x10^6 Mg (0.33 x10^6 tons).

The average value of vermiculite concentrate sold and used by U.S. producers in 1983 increased 7.6 percent to $107/Mg ($97/ton) compared with that of 1982.[37]

Imports and exports have declined since 1978. Annual imports during the 6-year period 1978 through 1983 averaged 23,000 Mg (25,000 tons).

The major uses for exfoliated vermiculite in 1983 were: agriculture (28 percent), insulation (24 percent), plaster and cement premixes (24 percent), and lightweight concrete aggregate (22 percent).

The principal vermiculite mining and beneficiating operations are those of W.R. Grace & Co. with operations in Montana and South Carolina.[38] Most of the vermiculite concentrate was shipped to 46 exfoliating lants in 30 States.[39]

Smaller deposits of vermiculite, which occur in North Carolina, xas, Wyoming, Colorado, and Nevada, are estimated to total 8 to 2.7 x10^6 Mg (2 to 3 x10^6 tons). Deposits in other countries ually include material that has exfoliation characteristics considered ferior to U.S. and South African vermiculite.

According to the U.S. Bureau of Mines, demand for vermiculite is ected to increase from a 1982 base at an annual average rate of ut 2 percent through 1990.[40] It is estimated that in 1984 domestic production of vermiculite concentrate and U.S. apparent consumption each be about 0.29 x10^6 Mg (0.32 x10^6 tons).

9.2 ECONOMIC ANALYSIS

9.2.1 Introduction

This section analyzes the economic effects of the regulatory alternatives discussed in Chapter 6 on the 17 mineral dryer and calciner industries. Economic profile information presented earlier in Section 9.1 is a primary input to the analysis. Section 9.3 provides a discussion of the socio-economic effects of the pollution control costs.

As noted in previous chapters, the facilities of interest are dryers and calciners. For some of the industries both dryers and calciners are present, while for other industries only dryers, or only calciners, may be present.

9.2.2 Executive Summary

The economic analysis of the regulatory alternatives proposed for this New Source Performance Standard (NSPS) indicates that there are not likely to be significant adverse effects. For three industries (industrial sand, roofing granules and alumina) the NSPS control costs are zero or negative for every model facility. For 15 of the 17 industries, the NSPS control costs on the model facilities would result in price increases ranging from slightly negative to a maximum of 1.72 percent, with the vast majority below 0.50 percent. The other two industries, lightweight aggregate and fire clay, have price increases ranging from 1.47 to 2.31 percent, and zero to 2.02 percent, respectively.

Price increases of these magnitudes are not likely to cause significant adverse effects. In a few cases there may be delays in the construction of new facilities compared to what would have occurred in the absence of the NSPS. Substitution effects within the industries are not likely to be exacerbated by this NSPS because most product prices will rise by similar but small percentages.

Many of the industries manufacture products that are used as inputs in construction or other manufacturing industries. They will therefore be subject to general economic cycles and may experience lower baseline growth and capacity utilization occasionally. Although general market conditions may affect the baseline economic variability of some of the 17 industries, the addition of NSPS controls, by itself, does not represent an overall adverse economic impact for any of the industries.

The total control cost in the fifth year is estimated to be less than $3 million, thus falling well below the $100 million criterion for a major rule given in Executive Order 12291. Finally, the industries involved in this analysis include a substantial number of small businesses. However, the provisions of the Regulatory Flexibility Act concerning significant economic effects on small businesses do not indicate any significant adverse effects for the industries analyzed.

9.2.3 General Methodology of the Analysis

This section provides a general overview of the methodology used to assess the economic effects of the regulatory alternatives on the 17 industries and the associated model facilities. The sections that follow will describe the methodology in more detail.

Because each State Implementation Plan (SIP) contains particulate emission control standards, any new facility would have to meet the SIP standards even in the absence of an NSPS. Therefore, this analysis focuses on the incremental increase in pollution control costs above those "baseline" control costs that are required to meet the various SIP standards.

The NSPS only applies to new, modified, or reconstructed dryers and calciners. The model facilities are described in Chapter 6 and will not be repeated here. However, some additional discussion of the model facilities from the perspective of the economic analysis is worthwhile at this point. The model facilities represent individual pieces of equipment (dryers and calciners), and do not represent an entire plant in the economic sense. Frequently an entire plant might have two or more dryers, or two or more calciners, or some combination of dryers and calciners. Also, other pieces of equipment (such as crushers, conveyors, and silos) are required as part of the total production process.

quite likely to be faced with the prospect of replacing individual dryers and calciners. Therefore, this analysis considers only that portion of total revenue for an entire plant, which passes through an individual dryer or calciner. For example, if an entire plant has two calciners, and one of the calciners is modified (or reconstructed) and becomes subject to the NSPS, this analysis only considers one-half of the total revenue for the plant in evaluating the economic effect of the NSPS.

The analysis highlights a situation that involves an individual dryer or an individual calciner. However, 6 of the 17 industries use both dryers and calciners. Therefore, the potential exists for a cumulative economic effect that involves a dryer plus a calciner, and the analysis includes consideration of this possibility.

In the analysis that follows, each model facility is evaluated as if it is part of an entire plant that stands alone. The economic effects are evaluated on model facilities whose description is based on representative characteristics of new or expanded facilities, such as megagrams per hour of capacity and annual hours of operation. The model facilities provide an indication of the degree to which all actual new facilities would be affected, by incorporating into the models the major characteristics prevailing in various size segments of the mineral dryer and calciner industries. The model facilities are not intended to duplicate any particular existing facility as any actual facility may differ in one or more of the characteristics.

9.2.4 Percent Price Increase

In calculating the percent price increases for the various industries and model facilities, the pre-NSPS control prices that are used in the economic analysis are the same prices presented earlier in Chapter 8 as part of the calculation of product recovery credits. The prices generally represent the first commercially-saleable product after the drying or calcining stage that has a published price. As discussed in Chapter 8, the pollution control costs are based on January 1984 dollars. Therefore, to maintain internal consistency, no prices more recent than January 1984 are used in the economic analysis. The product prices of some of the 17 industries have a tendency to fluctuate from one year to the next. Changes in the overall economy and especially changes in the level of economic activity in the construction industry influence a number of these prices. In these instances the price for any single year could be atypically high or low, and thus distort the results of the analysis which is designed to take a view that is longer than just a single year. In order to take into consideration fluctuations in prices, an average price over three years (1983, 1982, and 1981) is generally used rather than a price at a single point in time. For industries that have experienced a steady increase in prices over several years with little or no fluctuation, a price for a single year (1983) is used because an average would be overly conservative. In the case of titanium dioxide, Chapter 8 includes four separate prices, three of which represent a value assigned to product that is recovered at intermediate stages of the overall production process. For the economic analysis, the only product price that is used is the price of $1,433/Mg ($1,300/ton), because that is the price of the product that is offered for sale.

To calculate the expected (or most likely) price increase for each industry, a standard economic model is utilized. The model used is the competitive market model in which firms within each industry are assumed to be competitive rather than oligopolistic. This assumption is reasonable for the industries studied because 11 of 17 industries have 10 or more firms, and only 2 industries have less than 5 firms. Many of the firms also face competition from substitute products in addition to the competition from other firms within their industries.

In the competitive market model, each industry is initially in equilibrium at the point where its supply and demand curves intersect. Over time, the demand for each industry's product is expected to increase, shifting the demand curve outward by 1990. The NSPS control costs increase (or in a few cases, decrease) each new facility's production costs, thereby shifting the industry supply curve upward by the amount of the control cost per unit produced. The expected price is found at the intersection of these new supply and demand curves. The price in 1990 with the NSPS will be greater than the price would have been in the absence of the NSPS by the amount of the control cost per unit.

For ease of presentation, the percent price increase is calculated using a simplified but equivalent approach that divides annualized control costs by revenue, with the result expressed as the percentage price increase. Table 9-3 shows an example of the percent price increase calculation. The production rate of 23 megagrams per hour (Mg/h) (25 tons/h) is multiplied by 4,000 hours of operation per year to yield 92,000 megagrams per year (101,000 tons/yr) of production. The annual production of 92,000 megagrams is then multiplied by the price per megagram of $36 and the result is annual revenue. The control costs associated with the NSPS regulatory alternative, minus the baseline control costs, yields the incremental annualized control cost. In the example, the baseline represents a cost of $86,000 per year and the NSPS (RA III) represents a cost of $93,000 per year, or a net increase of $7,000 per year (in this particular case the cost is slightly lower for RA II). Finally, the incremental annualized control costs divided by the annual revenue results in the percent price increase, which in the example is 0.21 percent (about 1/5 of 1 percent).

Table 9-4 shows the results of the percent price increase calculation for all 17 industries. The results shown are for RA II and RA III. The annualized control costs for RA III are generally higher than the control costs for RA II. However, in many cases there is no difference between the two alternatives. Some industries include comparative data for a baghouse versus a wet scrubber. For these industries the two controls are interchangeable from an engineering viewpoint. In most cases the control costs for the baghouse are lower than the control costs for the wet scrubber, due to product recovery credits. Firms will generally choose the lower cost alternative, and

TABLE 9-3. EXAMPLE: PERCENT PRICE INCREASE CALCULATION

BALL CLAY

(Vibrating-grate Dryer)

23	Mg/hr[a]
X 4,000	x Hrs of operation/yr
92,000	= Mg of production/yr
$ 36	Price/Mg
X 92,000	x Mg of production/yr
$ 3,312,000	= Revenue/yr
$ 93,000	NSPS control costs[b]
- 86,000	- SIP Baseline control costs
$ 7,000	= Incremental annualized control cost
$ 7,000	Incremental annualized control cost
$ 3,312,000	÷ Revenue/yr
= 0.21%	= Percent price increase

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[a] To convert from megagrams to short tons multiply by 1.102.
[b] RA III.

TABLE 9-4. PERCENT PRICE INCREASE

Industry/ facility	Size (Mg/h)	Operation (H/yr)	Production (Mg/yr)	Price ($/Mg)	Revenue ($/yr)	RA II-I		RA III-I	
						Control costs ($/yr)	Percent price increase	Control costs ($/yr)	Percent price increase
Alumina									
Flash calciner	a	a	448,000	297.00	133,056,000	-22,000	-0.02	b	b
Rotary calciner	23	8,000	184,000	297.00	54,648,000	-14,000	-0.03	b	b
	32	8,000	256,000	297.00	76,032,000	-15,000	-0.02	b	b
	45	8,000	360,000	297.00	106,920,000	-17,000	-0.02	b	b
Ball Clay									
Rotary dryer	a	a	55,800	36.00	2,009,000	5,000	0.25	b	b
Vibrating-grate dryer	11	4,000	44,000	36.00	1,584,000	5,000	0.32	6,000	0.38
	23	4,000	92,000	36.00	3,312,000	7,000	0.21	7,000	0.21
Bentonite									
Fluid bed dryer BH^c	40	a	266,500	43.00	11,460,000	22,000	0.19	23,000	0.20
ESP^d	40	a	351,000	43.00	15,093,000	24,000	0.16	34,000	0.23
Rotary dryer	18	5,800	104,400	43.00	4,489,000	11,000	0.25	12,000	0.27
	32	5,800	185,600	43.00	7,981,000	15,000	0.19	16,000	0.20
	54	5,800	313,200	43.00	13,468,000	19,000	0.14	20,000	0.15
Diatomite									
Flash dryer	4	8,000	32,000	197.00	6,304,000	10,000	0.16	27,000	0.43
	11	8,000	88,000	197.00	17,336,000	23,000	0.13	48,000	0.28
Rotary dryer	a	a	37,800	197.00	7,447,000	3,000	0.04	4,000	0.05
Rotary calciner BH^c	4	6,500	26,000	197.00	5,122,000	7,000	0.14	b	b
BH^c	11	6,500	71,500	197.00	14,086,000	8,000	0.05	b	b
WS^d	4	6,500	26,000	197.00	5,122,000	8,000	0.59	b	b
WS^d	11	6,500	71,500	197.00	14,086,000	17,000	0.48	b	b
Feldspar									
Rotary dryer	a	a	16,000	36.00	576,000	0	0	1,000	0.17
	18	4,500	81,000	36.00	2,916,000	0	0	3,000	0.10
	27	5,200	140,400	36.00	5,054,000	1,000	0.02	7,000	0.14
Fluid bed dryer	a	a	43,200	36.00	1,555,000	9,000	0.58	10,000	0.64
	a	a	120,000	36.00	4,320,000	13,000	0.30	14,000	0.32

(continued)

TABLE 9-4. (continued)

Industry/ facility	Size (Mg/h)	Operation (H/yr)	Production (Mg/yr)	Price ($/Mg)	Revenue ($/yr)	RA II-I Control costs ($/yr)	RA II-I Percent price increase	RA III-I Control costs ($/yr)	RA III-I Percent price increase
Fire Clay									
Rotary dryer BH[c]	9	3,000	27,000	17.60	475,000	4,000	0.84	b	b
WS[d]	9	3,000	27,000	17.60	475,000	1,000	0.21	2,000	0.42
BH[c]	27	3,000	81,000	17.60	1,426,000	5,000	0.35	6,000	b
WS[d]	27	3,000	81,000	17.60	1,426,000	3,000	0.21	4,000	0.28
BH[c]	45	3,000	135,000	17.60	2,376,000	6,000	0.25	b	b
WS[d]	45	3,000	135,000	17.60	2,376,000	3,000	0.13	b	b
Vibrating-grate dryer	23	2,000	46,000	17.60	810,000	0	0	b	b
Rotary calciner	9	8,000	72,000	17.60	1,267,000	15,000	1.18	b	b
	18	8,000	144,000	17.60	2,534,000	24,000	0.95	b	b
Fuller's Earth									
Fluid bed dryer	a	a	340,200	54.00	18,371,000	17,000	0.09	16,000	0.09
Rotary dryer BH[c]	4	7,500	30,000	54.00	1,620,000	8,000	0.49	9,000	0.56
WS[d]	4	7,500	30,000	54.00	1,620,000	3,000	0.19	6,000	0.37
BH[c]	14	7,500	105,000	54.00	5,670,000	9,000	0.16	b	b
WS[d]	14	7,500	105,000	54.00	5,670,000	6,000	0.11	8,000	0.14
BH[c]	27	7,500	202,500	54.00	10,935,000	10,000	0.09	11,000	0.10
WS[d]	27	7,500	202,500	54.00	10,935,000	6,000	0.05	13,000	0.12
Rotary calciner	4	8,000	32,000	54.00	1,728,000	9,000	0.52	b	b
	23	8,000	184,000	54.00	9,936,000	12,000	0.12	b	b
	41	8,000	328,000	54.00	17,712,000	14,000	0.08	b	b
Gypsum									
Rotary dryer	45	5,600	252,000	9.00	2,268,000	11,000	0.49	12,000	0.53
	73	5,600	408,800	9.00	3,679,000	11,000	0.30	12,000	0.33
Flash calciner	9	5,600	50,400	24.00	1,210,000	7,000	0.58	b	b
Kettle calciner	11	5,600	61,600	24.00	1,478,000	6,000	0.41	b	b

(continued)

TABLE 9-4. (continued)

Industry/ facility	Size (Mg/h)	Operation (H/yr)	Production (Mg/yr)	Price ($/Mg)	Revenue ($/yr)	RA II-I		RA III-I	
						Control costs ($/yr)	Percent price increase	Control costs ($/yr)	Percent price increase
Industrial Sand									
Rotary dryer	45	1,800	81,000	13.20	1,069,000	0	0	b	b
	91	1,800	163,800	13.20	2,162,000	0	0	b	b
	136	4,000	544,000	13.20	7,181,000	0	0	b	b
Fluid bed dryer	45	2,000	90,000	13.20	1,188,000	0	0	b	b
	91	6,400	582,000	13.20	7,688,000	0	0	b	b
	182	6,400	1,164,800	13.20	15,375,000	0	0	b	b
Kaolin									
Rotary dryer	18	3,000	54,000	86.00	4,644,000	4,000	0.09	b	b
Spray dryer	14	8,000	112,000	86.00	9,632,000	7,000	0.07	8,000	0.08
	27	8,000	216,000	86.00	18,576,000	7,000	0.04	b	b
Rotary calciner BH[c]	5	8,000	40,000	132.00	5,280,000	11,000	0.21	b	b
WS[d]	5	8,000	40,000	132.00	5,280,000	12,000	0.23	b	b
Flash calciner	a	a	24,000	132.00	3,168,000	7,000	0.22	b	b
Multiple hearth furnace	4	8,000	32,000	132.00	4,224,000	7,000	0.17	b	b
Lightwt. Aggregate									
Rotary calciner BH[c]	18	8,000	144,000	4.50	648,000	15,000	2.31	b	b
WS[d]	18	8,000	144,000	4.50	648,000	33,000	5.09	b	b
BH[c]	27	8,000	216,000	4.50	972,000	17,000	1.75	b	b
WS[d]	27	8,000	216,000	4.50	972,000	62,000	6.38	b	b
BH[c]	36	8,000	288,000	4.50	1,296,000	19,000	1.47	b	b
WS[d]	36	8,000	288,000	4.50	1,296,000	87,000	6.71	b	b
Magnesium Compounds									
Rotary Calciner									
$Mg(OH)_2$ feed	4	8,000	32,000	236.00	7,552,000	4,000	0.05	b	b
	9	8,000	72,000	236.00	16,992,000	7,000	0.04	b	b
Magnesite feed	a	a	144,000	236.00	33,984,000	-9,000	-0.03	b	b

(continued)

TABLE 9-4. (continued)

Industry/ facility	Size (Mg/h)	Operation (H/yr)	Production (Mg/yr)	Price ($/Mg)	Revenue ($/yr)	RA II-I		RA III-I	
						Control costs ($/yr)	Percent price increase	Control costs ($/yr)	Percent price increase
Magnesium Compounds (Cont.)									
Multiple hearth furnace									
$Mg(OH)_2$ feed	a	a	16,000	349.00	5,584,000	1,000	0.02	b	b
	a	a	40,000	349.00	13,960,000	-3,000	-0.02	b	b
	a	a	72,000	349.00	25,128,000	-5,000	-0.02	b	b
Magnesite feed	a	a	40,000	349.00	13,960,000	-4,000	-0.03	b	b
	a	a	72,000	349.00	25,128,000	-11,000	-0.04	b	b
Perlite									
Rotary dryer	23	2,900	66,700	35.00	2,335,000	16,000	0.69	b	b
	a	a	130,500	35.00	4,568,000	22,000	0.48	b	b
Expansion furnace	1	1,600	1,600	182.00	291,000	3,000	1.03	b	b
Roofing Granules									
Fluid bed dryer	36	4,000	144,000	39.00	5,616,000	0	0	b	b
Rotary dryer	14	6,000	84,000	39.00	3,276,000	0	0	b	b
	54	6,000	324,000	39.00	12,636,000	0	0	b	b
	200	4,200	840,000	39.00	32,760,000	0	0	b	b
Talc									
Flash dryer	a	a	16,800	111.00	1,865,000	5,000	0.27	b	b
Rotary dryer	9	7,400	66,600	111.00	7,393,000	6,000	0.08	7,000	0.09
	18	7,400	133,200	111.00	14,785,000	7,000	0.05	b	b
Rotary calciner	4	8,000	32,000	111.00	3,552,000	9,000	0.25	b	b
Titanium Dioxide									
Rotary dryer (direct)	2	8,000	16,000	1,433.00	22,928,000	6,000	0.03	8,000	0.03
	6	8,000	48,000	1,433.00	68,784,000	5,000	0.01	6,000	0.01
	a	a	112,000	1,433.00	160,496,000	4,000	0.00	b	b

(continued)

TABLE 9-4. (continued)

Industry/ facility	Size (Mg/h)	Operation (H/yr)	Production (Mg/yr)	Price ($/Mg)	Revenue ($/yr)	RA II-I		RA III-I	
						Control costs ($/yr)	Percent price increase	Control costs ($/yr)	Percent price increase
Titanium Dioxide (Cont.)									
Rotary dryer (indirect)	11	8,000	88,000	1,433.00	126,104,000	-14,000	-0.01	b	b
Flash dryer	a	a	184,000	1,433.00	263,672,000	-36,000	0.01	-19,000	0.01
Fluid bed dryer	a	a	287,000	1,433.00	411,271,000	64,000	0.02	121,000	0.03
	a	a	287,000	1,433.00	411,271,000	3,000	0.00	17,000	0.00
Spray dryer	a	a	16,000	1,433.00	22,928,000	-11,000	-0.05	-14,000	-0.06
	a	a	32,000	1,433.00	45,856,000	-41,000	-0.09	-50,000	-0.11
	a	a	56,000	1,433.00	80,248,000	-70,000	-0.09	-86,000	-0.11
Rotary calciner	a	a	16,000	1,433.00	22,928,000	0	0.00	b	b
	a	a	32,000	1,433.00	45,856,000	0	0.00	b	b
Vermiculite									
Rotary dryer	9	2,500	22,500	107.00	2,408,000	0	0	b	b
	18	2,500	45,000	107.00	4,815,000	0	0	b	b
Fluid bed dryer	54	4,800	259,200	107.00	27,734,000	8,000	0.03	9,000	0.03
Expansion furnace	1	3,000	3,000	257.00	771,000	1,000	0.13	b	b

a Confidential.
b RA II = RA III.
c BH: Baghouse.
d WS: Wet Scrubber.
e ESP: Electrostatic Precipitator.

the percent price increase for the lower cost alternative should therefore be the more accurate estimate of the industry percent price increase.

A review of Table 9-4 reveals that for two industries (industrial sand, roofing granules) the control costs are zero for every model facility. For one industry (alumina) the control costs are negative for every model facility. For most of the remaining industries the control costs for the individual model facilities yield percent price increases that vary from slightly negative to slightly positive. The negative price increases (net savings) are due to product recovery credits. For those cases where model facilities have negative price increases, the firms would be likely to try to achieve the potential savings in the long-run regardless of the NSPS. One possible explanation as to why firms are not currently achieving these savings is that the percent savings are relatively small. Consequently, any changes in the overall operation of the firm in order to achieve the savings might have a low priority. Two industries that contain some model facilities with price increases that are higher than the other industries are the fire clay industry, 1.18 percent (small rotary calciner), and the lightweight aggregate industry, 2.31 percent (small baghouse). Fire clay uses both dryers and calciners and could have a combined price increase of 2.02 percent. It should also be noted that for lightweight aggregate, the price increase does, in fact, range as high as 6.71 percent in the case of the large wet scrubber; however, this control is not likely to be used given the availability of lower cost control options.

An economic effect of particular interest is whether industry output would be reduced in 1990 due to the NSPS-induced price increase. Because the standard applies only to new, modified or reconstructed sources, the effect of a price increase, therefore, is to delay the construction of new sources. If price in 1990 is greater with the NSPS than it would have been without the NSPS, then output in 1990 will be less than it would have been in the absence of the NSPS, and some sources that would have been constructed in the absence of the NSPS will be delayed until after 1990.

The extent of any reduction in output caused by a price increase is measured by the price elasticity of demand. For products such as minerals that are generally used as inputs to produce other products, price elasticities commonly fall between -0.2 and -1.0. An elasticity of -0.5, for example, means that a one percent price increase will lead to a 0.5 percent decrease in purchases. Price elasticities are computed holding all other prices constant. If the prices of substitute products increase along with the price of the product being analyzed, as is the case for many of the minerals in this study, the net effect on output will be less than that predicted by the price elasticity.

Since virtually all of the percentage price increases in this analysis are less than 3.0 percent, 1990 output should be reduced by no more than 3.0 percent (and considerably less in most industries) due to the NSPS. Thus, the NSPS will not have a significant effect on output nor delay construction of new sources significantly.

9.2.5 Individual Industry Review

The purpose of this section is to review each of the industries and model facilities on an individual basis. For those model facilities that have control costs that are zero or negative, little discussion is necessary.

9.2.5.1 Alumina. The incremental annualized control costs are negative for all model facilities (RA II and RA III). A negative control cost means a net savings occurs.

9.2.5.2 Ball Clay. For each model facility in the ball clay industry the percent price increase is small. The highest price increase is 0.38 percent. Therefore the NSPS is not likely to have a significant economic effect on this industry. The control costs for RA II and RA III are the same for the rotary dryer.

9.2.5.3 Bentonite. The control costs for RA II and RA III differ slightly for some of the model facilities in the bentonite industry. However, in both cases, the percent price increases are small, with the highest price increase being 0.27 percent. As a result, the NSPS is not likely to have a significant economic effect on this industry.

9.2.5.4 Diatomite. All of the individual model facilities for the diatomite industry have percent price increases of less than 0.60 percent for RA II and RA III. The diatomite industry is one of the industries that includes dryers and calciners and therefore the possible cumulative effect needs to be considered. Combinations of the model dryers and calciners result in price increases of 1.02 percent, or less. Considering baghouses rather than the more costly wet scrubbers, the price increases are 0.57 percent or less.

As described in Section 9.1, the financial and economic condition of the industry is healthy. The capacity utilization rate for the industry has been high, prices have been increasing by approximately 5 to 10 percent per year, imports are insignificant, and some new plants in the industry are being actively considered. Overall, potential price increases of the magnitude under consideration here are not likely to have a significant economic effect in this case.

9.2.5.5 Feldspar. Four of the five model facilities in the feldspar industry have product price increases of less than one-half of 1 percent, and the fifth model facility is only slightly over one-half of 1 percent (for both RA II and RA III). Price increases of this size are not likely to have a significant adverse economic effect on this industry.

9.2.5.6 Fire Clay. The control costs for RA II and RA III for the fire clay industry are either identical or similar for all of the model facilities. Most of the rotary dryer model facilities for this industry have percent price increases of less than 0.50 percent. The mall rotary dryer with a baghouse has a price increase of 0.84 percent, ut with a wet scrubber the price increase is only 0.21 percent. The ibrating-grate dryer has a zero percent price increase. The two rotary lciner model facilities have price increases of 1.18 and 0.95 percent. e fire clay industry is one of the industries that includes dryers d calciners. Therefore, there is the potential in this industry for cumulative economic effect to occur due to NSPS control costs on the yers and NSPS control costs on the calciners. Cumulative impacts could be as high as 2.02 percent although it would be only 1.60 percent if the less costly rotary dryer with a wet scrubber were used.

As described in Section 9.1, the baseline financial and economic fundamentals for the industry are not strong. The industry is dependent to a significant degree on the financial health of basic manufacturing industries such as steel and aluminum. The value of fire clay relative to the value of final manufactured products is small. Also, there is no significant competition from imports. These two factors provide a qualitative indication that demand is not likely to be highly price elastic. For illustration, even if the relatively high elasticity figure of -1.0 is assumed, 1990 output reduction would be at most 2.02 percent. Unfortunately, data limitations precluded a more thorough analysis of the elasticity as was done for lightweight aggregate; this analysis is provided in the Docket. Therefore, although the industry is not currently healthy, the NSPS-induced price increase is not likely to have a significant effect on industry output or on the timing of new construction.

9.2.5.7 Fuller's Earth. All of the individual model facilities have percent price increases below 0.60 percent. The control costs for RA II and RA III are either the same, or nearly the same, for virtually all of the model facilities.

The fuller's earth industry is one of the industries that includes dryers and calciners. As a result the possibility exists for a cumulative economic effect to occur. However, for nearly all of the potential combinations of a dryer and a calciner, the resulting percent price increase is about 1 percent, or less. In general, the fuller's earth industry is not likely to experience significant economic effects due to the NSPS.

9.2.5.8 Gypsum. The control costs for RA II and RA III are generally the same for the gypsum industry. All of the model facilities have a percent price increase of 0.58 percent, or less. The price used in the calculation of the percentage price increase is quite conservative because it does not include any proportionate share of revenue due to the sale of wallboard. Since wallboard has a much higher selling price than gypsum, the revenue figure is conservatively low and this results in an upward bias in the calculated percent price increase.

The gypsum industry closely follows the cycles of the construction industry. The gypsum industry is in a strong financial and economic condition. The industry is operating at a high capacity utilization rate, and prices are increasing. Overall, price increases of the magnitude under consideration here are not likely to have a significant economic effect on the industry.

The gypsum industry is one of the industries that includes dryers and calciners, and so there is the possibility of a cumulative effect on the industry. However, the cumulative price increases are approximately 1 percent, or less. The strong economic condition of the industry coupled with the use of a conservative price indicates that the potential cumulative effect should not be significant.

9.2.5.9 Industrial Sand. This industry has no incremental annualized control costs for RA II and RA III since the control techniques associated with these alternatives are identical to those used in the baseline (RA I).

9.2.5.10 Kaolin. For the kaolin industry RA II and RA III are either the same, or nearly the same, for all model facilities. All of the model facilities have percent price increases of less than 0.25 percent. Although the financial condition of the industry is improving, it is still not in a strong position due to excess capacity. However, the price increases for the model facilities do not suggest significant economic effects.

9.2.5.11 Lightweight Aggregate. The control costs for RA II and RA III are the same for all model facilities in this industry. The lightweight aggregate (LWA) industry has the lowest product price of the 17 industries. To a large degree the low product prices lead to percent price increases that are higher than for most of the other industries.

For example, the three model facilities with a baghouse each have price increases of approximately 2 percent (with a wet scrubber the price increases range from about 5.1 to 6.7 percent).

As described in Section 9.1, total production for the industry has been depressed over the last few years. The overall baseline financial and economic condition of this industry is not strong but is improving. The LWA industry faces varying degrees of competition from several substitutes, including construction sand and gravel, crushed stone, pumice, and to a lesser degree perlite and vermiculite, as discussed earlier in Section 9.1.

Because the price increase is somewhat higher for LWA than for most of the other minerals, an empirical demand equation for LWA is developed to gauge the size of its elasticity. (A technical discussion of the estimation procedure is available in the Docket.) The empirical estimate of elasticity for LWA is -1.0. This means that a 1 percent increase in price will lead to a 1 percent reduction in output in 1990 compared to what it would have been in the absence of the NSPS. Or, in other words, construction of new capacity equal to 1 percent of total industry output will be delayed until after 1990 because of the NSPS.

Because the price increases for the baghouse control option are substantially less than the price increases for the wet scrubber control option, firms will opt for the baghouse. Thus, the baghouse control option will drive the percent price change in the LWA market. With an elasticity of -1.0, both the percent price increase and the percent output decrease for 1990 in the LWA industry will range between 1.47 and 2.31 percent. This is not likely to result in significant adverse effects for the industry.

9.2.5.12 Magnesium Compounds. The NSPS is not likely to have a significant economic effect on the magnesium compounds industry. Due to the high product price the percent price increase for each model facility is quite small, below 0.10 percent and in many cases it is negative. The results are the same for RA II and RA III.

9.2.5.13. <u>Perlite</u>. The control costs for all three model facilities in the perlite industry are the same for RA II and RA III. For the two rotary dryer model facilities the price increase is below 1 percent (0.48 to 0.69 percent). For the expansion furnace model facility the price increase is 1.03 percent. Vermiculite is a close substitute for perlite, and although this might otherwise suggest that vermiculite would act as a constraint on perlite price increases, vermiculite is also one of the 17 industries included in the analysis. Vermiculite and perlite have similar (though not identical) percent increases and so any net competitive advantage to one or the other, due solely to the NSPS, should be small. Overall the industry is not likely to experience significant economic effects due to the NSPS.

9.2.5.14 <u>Roofing Granules</u>. This industry has no incremental annualized control costs for RA II and RA III since the control techniques associated with these alternatives are identical to those used in the baseline (RA I).

9.2.5.15 <u>Talc</u>. All of the four individual model facilities for the talc industry have percent price increases of under 0.30 percent for both RA II and RA III. The talc industry includes dryers and calciners, but no combination of a model dryer and a model calciner yields a percent price increase of greater than 0.52 percent. The talc industry is not likely to experience a significant economic effect due to the NSPS.

9.2.5.16 <u>Titanium Dioxide</u>. Although the annualized control costs for RA II and RA III differ in most cases, neither alternative is likely to have a significant economic effect on the titanium dioxide ndustry. For all of the model facilities the percent price increases re small (or negative). The titanium dioxide industry is one of the ndustries that includes dryers and calciners. However, the control osts associated with the rotary calciner are zero for this industry cause the control techniques are identical among regulatory alterna- ves, including the baseline (RA I).

9.2.5.17 Vermiculite. All four of the model facilities for the vermiculite industry are below a price increase of 0.20 percent for both RA II and RA III. Perlite is a close substitute for vermiculite, and although this might otherwise suggest that perlite would act as a constraint on vermiculite price increases, perlite is also one of the 17 industries included in the analysis. Perlite and vermiculite have similar (though not identical) percent price increases and so any net competitive advantage to one or the other, due solely to the NSPS, should be insignificant. In general, the industry is not likely to experience significant economic effects due to the NSPS.

9.3 SOCIO-ECONOMIC ASSESSMENT

9.3.1 Executive Order 12291

The purpose of Section 9.3.1 is to address those tests of macroeconomic effects as presented in Executive Order 12291, and, more generally, to assess any other significant macroeconomic effects that may result from the NSPS. Executive Order 12291 stipulates as "major rules" those that are projected to have any of the following results:

- An annual effect on the economy of $100 million or more.
- A major increase in costs or prices for consumers; individual industries; Federal, State, or local government agencies; or geographic regions.
- Significant adverse effects on competition, employment, investment, productivity, innovation, or on the ability of U.S.-based enterprises to compete with foreign-based enterprises in domestic or export markets.

9.3.1.1 Annualized Costs. A complete table of the fifth-year annualized control costs was presented earlier in Chapter 8. The calculations include the gradual replacement of existing facilities, as well as additional facilities required to meet increases in demand. Table 9-5 shows a summary of the fifth-year incremental annualized control costs. The costs are shown for Regulatory Alternative II and Regulatory Alternative III. In addition, the costs are shown first using the baghouse costs, and then using the wet scrubber costs. For

TABLE 9-5. SUMMARY OF FIFTH-YEAR NATIONWIDE INCREMENTAL ANNUALIZED CONTROL COSTS

ndustry/facility	Typical facility size^a	No. of typical facilities in fifth year^b	Pollution control device	Incremental annualized control cost in fifth year RA II-I $000	Incremental annualized control cost in fifth year RA III-I $000
lumina					
Flash calciner	L	c	ESP	-66	-66
Rotary calciner	S	15	ESP	-210	-210
all Clay					
Rotary dryer	M	c	BH	0	0
Vibrating-grate dryer	M	2	BH	10	12
ntonite					
Fluid bed dryer	M	0	BH	0	0
Fluid bed dryer	M	0	ESP	0	0
Rotary dryer	M	3	BH	45	48
tomite					
lash dryer	S	3	WS	30	81
otary dryer	M	1	BH	3	4
otary calciner	L	2	BH	16	16
otary calciner	L	2	WS	34	34
dspar					
uid bed dryer	M	c	BH	9	10
uid bed dryer	L	c	BH	0	0
tary dryer	L	1	WS	1	7
Clay					
tary dryer	M	3	BH	15	18
tary dryer	M	3	WS	9	12
brating-grate dryer	M	1	WS	0	0
tary calciner	M	0	WS	0	0
r's Earth					
id bed dryer	L	c	BH	0	0
ry dryer	S	6	BH	48	54
ry dryer	S	6	WS	18	36
ry calciner	M	2	BH	24	24
ry dryer	M	19	BH	209	228
calciner	M	47	BH	329	329
e calciner	M	40	BH	240	240

(continued)

TABLE 9-5. (continued)

Industry/facility	Typical facility size[a]	No. of typical facilities in fifth year[b]	Pollution control device	Incremental annualized control cost in fifth year RA II-I $000	RA III-I $000
Industrial Sand					
Fluid bed dryer	M	6	WS	0	0
Rotary dryer	S	35	WS	0	0
Kaolin					
Rotary dryer	M	10	BH	40	40
Spray dryer	M	12	BH	84	96
Spray dryer	L	6	BH	42	42
Flash calciner	S	c	BH	0	0
Multiple hearth furnace	S	5	WS	35	35
Rotary calciner	S	0	BH	0	0
Rotary calciner	S	0	WS	0	0
Lightweight Aggregate					
Rotary calciner	M	7	BH	119	119
Rotary calciner	M	7	WS	434	434
Magnesium Compounds					
Multiple hearth furnace					
$Mg(OH)_2$	L	c	ESP	-5	-5
Magnesite feed	M	c	BH	-8	-8
Rotary calciner					
$Mg(OH)_2$ feed	S	2	ESP	8	8
Magnesite feed	L	c	BH	0	0
Perlite					
Rotary dryer	M	3	BH	48	48
Expansion furnace	S	62	BH	186	186
Roofing Granules					
Fluid bed dryer	M	0	WS	0	0
Rotary dryer	S	11	WS	0	0
Rotary dryer	M	3	WS	0	0
Talc					
Flash dryer	S	c	BH	80	80
Rotary dryer	M	0	BH	0	0
Rotary calciner	S	2	BH	18	18

(continued)

TABLE 9-5. (continued)

ndustry/facility	Typical facility size[a]	No. of typical facilities in fifth year[b]	Pollution control device	Incremental annualized control cost in fifth year RA II-I $000	RA III-I $000
itanium Dioxide					
Flash dryer	L	0	WS	0	0
Fluid bed dryer	M	c	WS	0	0
Rotary dryer (direct)	L	c	BH	4	4
Rotary dryer (indirect)	M	1	WS	-14	-14
Spray dryer	M	c	BH	-123	-150
Rotary calciner	S	c	WS	0	0
Rotary calciner	M	c	WS	0	0
rmiculite					
luid bed dryer	L	0	BH	0	0
otary dryer	M	2	WS	0	0
xpansion furnace	S	30	BH	30	30
AL[d]				1,308	1,406
AL[e]				1,626	1,724

small, M = medium, L = large.
ures are rounded and include reconstructions, modifications and new grass
ts plants.
idential information.
l includes diatomite rotary calciners, fire clay rotary dryer, fuller's
h rotary dryer, kaolin rotary calciner, and lightweight aggregate rotary
iner baghouse costs (and not wet scrubber costs).
l includes diatomite rotary calciners, fire clay rotary dryer, fuller's
h rotary dryer, kaolin rotary calciner, and lightweight aggregate rotary
iner wet scrubber costs (and not baghouse costs).

all of the cases the results are far below the $100 million level that stipulates a major rule. Regulatory Alternative III using wet scrubber costs, which is the most expensive case, has a total nationwide incremental annualized control cost of less than $3 million per year in the fifth year for all of the 17 mineral industries combined.

9.3.1.2 Regional Effects and Employment. Although some of the individual industries are concentrated in a particular region, if the 17 industries are considered as a group, the plants are widely dispersed geographically. Similarly, a few of the model facilities discussed previously might experience financial difficulties separate from NSPS effects, but if the 17 industries are considered as a group the NSPS is not likely to cause significant regional or employment economic effects.

9.3.2 Regulatory Flexibility

The Regulatory Flexibility Act (RFA) of 1980 requires that differential effects of Federal regulations upon small business be identified and analyzed. The RFA stipulates that an analysis is required if a "substantial number" of small businesses will experience "significant effects". Both measures -- substantial numbers of small businesses and significant effects -- must be met, to require an analysis. If either measure is not met then no analysis is required.

The EPA has developed guidelines to use in implementing the RFA's general provisions. During the course of writing a large number of regulatory standards EPA encounters a wide variety of industries. Due to the diverse economic circumstances of the industries no single analytical formula is applicable for all industries at all times with respect to an assessment of differential economic effects on small businesses. Therefore, the EPA guidelines recognize that individual cases will require the exercise of a degree of judgment in implementing the Act's provisions.[41] If a regulation applies to more than 20 percent of the small businesses in a particular industry, the EPA defines this as a substantial number of small businesses. The EPA definition of significant effect involves four tests: (1) prices for small entities rise 5 percent or more, assuming costs are passed on to consumers; or (2) annualized investment costs for pollution control are greater than 20 percent of total capital spending; or (3) control costs as a percentage of sales for small entities are 10 percent greater than control costs as a percentage of sales for large entities; or (4) the requirements of the regulation are likely to result in closures of small entities.

The Act's definition of "small business" is based on definitions developed by the Small Business Administration (SBA). The SBA's definitions are listed in 13 CFR Part 121 by Standard Industrial Classification (SIC) categories. For most of the mineral dryer and calciner industries, the SBA defines a small business as one with 500 or fewer employees (the 2 exceptions are gypsum and titanium dioxide, each of which is 1,000 employees).[42] As part of the development of this proposed standard a considerable amount of effort has been devoted to the task of identifying small businesses in the 17 industries. Steps that have been taken to identify small businesses include an extensive review of standard financial reference sources such as Moody's and Standard & Poor's, a mailing of Section 114 information requests, and an electronic data base search. Most of the mineral dryer and calciner industries do include small businesses according to the SBA definition. Because the standard under consideration here is n NSPS, the standard would apply to all businesses (both small and arge) in the 17 industries, and as a result the test of a substantial umber of small businesses is met.

Although there are a substantial number of small businesses, the asure of significant effects is not likely to be met. As described rlier, the absolute level of the percent product price increases is ite small for most of the industries, typically about one-half of 1 rcent or less. Thus, the first test is never triggered. Neither the second or fourth tests triggered. The third test is occasional-triggered, but the absolute sizes of the numbers are so small as to this test inapplicable. For example, in the diatomite industry, a l flash dryer (4 Mg/hr) has control costs as a percentage of sales are 23 percent higher than the corresponding percentage for a larger flash dryer (11 Mg/hr). But the absolute levels of these two percentages are 0.16 percent and 0.13 percent, and the 23 percent difference between them is virtually meaningless. Thus, because the absolute level of the percent product price increases is quite small for most of the industries, and because the tests are presented as guidelines, an interpretation of the spirit and purpose of the Act indicates that the industries do not exceed the Act's tests.

For the fire clay industry and the lightweight aggregate industry some additional discussion of the RFA will be useful. In the case of the fire clay industry all of the model facilities (and the combinations of dryers and calciners) are appreciably below the 5 percent test, and so this test is not met. The difference in the price increase between the small model facility and the large model facility is in excess of the 10 percent test. However, the fact that the industry is well below the 5 percent test is the more important measure in this case as argued previously. For perspective, there are about 10 firms in the industry, of which available information indicates that about 1 to 3 firms could be small firms. In the case of the LWA industry there are two control options available -- a baghouse or a wet scrubber. The baghouse control option is technically feasible and has a product price increase of considerably less than 5 percent, and so the 5 percent test is not met. There is more than a 10 percent difference in the price increase for the small model facility versus the large model facility. However, here again the fact that the industry is well below the 5 percent test is the more important measure in this case. For perspective, there are about 32 firms in the LWA industry, of which available information indicates that about one-half are small firms. The size of the marketing area for an LWA firm is generally local or regional in nature, rather than national or international. Therefore, any single LWA firm does not compete with all other LWA firms in the country. Consequently, a small LWA firm that is competitive under baseline conditions will not necessarily lose its local or regional competitive edge to a large firm in another part of the country simply as the result of a relative difference in NSPS control costs. Also, as described earlier, the NSPS only applies to new, modified, or reconstructed dryers and calciners and so existing small firms will not automatically experience any change due to the NSPS.

It should be noted that a small model facility and a small business are not necessarily one and the same. However, due to data limitations, that conservative assumption has been used in the discussion. To the extent that small businesses and small model facilities are not the same, the potential differential economic effects would be reduced or eliminated. For example, if a "small business" owns a medium or a large model facility (rather than a small model facility) the Regulatory Flexibility test of a 10 percent difference would not be met. Overall, adverse economic effects on small businesses are not likely.

9.4 REFERENCES FOR CHAPTER 9

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CALCINERS AND DRYERS IN MINERAL INDUSTRIES

BACKGROUND INFORMATION FOR DEVELOPMENT OF NEW SOURCE PERFORMANCE STANDARDS

APPENDICES A-D

October 1985

APPENDIX A

EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

In the Federal Register of August 21, 1979, mineral processing plants were a major source category on the Priority List for development of new source performance standards. Preliminary information gathering was conducted in-house by EPA in 1979 and 1980. A screening study was initiated in August 1980 that led to the decision to develop a background information document (BID) on calciners and dryers in mineral industries.

The source category survey (Phase I) was undertaken in January 1981. In October 1982, an effort was begun to obtain the information needed to develop the BID (Phase II). The information gathering effort included literature surveys; canvassing of State, regional, and local air pollution control agencies; plant visits; meetings with industry representatives; contact with engineering consultants and equipment vendors; and emission source testing. Significant events relating to the evolution of the BID are itemized in Table A-1. Information about the gypsum and lightweight aggregate (LWA) industries was gathered concurrently, prior to becoming part of this effort. The activities for the gypsum and LWA industries have been incorporated chronologically into Appendix A.

TABLE A-1. EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

Date	Company, consultant, or agency/location	Nature of action
07/19/79	A. P. Green Refractories Company Mexico, Mo.	Plant visit
08/01/79	American Industrial Clay Company Sandersville, Ga.	Plant visit
11/13/79	Redco, Inc. North Hollywood, Calif.	Plant visit
11/14/79	Persolite Products, Inc. Florence, Colo.	Plant visit
11/15/79	Grefco, Inc. Antonito, Colo.	Plant visit
11/15/79	Silbrico Corp. Antonito, Colo.	Plant visit
11/16/79	Johns-Manville Perlite Corp. Antonito, Colo.	Plant visit
11/28/79	United States Gypsum Company Shoals, Ind.	Plant visit
11/29/79	Flintkote Company Sweetwater, Tex.	Plant visit
12/26/79	Carolina Stalite Company Salisbury, N.C.	Section 114 information reque
02/25/80	Texas Industries, Inc. Houston, Tex.	Plant visit
02/26/80	Hydraulic Press Brick Company Cleveland, Ohio	Plant visit
03/12/80	National Gypsum Company Wilmington, N.C.	Plant visit
04/17/80	United States Gypsum Company Fort Dodge, Iowa	Plant visit
04/18/80	C-E Raymond Abilene, Kans.	Plant visit

(conti

TABLE A-1. (continued)

Date	Company, consultant, or agency/location	Nature of action
04/21/80	United States Gypsum Company Sweetwater, Tex.	Plant visit
04/21/80	Flintkote Company Sweetwater, Tex.	Plant visit
04/23/80	Flintkote Company Blue Diamond, Tex.	Plant visit
05/06/80	National Gypsum Company Savannah, Ga.	Plant visit
05/19-23/80	Plant H2	Emission testing
05/23/80	Solite Corp. Arvonia, Va.	Plant visit
05/23/80	Amlite Corp. Snowden, Va.	Plant visit
05/29/80	Carolina Stalite Company Salisbury, N.C.	Plant visit
05/29/80	United States Gypsum Company East Chicago, Ill.	Plant visit
06/03-06/80	Plant H1	Emission testing
06/06/80	General Shale Products Corp. West Memphis, Ark.	Section 114 information request
6/09/80	Texas Industries, Inc. Clodine, Tex.	Plant visit
/09/80	Aglite, Inc. Minneapolis, Minn.	Plant visit
/19/80	United States Gypsum Company Southland, Okla.	Plant visit
29/80	National Gypsum Company Richmond, Calif.	Plant visit

(continued)

TABLE A-1. (continued)

Date	Company, consultant, or agency/location	Nature of action
07/02/80	National Gypsum Company Charlotte, N.C.	Industry meeting
07/14/80	Hydraulic Press Brick Company Cleveland, Ohio	Section 114 information reques
07/14-17/80	Plant H4	Emission testing
07/22/80	Chandler Materials Company Choctaw & Tulsa, Okla.	Section 114 information reques
	Galite Corp. Rockmart, Ga.	
	Big River Industries Baton Rouge, La.	
07/22/80	Texas Industries, Inc. Clodine, Tex.	Plant visit
07/23/80	Tombigbee Lightweight Aggregate Corp., Livingston, Ala.	Section 114 information reque
07/25/80	Vulcan Materials Company Bessemer, Ala.	Section 114 information reque
08/03/80	United States Gypsum Company Chicago, Ill.	Industry meeting
08/04/80	United States Gypsum Company Fort Dodge, Iowa	Plant visit
08/21/80	Arkansas Lightweight Aggregate Corp., West Memphis, Ark.	Plant visit
08/22/80	Galite Corp. Rockmart, Ga.	Plant visit
08/22/80	Vulcan Materials Company Bessemer, Ala.	Plant visit
08/26/80	Tombigbee Lightweight Aggregate Corp., Livingston, Ala.	Plant visit

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TABLE A-1. (continued)

Date	Company, consultant, or agency/location	Nature of action
08/28/80	Big River Industries Baton Rouge, La.	Plant visit
09/04/80	Lawson-United Feldspar and Mineral Company, Spruce Pine, N.C.	Plant visit
09/04/80	Harris Mining Company Spruce Pine, N.C.	Plant visit
09/12/80	Plant K7	Emission testing
09/30/80	W. R. Grace & Company Enoree, S.C.	Plant visit
10/02/80	Plant H6	Emission testing
10/07/80	Lorusso Corp. Walpole, Ma.	Section 114 information request
10/24-31/80	Plant H3	Emission testing
12/22/80	Mailout to industry members, trade associations, equipment vendors and consultants	Request for comment on draft BID Chapters 3, 4, 5, and 6 (Gypsum)
01/06/81	Research Triangle Institute Research Triangle Park, N.C.	Project start date for Phase I contractor
03/03/81	Plant K6	Emission testing
05/06/81	Solite Corp. Arvonia, Va.	Section 114 information request
07/13/81	Amlite Corp. Snowden, Va.	Plant visit
7/20/81	The Fuller Company Bethlehem, Pa.	Plant visit
7/21/81	F. L. Smidth and Company Cresskill, N.J.	Plant visit

(continued)

TABLE A-1. (continued)

Date	Company, consultant, or agency/location	Nature of action
07/29/81	Pennsylvania Glass Sand Corp. Berkeley Springs, W. Va.	Plant visit
07/29/81	Grefco, Inc. Lompoc, Calif.	Plant visit
07/31/81	Plant K1	Emission testing
08/06/81	Freeport Kaolin Company Gordon, Ga.	Plant visit
08/06/81	U. S. EPA, Research Triangle Institute, China Clay Producers Association	Meeting to discuss development of mineral drying and calcining source category survey
08/07/81	Oil-Dri Corp. of America Ochlocknee, Ga.	Plant visit
08/12/81	American Cyanamid Company Savannah, Ga.	Plant visit
08/13/81	H. C. Spinks Clay Company Paris and Gleason, Tenn.	Plant visits
08/17/81	Black Hills Bentonite Company Mills, Wyo.	Plant visit
08/18/81	Wyo-Ben, Inc. Lucerne, Wyo.	Plant visit
08/25-26/81	3M Company St. Paul, Minn. and Wausau, Wis.	Plant visits
10/07/81	Eastern Magnesia Talc Company Johnson, Vt.	Plant visit
11/18/81	A. P. Green Refractories Company Mexico, Mo.	Plant visit
11/19/81	Allied Chemical Company Owensville, Mo.	Plant visit

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TABLE A-1. (continued)

Date	Company, consultant, or agency/location	Nature of action
11/20/81	Aluminum Company of America Point Comfort, Tex.	Plant visit
09/23/82	E. I. du Pont de Nemours & Company DeLisle, Miss.	Plant visit
10/82	U. S. EPA Research Triangle Park, N.C.	Draft Source Category Survey: Mineral Dryers and Calciners
10/18/82	Midwest Research Institute Raleigh, N.C.	Project start date for Phase II contractor
12/13/82	Reynolds Metals Company Richmond, Va. Old Hickory Clay Company Mayfield, Ky. Cyprus Industrial Minerals Company Gleason, Tenn. IMC Corp. Mundelein, Ill. American Colloid Company Lethohatchee, Ala.	Section 114 information request
	N. L. Baroid, N. L. Industries, Inc. Houston, Tex. Dresser Industries, Inc. Dallas, Tex. I. U. International, International Management Corp., Philadelphia, Pa. Cedar Heights Clay Company, Oak Hill, Ohio Floridin Company Quincy, Fla.	
	Mid-Florida Mining Company Lowell, Fla. Balcones Minerals Corp. La Grange, Tex.	

(continued)

TABLE A-1. (continued)

Date	Company, consultant, or agency/location	Nature of action
12/13/82	Combustion Engineering, Inc. Windsor, Conn.	Section 114 information request
	Florida Rock Industries, Inc. Brooksville, Fla.	
	Whitehead Brothers Company Leesburg, N.J.	
	Manley Brothers, Inc. Chesteron, Ind.	
	Jesse S. Morie & Son, Inc. Junction City, Ga.	
	Southern Talc Company, Inc. Chatsworth, Ga.	
	The Milwhite Company, Inc. Houston, Tex.	
	Gouverneur Talc, Inc. Gouverneur, N.Y.	
	Windsor Minerals, Inc. Windsor, Vt.	
	Vermont Talc Chester, Vt.	
12/13/82	Gulf and Western Natural Resources Group, Nashville, Tenn.	Section 114 information request
	SCM Corp. New York, N.Y.	
	Patterson Vermiculite Company Enoree, S.C.	
	Virginia Vermiculite, Ltd. Arlington, Va.	
	The Schundler Company Metuchen, N.J.	
	Strong-Lite Products Pine Bluff, Ark.	
	Grefco Minerals, Inc. Torrance, Calif.	
	United States Gypsum Company Chicago, Ill.	
	Armstrong World Industries Lancaster, Pa.	

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TABLE A-1. (continued)

Date	Company, consultant, or agency/location	Nature of action
12/13/82	Carolina Perlite Company Gold Hill, N.C.	Section 114 information request
	Eagle-Picher Industries, Inc. Reno, Nev.	
	Witco Chemical Corp. Woodcliff Lake, N.J.	
	Amoco Minerals Corp. Englewood, Colo.	
	The Feldspar Corp. Spruce Pine, N.C.	
	IMC Chemical Group, Inc. Spruce Pine, N.C.	
	Foote Minerals Company Kings Mountain, N.C.	
	Barcroft Company Lewes, Del.	
	Basic Chemicals Gabbs, Nev.	
	Martin-Marietta Chemicals Manistee, Mich.	
12/13/82	Harbison-Walker Refractories Ludington, Mich.	Section 114 information request
	Bird & Son, Inc. Charleston, S.C.	
	H. B. Reed, Inc. Highland, Ind.	
	Spartan Minerals Corp. Pacolet, S.C.	
	Oil-Dri Corp. of America, Inc. Chicago, Ill.	
	Black Diamond Company Galena, Kans.	
	Ormet Corp. Burnside, La.	
	Frederick J. Dando Company Irondale, Ohio	
	Excel-Minerals Company Buttonwillow, Calif.	

(continued)

TABLE A-1. (continued)

Date	Company, consultant, or agency/location	Nature of action
12/23/82	Carolina Stalite Company Salisbury, N.C. Tombigbee Lightweight Aggregate Corp. Livingston, Ala. Vulcan Materials Company Birmingham, Ala. Galite Corp. Rockmart, Ga. Allied Chemical Company Morristown, N.C. Martin-Marietta Aluminum, Inc. St. Croix, U.S. Virgin Islands Englehard Minerals Company Attapulgus, Ga.	Section 114 information request
12/29/82	Sutherland, Asbill and Brennan Atlanta, Ga.	Section 114 information request
12/30/82	W. R. Grace & Company Cambridge, Mass.	Section 114 information request
03/03/83	The Feldspar Corp. Spruce Pine, N.C.	Plant visit
	Lawson United Feldspar and Mineral Company, Spruce Pine, N.C.	Plant visit
03/31/83	Jesse S. Morie & Son, Inc. Mauricetown, N.J.	Plant visit
03/18/83	Basic, Incorporated Gabbs, Nev.	Plant visit
03/21/83	International Minerals & Chemical Corp., Aberdeen, Miss.	Plant visit
03/22/83	American Colloid Company Aberdeen, Miss.	Plant visit
03/24/83	Cyprus Industrial Minerals Company Gleason, Tenn.	Plant visit

(continu

TABLE A-1. (continued)

Date	Company, consultant, or agency/location	Nature of action
03/31/83	New Jersey Silica Sand Corp. Millville, N.J.	Plant visit
04/05/83	Carolina Perlite Company Gold Hill, N.C.	Plant visit
04/07/83	C-E Refractories Vandalia, Mo.	Plant visit
04/08/83	A. P. Green Refractories Company Mexico, Mo.	Plant visit
04/13/83	W. R. Grace & Company Irondale, Ala.	Plant visit
04/14/83	Tombigbee Lightweight Aggregate Corp. Livingston, Ala.	Plant visit
04/19/83	Floridin Company Quincy, Fla.	Plant visit
04/28/83	Martin-Marietta Alumina, Inc. St. Croix, U.S. Virgin Islands	Plant visit
05/04/83	Pioneer Talc Company Allamore, Tex.	Plant visit
05/04/83	The Milwhite Company, Inc. Van Horn, Tex.	Plant visit
05/10/83	Aluminum Company of America Point Comfort, Tex.	Plant visit
05/11/83	Virginia Vermiculite, Ltd. Trevilians, Va.	Plant visit
5/12/83	C-E Minerals Andersonville, Ga.	Plant visit
5/17/83	Manville Products Corp. No Agua, N. Mex.	Plant visit
/18/83	Eagle-Picher Industries, Inc. Lovelock, Nev.	Plant visit

(continued)

TABLE A-1. (continued)

Date	Company, consultant, or agency/location	Nature of action
05/24/83	Harbison-Walker Refractories Ludington, Mich.	Plant visit
05/25/83	Martin-Marietta Chemicals Manistee, Mich.	Plant visit
06/02/83	American Cyanamid Company Savannah, Ga.	Plant visit
06/07/83	Freeport Kaolin Company Gordon, Ga.	Plant visit
06/07/83	Burgess Pigment Company Sandersville, Ga.	Plant visit
07/12/83	Plant C1	Pretest survey
08/22/83	C-E Refractories Vandalia, Mo.	Plant visit
08/04/83	United States Gypsum Company Shoals, Ind.	Plant visit
09/13-16/83	Plant I1	Emission testing
09/20-22/83	Plant C1	Emission testing
09/16/83	GAF Corp. Blue Ridge Summit, Pa.	Plant visit
09/26-29/83	Plant J1	Emission testing
09/30/83	Plant F1	Pretest survey
10/17-21/83	Plant F2	Emission testing
10/20/83	Ormet Corp. Burnside, La.	Plant visit
11/10/83	Kaiser Aluminum and Chemical Corp. Gramercy, La.	Plant visit

(continued)

TABLE A-1. (continued)

Date	Company, consultant, or agency/location	Nature of action
11/22/83	U. S. EPA, Representatives of the Perlite Institute	Meeting to discuss mineral dryers and calciners study
01/30-2/2/84	Plant M1	Emission testing
02/8-16/84	Plant P1	Emission testing
02/12-15/84	Plant F1	Emission testing
04/16-18/84	Plant F3	Emission testing
07/12-13/84	Plant P2	Emission testing
08/31/84	Mail-out to industry members, trade associations, equipment vendors, and consultants	Request for comment on draft BID Chapters 3, 4, 5, and 6 and Preliminary Cost Analyses
09/17/85	U. S. EPA and industry representatives	NAPCTAC meeting

APPENDIX B

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

This appendix consists of a reference system, cross-indexed with the October 21, 1974, Federal Register (39 FR 37419) containing the Agency guidelines concerning the preparation of environmental impact statements. This index can be used to identify sections of the document which contain data and information germane to any portion of the Federal Register guidelines.

TABLE B-1. CROSS-INDEXED REFERENCE SYSTEM TO HIGHLIGHT ENVIRONMENTAL IMPACT PORTIONS OF THE DOCUMENT

Agency guidelines for preparing regulatory action environmental impact statements (39 FR 37419)	Location within the Background Information Document
1. BACKGROUND AND SUMMARY OF REGULATORY ALTERNATIVES	
Summary of regulatory alternatives	The regulatory alternatives from which standards will be chosen for proposal are summarized in Chapter 1, Section 1.1.
Statutory basis for proposing standards	The statutory basis for proposing standards is summarized in Chapter 2, Section 2.1.
Relationship to other regulatory agency actions	The relationships between the regulatory agency actions are discussed in Chapter 3.
Industries affected by the regulatory alternatives	A discussion of the industries affected by the regulatory alternatives is presented in Chapter 3, Section 3.2. Further details covering the business and economic nature of the industry are presented in Chapter 9, Section 9.1.
Specific processes affected by the regulatory alternatives	The specific processes and facilities affected by the regulatory alternatives are summarized in Chapter 1, Section 1.1. A detailed technical discussion of the processes affected by the regulatory alternatives is presented in Chapter 3, Sections 3.1 and 3.2.
2. REGULATORY ALTERNATIVES	
Control techniques	The alternative control techniques are discussed in Chapter 4.

(continued)

TABLE B-1 (continued)

Agency guidelines for preparing regulatory action environmental impact statements (39 FR 37419)	Location within the Background Information Document
Regulatory alternatives	The various regulatory alternatives, including "no additional regulatory action," are defined in Chapter 6. A summary of the major alternatives considered is included in Chapter 1, Section 1.1.
3. ENVIRONMENTAL IMPACT OF THE REGULATORY ALTERNATIVES	
Primary impacts directly attributable to the regulatory alternatives	The primary impacts on mass emissions and ambient air quality due to the alternative control systems are discussed in Chapter 7, Sections 7.1, 7.2, 7.3, 7.4, and 7.5. A matrix summarizing the environmental impacts is included in Chapter 1.
Secondary or induced impacts	Secondary impacts for the various regulatory alternatives are discussed in Chapter 7, Section 7.1.
4. OTHER CONSIDERATIONS	A summary of the potential adverse environmental impacts associated with the regulatory alternatives is included in Chapter 1, Section 1.2, and Chapter 7. Potential socio-economic and inflationary impacts are discussed in Chapter 9, Sections 9.2 and 9.3. Irreversible and irretrievable commitments of resources are discussed in Chapter 7, Section 7.6.

APPENDIX C. SUMMARY OF TEST DATA

The results of EPA-conducted and industry-conducted (EPA-approved) particulate emission tests for dryers and calciners at 46 mineral processing plants are presented in this appendix. Data on sulfur dioxide (SO_2), nitrogen oxide (as NO_2), trace metals, and controlled visible emissions and process fugitive emissions measured in conjunction with the particulate tests are also presented. The particulate emission measurements include mass emission levels and some particle size distributions. Testing methodologies are described in Appendix D.

C.1 DESCRIPTION OF SOURCES

A brief description of the emission source, operating conditions of the process unit and control equipment, and a schematic of the system tested (when available) are presented in this section for each facility tested. Unless noted, all information has been obtained from the EPA-conducted and EPA-approved tests cited in Chapters 3 and 4.

C.1.1 Alumina

C.1.1.1 Plant A1--Industry Test. The flash calciner tested at Plant A1 is controlled by an electrostatic precipitator (ESP). The calciner was operating at 90 percent of capacity and was fired by natural gas. Opacity data based on 5-minute, 15-second averages at the ESP outlet ranged from 5 to 6.7 percent. No process or control device upsets were noted in the test report. Operating parameters and the chematic of the system tested are given in the Confidential Addendum to his document.

C.1.1.2 Plant A2--Industry Test. The outlets of four ESP's that ontrol emissions from two rotary calciners were tested for particulate issions at Plant A2. The tests were conducted during normal plant operations; no plant upsets were encountered during the test runs. The calciners, which were fired with No. 6 fuel oil, operated at 105 to 117 percent of design process rates. Two of the ESP's had specific collection areas (SCA) of 0.5 m^2 per m^3/min (147 ft^2 per 1,000 acfm), and the other two had SCA's of 1.1 m^2 per m^3/min (344 ft^2 per 1,000 acfm). Additional operating parameters and the schematic of the system tested are given in the Confidential Addendum to this document.

C.1.2 Ball Clay

C.1.2.1 Plant B1--Industry Test. Figure C-1 is a schematic of the system tested. The vibrating-grate dryer was controlled by a pulse-jet fabric filter. The dryer operated at 81 percent of design capacity during the test and was fired by natural gas. Two types of ball clay were blended during the test. Actual operating parameters for the fabric filter include an air-to-cloth ratio of 4.5:1 and a pressure drop of 1.0 kPa (4.0 in. w.c.). No plant upsets were noted in the test report.

C.1.3 Bentonite

C.1.3.1 Plant C1--EPA Test. Figure C-2 is a schematic of the system tested. The direct-fired rotary dryer at Plant C1 was controlled by a fabric filter preceded by a product recovery cyclone. Testing was performed at the cyclone inlet and the baghouse outlet. Particulate mass and particle size distribution data were collected at both locations simultaneously. The dryer operated at 96 percent of capacity during the tests and was fired with pulverized coal. The normal blend of four grades of bentonite was processed during the emission tests.

Some fluctuation in the dryer fire box temperature was observed throughout testing of the dryer. The fluctuations are normal and are caused by variations in the feed moisture content and amount of fines in the coal. The coal feed rate was adjusted when the fire box temperature dropped below 820°C (1500°F).

Additional air was added to the baghouse by a baghouse heating system. The actual operating air-to-cloth ratio for the reverse-air fabric filter was 0.9:1. No abnormalities in fabric filter operation were noted during the testing. The 6-minute average opacity data taken at the baghouse exhaust stack during the tests ranged from 0 to 8.3 percent.

C.1.3.2 Plant C3--Industry Test. The rotary dryer at Plant C3 was controlled by an ESP and operated at 96 percent of capacity during the particulate emission tests conducted at the ESP outlet. The specific collection area for the ESP was 2.97 m^2 per m^3/min (904 ft^2 per 1,000 acfm). Because the isokinetic sampling rate for Run No. 1 did not conform to EPA requirements, a fourth run was performed. Data from Run No. 1 were not included in the test report. No equipment operating problems were noted.

C.1.4 Diatomite

C.1.4.1 Plant D1--Industry Test. Particulate emission tests were conducted at the outlet of a wet scrubber controlling emissions from a rotary calciner at Plant D1. Feed material, which was preheated by kiln exhaust gases, was pneumatically conveyed through cyclones and air separators to the kiln. Product cooling air was used to preheat primary and secondary combustion air. The calciner operated between 89 and 104 percent of design capacity during the tests. No equipment operating problems were noted in the test report. A schematic of the system tested is presented in the Confidential Addendum to this document.

C.1.5 Feldspar

C.1.5.1 Plant E1--Industry Test. Particulate emission tests were conducted at the outlet of a wet scrubber controlling a rotary dryer at Plant E1. The dryer operated at 90 percent of capacity during the tests and was fired by No. 2 fuel oil. The operating pressure drop for the wet scrubber was 2.5 kPa (10 in. w.c.). No equipment operating problems were indicated in the test report.

C.1.5.2 Plant E2--Industry Test. Figure C-3 is a schematic of the system tested. The rotary dryer at Plant E2 was controlled by a wet scrubber. A multiple cyclone collector preceding the wet scrubber was used for product recovery. Particulate emission testing was conducted at the scrubber outlet. The dryer, fired by No. 2 fuel oil, operated at 100 percent of capacity during the test. The operating pressure drop for the scrubber during the test is given in the Confidential Addendum to this document. No unusual conditions were noted during sampling.

C.1.5.3 Plant E3--Industry Test. The rotary dryer tested at Plant E3 was controlled by a packed-bed wet scrubber. The cyclone preceding the scrubber was used for product recovery. Particulate emission testing was conducted at the scrubber outlet. The dryer operated at 100 percent of capacity during the test and was fired with No. 2 fuel oil. The operating pressure drop of the scrubber during testing was not noted. No equipment operating problems were noted in the test report.

C.1.6 Fire Clay

C.1.6.1 Plant F1--EPA Test. Figure C-4 is a schematic of the system tested. Particulate mass and particle size distribution tests were performed simultaneously on a rotary dryer at Plant F1 during the production of two types of fire clay: flint clay (Brohard) and Missouri plastic clay. The direct rotary dryer was fired with natural gas and operated at maximum capacity during the test series, based on the requirements of the material being processed and the desired product quality. All processes were operating normally during the emission testing. A trace metal analysis was also performed on a composite Method 5 particulate catch from each test location for each clay.

The cyclonic scrubber controlling emissions from the dryer was preceded by a product recovery cyclone. Particulate emission tests were conducted at the inlet of the cyclone and at the inlet and outlet of the scrubber. Particle size distributions were measured at the inlets of the cyclone and the scrubber. Because of excessive moisture in the scrubber outlet gas stream, particle size sampling was not possible at the scrubber outlet. The pressure drop across the cyclone/scrubber system ranged from 4.1 to 4.5 kPa (16.5 to 18 in. w.c.) throughout the testing.

During the first particulate run at the cyclone inlet, heavy particulate loading caused the positive pitot to plug. The gas velocity was back-calculated from the scrubber inlet gas flow rate. After the completion of the first run at the scrubber outlet stack, it was discovered that the thermocouple temperature readout was measuring low by approximately 21°C (38°F). The scrubber inlet/outlet temperatures for the subsequent runs were reviewed, and a representative stack temperature of 54°C (130°F) was used for the emissions calculations. The temperature adjustment resulted in an isokinetic sampling rate of 114 percent.

Visible emission (VE) observations were made at the outlet stack simultaneously with the emission testing. Visible emission measurements were also made of the process fugitive emissions at the rotary dryer feed inlet. No VE observations were made at the dryer product outlet because the system was totally enclosed with no visible leaks. All fugitive emission readings were 0 percent opacity. The 6-minute average opacity for all test runs ranged from 0.4 to 3.5 percent.

C.1.6.2 <u>Plant F2--EPA Test</u>. Figure C-5 is a schematic of the system tested. Particulate emission tests were conducted at the inlet to the multiple cyclone collector and the outlet of the venturi scrubber controlling emissions from a direct-fired rotary calciner processing Missouri flint clay. Particle size distribution tests were conducted simultaneously with the particulate tests at both locations. Because of inclement weather, only two sets of visible and process fugitive emission observations were performed, at the outlet of the scrubber and the calciner feed inlet, respectively. All VE measurements were 0 percent opacity at both locations. Fugitive emissions were not monitored at the product outlet because it was a totally enclosed system with no visible leaks.

The calciner operated at 100 percent of capacity and was fired with natural gas. During the tests, the scrubber liquid-to-gas ratio was 1,272 ℓ/1,000 m³ (12 gal/1,000 ft³). The pressure drop across the scrubber remained constant at an average value of 6.5 kPa (26 in. w.c.). Because of a high isokinetic sampling rate (118 percent) during the first test run, a fourth test run was conducted. Results for Run No. 1 re not included in the overall average. All processes were operating ormally during the emission testing.

C.1.6.3 <u>Plant F3--EPA Test</u>. Figure C-6 is a schematic of the stem tested. Tests were conducted at the inlet of a multiple cyclone llector, the inlet to a venturi scrubber, and at the outlet of the nturi scrubber controlling emissions from a rotary calciner processing olin clay at Plant F3. Testing was performed for particulate emissions, visible emissions, particle size distributions, sulfur dioxide and nitrogen oxide emissions, and trace metal content. All VE observations were 0 percent opacity from the scrubber stack. Process fugitive emission observations were not made because both the calciner feed inlet and product outlet were totally enclosed with no visible leaks.

The rotary calciner operated at 98 percent of capacity during all tests and was fired by pulverized coal. The scrubber flow rate measured during testing was 1,514 ℓ/min (400 gpm), and the pressure drop was approximately 4.5 kPa (18 in. w.c.). Other operating parameters of the scrubber during the test series are presented in the Confidential Addendum to this document.

Particle size distribution tests were not conducted at the scrubber outlet because of moisture in the flue gas. At the West induced draft (I.D.) fan inlet location (scrubber inlet), particle sizing Run Nos. 7B and 9B were not tabulated in the results due to an extremely low catch (underloaded) and extremely large catch (overloaded), respectively. No process upsets were reported.

C.1.7 Fuller's Earth

C.1.7.1 Plant G1--Industry Test. Figure C-7 is a schematic of the system tested. Particulate emission tests were performed at the outlet of the wet scrubber controlling emissions from the rotary dryer at Plant G1. During the test, the dryer operated at 102 percent of capacity and was fired with natural gas. The pressure drop of the scrubber was 2.5 kPa (10 in. w.c.) During the initial 14 minutes of Run No. 1, the make-up water to the scrubber was shut off. High stack temperature readings and particulate emission rates resulted from this malfunction. For this reason, data from Run No. 1 are not included in the test summary averages. No process operating problems were recorded in the test report.

C.1.8 Gypsum

C.1.8.1 Plant H1--EPA Tests. Figures C-8 and C-9 are schematics of the systems tested. Particulate emission tests were performed on fabric filters controlling emissions from a continuous kettle calciner and from a rotary dryer at Plant H1. The calciner operated at full capacity during the testing and was fired with natural gas. The direct-fired, cocurrent rotary dryer operated at 92 percent of capacity during the emission testing and was fired with natural gas.

The actual air-to-cloth ratios during testing were 2.9:1 and 6.4:1 for the calciner and dryer, respectively. Pressure drops across the fabric filters controlling the calciner and the rotary dryer ranged from 0.6 to 0.7 kPa (2.5 to 2.8 in. w.c.) and from 0.5 to 0.7 kPa (2.1 to 2.6 in. w.c.), respectively.

Three particle size distribution tests were conducted at the inlet and one test was conducted at the outlet of the rotary dryer fabric filter. Particle size distribution tests could not be conducted at the calciner testing points because a gas stream moisture content of approximately 70 percent caused condensation problems on the filter substrates. At the calciner inlet test point, the dry filter and cyclone catches were combined, and the resultant sample was submitted for a sedigraph particle size distribution analysis. No particle sizing was conducted at the outlet test locations.

Visible emission observations were made at the fabric filter outlets for both units. The 6-minute average opacities ranged from 0 to 0.6 percent for the kettle calciner and 0 to 0.4 percent for the rotary dryer. No unusual process operating problems were encountered during the test periods for either unit.

C.1.8.2 <u>Plant H1--Industry Test</u>. Emission tests were conducted at the outlet of a fabric filter controlling emissions from a kettle calciner at Plant H1. The calciner operated at 100 percent of design capacity during the test. The first test run was conducted at a high isokinetic sampling rate (121 percent). Results for Run No. 1 are not included in the overall average. No process or operating upsets were noted in the report.

C.1.8.3 <u>Plant H2--EPA Tests</u>. A direct-contact flash calciner sted at Plant H2 was controlled by a fabric filter and was fired by sidual fuel oil. The calciner operated at full capacity during the t series. Particulate emission tests were conducted at the inlet and tlet of the fabric filter. The actual air-to-cloth ratio during sting for the calciner baghouse was 5.5:1. Three particle size distribution tests were conducted at the baghouse inlet, and one test was conducted at the fabric filter outlet. Visible emission observations were also made at the fabric filter outlet. The range of 6-minute average opacities was 0 to 2.3 percent. No abnormalities in process operations were noted during the testing.

C.1.8.4 Plant H3--EPA Test. Figure C-10 is a schematic of the system tested. Particulate emission tests were performed at the fabric filter inlet and outlet during both continuous and batch operation of a kettle calciner at Plant H3. The opacity of the fabric filter plume was monitored during the particulate emission tests. Filter particulate catches from the six fabric filter inlet emission tests were analyzed for particle size distribution. The calciner was fired with natural gas during the testing.

The batch cycle lasted approximately 2 hours and 40 minutes. EPA Method 5 tests on the outlet of the pulse-jet fabric filter were conducted over an entire cycle, beginning in the middle of the cycle, through the dumping and charging, and to the middle of the next batch.

The calciner operated normally during the batch testing. Condensation in the baghouse during the batch tests caused the filter bags to become blinded with dust. Immediately following the testing, all filter bags required replacement. In addition, leaks were found around three of the cups to which the bags were attached, and the rachet and clamps on two filter bags had become loose enough to allow some inlet gases to pass through the baghouse untreated. Therefore, the batch kettle outlet data collected at the plant do not represent normal fabric filter operation on a batch kettle calciner and have not been tabulated. Method 5 tests on the inlet to the fabric filter were conducted over short intervals (approximately 20 minutes) during the middle of the batch. The inlet test data do not, therefore, represent emissions over the entire batch cycle.

The continuous kettle calciner tests were conducted on the same calciner and control device used for the batch kettle tests. The outlet portion of continuous test Run No. 4 was repeated at the conclusion of the other continuous test runs because of anisokinetic sampling conditions. Therefore, the outlet continuous kettle data do not represent normal fabric filter emission control capabilities and have not been tabulated. During the testing, the continuous kettle calciner operated normally and at full capacity. Tests conducted at the inlet of the continuous kettle calciner fabric filter are representative of normal inlet loadings for this unit. The actual baghouse air-to-cloth ratio during testing was 4.6:1.

During the batch and continuous kettle tests, an undetached steam plume existed at the outlet of the baghouse stack. This plume occasionally caused some difficulty in estimating plume opacity at the point where the steam plume dissipated. All VE observations recorded were 0 percent opacity.

C.1.8.5 Plant H4--EPA Test. Emission tests were conducted at the inlet and outlet of the fabric filter controlling the direct-contact flash calciner at Plant H4. The calciner operated at greater than 95 percent of capacity during the testing and was fired with natural gas. No abnormalities in fabric filter operation were noted in the test report. Visible emission observations were made during the particulate testing. All readings were 0 percent opacity. Three particle size distribution tests were conducted at the inlet and one test was conducted at the outlet of the fabric filter. A shutdown of the calciner at the beginning of Run No. 1 delayed testing for about 2 hours. The outlet test of Run No. 1 was subsequently voided and replaced by a later test. No other process operating problems occurred during the test series.

C.1.8.6 Plant H5--Industry Test. Figure C-11 is a schematic of the system tested. The direct-contact flash calciner at Plant H5 is ontrolled by a fabric filter. Particulate emission tests were conducted t the fabric filter outlet. The calciner operated at full design pacity during the testing, and no equipment operating problems were served. The calciner was fired with residual fuel oil. The air-to-oth ratio for the fabric filter was 3.2:1. Because the isokinetic pling ratio was out of specification, Run No. 1 was repeated. Data m the first Run No. 1 are not recorded in the test report. Visible ssion measurements were made concurrently with the particulate testing. 6-minute average opacities ranged from 0 to 0.6 percent.

C.1.9 Industrial Sand

C.1.9.1 Plant I1--EPA Tests. Figures C-12 and C-13 are schematics of the systems tested. Particulate emission tests were conducted at the inlets and outlets of wet scrubbers controlling emissions from a fluid bed dryer and from a rotary dryer at Plant I1. Particulate tests were also conducted at the exhaust duct of a fugitive emissions control hood for the fluid bed dryer finished product conveyor belt. The hood represents a source of particulate matter being discharged to the scrubber inlet and, hence, required testing to evaluate scrubber performance. Particle size distribution testing was performed at the fluid bed dryer hood exhaust outlet and at the rotary dryer scrubber outlet. Particle size distributions at the fluid bed dryer scrubber outlet could not be obtained because of entrained water droplets present in the stack gas.

The direct-fired fluid bed dryer operated at 97 percent of design capacity and was fired by propane gas. Pressure drop for the fluid bed dryer's wet scrubber averaged 0.7 kPa (3.0 in. w.c.), and the water flow rate ranged from 806 to 1,003 ℓpm (213 to 165 gpm) during the tests. The rotary dryer operated at 100 percent of capacity during the tests and was fired by propane gas. The pressure drop across the rotary dryer's cyclonic scrubber averaged 0.7 kPa (3.0 in. w.c.) during the tests. The water flow rate averaged 58.7 ℓpm (15.5 gpm).

Visible emission observations were made at both wet scrubber exhaust stacks. Fugitive emission observations were made at the fluid bed dryer process inlet and outlet and at the rotary dryer process inlet. Six-minute average opacity measurements at the rotary dryer scrubber outlet ranged from 0 to 0.6 percent. The 6-minute average opacities for the fluid bed dryer stack ranged from 0 to 1.5 percent. Fugitive emission observations at the rotary dryer process inlet resulted in 6-minute average opacities of 0.2 to 4.2 percent. All fugitive emission observations at the fluid bed dryer process inlet and outlet were zero percent opacity. All process conditions were normal during test activities, and no operating problems occurred.

C.1.9.2 Plant I2--Industry Test. Figure C-14 is a schematic of the system tested. Particulate emission tests were conducted at the outlet of an impinjet wet scrubber controlling emissions from a fluid bed dryer at Plant I2. The dryer operated at 91 percent of capacity during the tests and was fired by propane gas. The scrubber operated with a water flow rate of approximately 5.68 ℓ/min (150 gpm). The pressure drop for the scrubber measured 0.8 kPa (3 in.w.c.). No operating or process difficulties were indicated in the test report.

C.1.9.3 Plant I3--Industry Test. Particulate emission tests were conducted at the outlet of a venturi scrubber controlling emissions from a fluid bed dryer at Plant I3. The dryer operated at maximum capacity during the tests and was fired by No. 2 fuel oil. Actual operating parameters for the scrubber were not reported. Design parameters of the wet scrubber include a gas flow rate of 9.12 m^3/s (19,300 acfm), liquid flow rate of 341 ℓ/min (90 gpm), and a gas pressure drop across the throat of 4.38 kPa (1.75 in. w.c.). No operating or process upsets were noted in the test report.

C.1.9.4 Plant I4--Industry Test. Figure C-15 is a schematic of the plant tested. Particulate emissions were conducted at the outlet of a wet scrubber controlling emissions from a fluid bed dryer/cooler unit at Plant I4. The scrubber was preceded by twin cyclones. The dryer operated at 103 percent of design capacity during the tests and was fired by natural gas. A summary of visible emission observations in the test report indicated that the 6-minute average opacity ranged from 5 to 10 percent. No equipment operating problems were noted.

C.1.10 Kaolin

C.1.10.1 Plant J1--EPA Tests. Figures C-16 and C-17 are schematics f the systems tested. The inlet and outlet of the venturi scrubber ntrolling a multiple hearth furnace and the inlet and outlet to the bric filter controlling a flash calciner were tested at Plant J1. rticle size distribution samples were collected at all test sites cept the outlet of the scrubber. Particle size determinations were possible at this location because of the large quantity of water plets in the exhaust gases. Visible emission observations were made the exhaust stacks of the scrubber and fabric filter, and fugitive sion observations were made at the product discharge point of the h calciner. The product feed and discharge points of the multiple hearth furnace were totally enclosed; therefore, process fugitive emissions were not monitored at these locations.

The multiple hearth furnace and flash calciner operated at 115 percent and 82 percent of design capacity, respectively, during the tests and were fired by natural gas. All process conditions were normal during the testing except that the multiple hearth furnace was shut down for a period of 8 minutes during Run No. 2 due to problems with the product screw conveyor. Testing was discontinued for this period.

Excessive visible emissions were noted from the exhaust stack of the fabric filter during Run No. 1 for the flash calciner. Two bags were found to be loose. This problem was corrected for Run Nos. 2 and 3. Six-minute average opacities for Run No. 1 were 0 to 0.6 percent. The opacity during all other runs was 0 percent.

Visible emission observations for the multiple hearth furnace scrubber were all 0 percent. Process fugitive emission observations of the flash calciner inlet resulted in 6-minute average opacities of 0.8 to 8.9 percent.

C.1.10.2 Plant J2--Industry Tests. Figures C-18 and C-19 are schematics of the two systems tested. Particulate emission tests were conducted at the outlet of a shaker-type fabric filter controlling emissions from a spray dryer and at the outlet of a wet scrubber controlling emissions from a multiple hearth furnace at Plant J2. The spray dryer operated at 81 percent of capacity, and the multiple hearth furnace operated at 110 percent of capacity during the tests. Each unit was fired by natural gas.

Actual operating parameters for the two control devices were not reported. Design parameters for the fabric filter include gas flow rate of 1,699 m^3/min (60,000 acfm), pressure drop of 0.25 kPa (1 in. w.c.), total cloth area of 2,997 m^2 (32,256 ft^2), and air-to-cloth ratio of 2.7:1. Design parameters for the wet scrubber include gas flow rate of 5.71 m^3/s (12,100 acfm), pressure drop across the entire system of 4.5 to 5.3 kPa (18 to 21 in. w.c.), and liquid flow rate of 511 ℓ/min (135 gpm). No process upsets were noted in the test report.

C.1.10.3 Plant J3--Industry Test. Figure C-18 is a schematic of the system tested. Particulate emission tests were conducted at the outlet of the fabric filter controlling emissions from a spray dryer. The dryer operated at 83 percent of design capacity during the tests. The design air-to-cloth ratio for the fabric filter is 3.8:1, and the design pressure drop across the unit is 1.5 kPa (6 in. w.c.). The report noted that isokinetic sampling ratios were 100 percent ±10 percent. Individual isokinetic ratios were not reported for each run. No process upsets were noted in the report.

C.1.10.4 Plant J4--Industry Test. Figure C-18 is a schematic of the system tested. Particulate emission tests were conducted on a shaker-type fabric filter controlling emissions from a spray dryer. The dryer operated at 104 percent of maximum capacity during the tests and was fired by natural gas. Actual baghouse operating parameters were not reported. Design parameters for the fabric filter include an inlet gas flow rate of 39.18 m^3/s (83,000 acfm), a total cloth area of 4,459 m^2 (48,000 ft^2), and an air-to-cloth ratio of 1.7:1. No process upsets were noted in the test report.

C.1.11 Lightweight Aggregate

C.1.11.1 Plant K1--EPA Test. Figure C-20 is a schematic of the system tested. Particulate emission tests were conducted on the inlet and outlet of a medium-energy wet scrubber controlling emissions from a rotary calciner at Plant K1. Other tests included sulfur dioxide, nitrogen oxide, and hydrocarbon emissions (outlet only) and particle size distribution (inlet and outlet). Visible emission observations were made at the scrubber stack, and fugitive emission observations were made at the calciner seals.

The rotary calciner operated at 83 percent of design capacity during the tests and was fired by pulverized coal. No instrumentation was present at the test site to indicate water flow rate to the wet scrubber or the inlet and outlet gas flow rates, temperatures, or pressure drop. The design pressure drop is 1.5 kPa (6 in. w.c.). The 6-minute average opacities at the scrubber stack ranged from 0 to 8.8 percent. All process fugitive emission observations were zero percent opacity. No process upsets were reported.

C.1.11.2 Plant K2--EPA Test. Figure C-20 is a schematic of the system tested. Emission tests were conducted on a rotary calciner at

Plant K2 that was controlled by a wet scrubber. The production rate during the test was kept constant at 83 percent of design capacity. The calciner was fired with pulverized coal. No instrumentation was present at the plant to measure the scrubber pressure drop, inlet and outlet gas flow rates and temperatures, or liquid flow rates.

Particulate and particle size tests were conducted simultaneously at the scrubber inlet and outlet test locations. The first set of particulate tests at the scrubber inlet was voided due to an excessive post-test leak and loss of sample during the recovery phase. These data were not included in the report. The scrubber mist eliminator was not functional during testing; therefore, outlet data are not representative of normal scrubber performance and are not included.

Three particle size distribution samples were collected at the scrubber inlet. Tests for sulfur dioxide were conducted simultaneously at the scrubber inlet and outlet test locations, and tests for nitrogen dioxide and hydrocarbon contents in the scrubber exhaust gas were performed concurrent with the SO_2 tests. Visible emission observations and SO_2 tests performed at the scrubber outlet are not representative due to the faulty mist eliminator. Fugitive emission observations were made at the calciner feed inlet and at the calciner seals. The 6-minute average opacities at the inlet ranged from 6.3 to 10.0 percent. All opacities were 0 percent at the calciner seals. The process operated normally for the duration of the tests.

C.1.11.3 Plant K3--Industry Test. Figure C-21 is a schematic of the systems tested. Particulate emission tests were conducted at the outlets of wet scrubbers controlling emissions from two rotary calciners at Plant K3. The calciners operated at 109 and 100 percent of design capacity, respectively, and were fired by pulverized coal. The pressure drop across each of the scrubbers was 3.5 kPa (14 in. w.c.). During the tests on one calciner, a multiple cyclone collector preceded the wet scrubber for product recovery. The cyclone collector was bypassed during the tests on the other calciner. Measurements of SO_2 concentration were also made at the multiple cyclone collector inlet. No process upsets were reported in the test reports.

C.1.11.4 Plant K4--Industry Test. Figure C-22 is a schematic of the system tested. Particulate emission tests were conducted at the outlet of a wet scrubber (gravity spray chamber) controlling emissions from a rotary calciner. The calciner operated at 92 percent of capacity during the tests and was fired by No. 2 fuel oil. Visible emission observations were made at the scrubber outlet after completion of the third particulate run and have not been tabulated. The design pressure drop for the wet scrubber is 0.5 kPa (2 in. w.c.). The pressure drop during the test was not reported. During the period of testing, the plant and all associated air pollution control equipment were operating normally.

C.1.11.5 Plant K5--Industry Test. Figure C-23 is a schematic of the system tested. Particulate emission tests were conducted at the inlet and outlet of a reverse-air fabric filter controlling emissions from a rotary calciner. The calciner operated at maximum capacity during the tests and was fueled by pulverized coal. Actual operating parameters for the fabric filter were not reported. Design parameters for the fabric filter include a total cloth area of 520 m^2 (5,600 ft^2), a pressure drop of 1.2 to 1.9 kPa (5 to 8 in. w.c.), and an air-to-cloth ratio of 5:1.

During Run No. 2, a malfunction of the coal mill caused a temporary shutdown of the system. Testing was resumed in about 2 minutes. No other process upsets were noted in the test report.

C.1.11.6 Plant K6--EPA Test. Emission tests were conducted on a medium-energy impinjet wet scrubber controlling emissions from a rotary calciner. The rotary calciner operated at 100 percent of design capacity and was fired with pulverized coal. Tests included particulate emissions, sulfur dioxide, nitrogen oxide, and hydrocarbon emissions, and trace etal content.

Some problems occurred during hydrocarbon sampling due to the high oisture content of the scrubber exhaust gas. Subsequently, only 1 hour continuous hydrocarbon monitoring data was obtained. The hydrocarbon ncentrations varied from 140 to 220 ppm with an average concentration 175 ppm as methane. This average concentration corresponds to an ssion rate of 4.2 kg/h (9.3 lb/h).

Visible emission observations were made at the scrubber exhaust stack, and fugitive emission observations were made at the calciner seals. The 6-minute average opacity measurements at the scrubber outlet ranged from 0 to 15 percent. All fugitive emission observations were 0 percent opacity.

No instrumentation was present at the test site to indicate the water flow rate, the inlet and outlet gas flow rates, or pressure drop for the wet scrubber. The design pressure drop across the wet scrubber is 2.5 kPa (10 in. w.c.). Process operations were normal.

C.1.12 Magnesium Compounds

C.1.12.1 Plant L1--Industry Test. Figure C-24 is a schematic of the system tested. Particulate emission tests were conducted at the outlet of a reverse-air fabric filter controlling emissions from a multiple hearth furnace. The furnace operated at 85 percent of capacity (based on process feed rates) during the test and was fired by No. 6 fuel oil. The report notes that opacity was observed by State testing personnel and that all opacity readings were 0 percent. The air-to-cloth ratio of the fabric filter during the tests was 1.4:1. Process operations were normal.

C.1.12.2 Plant L2--Industry Test. Figure C-25 is a schematic of the system tested. Particulate emission tests were conducted at the outlet of two ESP's in series controlling emissions from a rotary calciner. The calciner operated at 92 percent of capacity during the tests and was fired by natural gas. The combined specific collection area of the two ESP's was 1.8 m^2 per m^3/min (550 ft^3/1,000 acfm) during the tests. No process upsets were noted in the report.

C.1.12.3 Plant L3--Industry Test. Emission tests were conducted at the outlet of the wet scrubber controlling emissions from a rotary calciner. The scrubber was preceded by a product recovery cyclone. During the tests, pressure drop across the scrubber was 2.5 kPa (10 in. w.c.). The calciner operated at 95 percent of capacity during the tests and was fired by No. 6 fuel oil. No process upsets were noted in the test report.

C.1.12.4 Plant L4--Industry Test. Particulate emission tests were conducted at the outlet of an ESP controlling emissions from a rotary calciner. Based on process feed rates, the calciner operated at maximum capacity during the tests and was fired by natural gas. The specific collection area of the ESP was 4.8 m^2 per m^3/min (1,458 ft^2/1,000 acfm) during the tests. No process upsets were noted in the test report.

C.1.13 Perlite

C.1.13.1 Plant M1--EPA Test. Figure C-26 is a schematic of the system tested. Emission tests were conducted on the identical East and West stacks of a fabric filter controlling emissions from a perlite expansion furnace at Plant M1. The fabric filter was preceded by a product collection cyclone. Visible emission observations were made at the two outlet stacks simultaneously with the particulate tests. Visible emission measurements of process fugitive emissions were made at the expansion furnace feed inlet. No VE measurements were taken at the product outlet because the system is totally enclosed with no visible leaks. One particle size distribution test (at the fabric filter West stack) was conducted, and trace metal analyses were performed on the Method 5 particulate catches from the two stacks. The expansion furnace operated at 93 percent of design capacity during the test series, and natural gas was used to fire the furnace. All processes operated normally during the emission testing.

Two of the four fabric filter fans malfunctioned on three separate occasions during the test series. Since testing was discontinued, none f the malfunctions affected any of the Method 5 test runs. As a result f the malfunctions, Run No. 3 (Method 5) was performed at night, and VE eadings could not be taken. Also, only one 2-hour particle size run s completed because of the fan malfunctions.

The 6-minute average opacity measurements made at the baghouse acks ranged from 0 to 20 percent. Fugitive emissions were observed at e furnace feed inlet using Method 22 instead of Method 9. The per- ntage of time with visible emissions at this location ranged from 0 to percent.

C.1.13.2 Plant M2--Industry Test. Figure C-27 is a schematic of system tested. Particulate emission tests were conducted at the et of the fabric filter controlling emissions from two rotary dryers. dryers operated at 139 percent of capacity (combined production) and were fired by diesel fuel. The fabric filter was preceded by dual cyclones (one on each dryer for product recovery). Visible emission observations were made by State personnel at the fabric filter outlet. Average opacities ranged from 0 to 15 percent. Actual fabric filter operating parameters were not reported. Design parameters of the fabric filter include a gas flow rate of 1,274 m^3/min (45,000 acfm), a total cloth area of 637 m^2 (22,500 ft^2), and air-to-cloth ratio of 2.0:1 during normal cycles. The design pressure drop is 0.7 kPa (3 in. w.c.). No process upsets were noted in the test report.

C.1.13.3 Plant M3--Industry Test. Particulate emission tests were conducted at the outlet of a reverse-air fabric filter controlling emissions from an expansion furnace. The furnace operated at maximum capacity during the tests and was fired by natural gas. No process upsets were noted in the test report. The baghouse air-to-cloth ratio was not reported.

C.1.14 Roofing Granules

C.1.14.1 Plant N1--Industry Test. Particulate emission tests were conducted at the outlet of a wet scrubber controlling emissions from a rotary dryer. The dryer operated at maximum capacity during the tests and was fired by No. 2 fuel oil. The pressure drop for the scrubber was 1.1 kPa (4.5 in. w.c.) during the tests. No process upsets were noted in the report.

C.1.15 Titanium Dioxide

C.1.15.1 Plant P1--EPA Tests. Figures C-28 and C-29 are schematics of the systems tested. Tests were conducted on two fabric filters and a wet scrubber controlling emissions from spray dryer Nos. 1 and 2 at Plant P1 during production of titanium dioxide (TiO_2) by the chloride process. Tests were also conducted at the outlets of two I.D. fans that precede control equipment (conditioning towers, two wet ESP's, and a wet scrubber) for a rotary calciner during production of TiO_2 by the sulfate process. The spray dryers operated at 80 percent of design capacity during the tests. The actual air-to-cloth ratio for the spray dryer No. 1 baghouse was 3.5:1. The rotary calciner operated at 90 percent of capacity during all tests. The dryers and the calciner were fired with natural gas. Tests included particulate emissions, particle size distributions, visible and fugitive emissions, sulfur dioxide and nitrogen oxide emissions, and trace metal content. The actual SCA for the calciner ESP's was 0.75 m^2 per m^3/min (228 ft^2/1,000 acfm). The actual pressure drop for the wet scrubber is given in the Confidential Addendum.

During dryer Run No. 2, the feed mechanisms of spray dryer No. 1 automatically shut down for no apparent reason, and testing was discontinued. Plant personnel restarted the unit, and within 1 hour the process achieved a steady state. Testing was then resumed. No particle size testing was conducted during Run No. 4.

During tests of the rotary calciner, the East conditioning tower was partially plugged, causing an uneven distribution in the volume of exhaust gas coming from the rotary calciner to each of the two conditioning towers. The product quality, uncontrolled emission level, and overall control process were not affected by this uneven distribution.

During calciner Run Nos. 2 and 3, the West conditioning tower flow meter was not functioning properly. Between Run Nos. 2 and 3, the natural gas to the rotary calciner was shut off for approximately 10 minutes because several bricks from the calciner lining plugged the discharge end of the calciner. The problem was immediately corrected, and Run No. 3 was started when the kiln achieved normal operation.

Because of the presence of water droplets in the flue gas, particle sizing was not performed in the spray dryers wet scrubber stack, the calciner exhaust stack, and the outlets from the East and West ESP's.

Six-minute average opacities measured at the spray dryer's wet scrubber outlet ranged from 1.5 to 19 percent. Visible emission observations were not made during Run No. 12 because of cloudy conditions. Average opacity was 0 percent at the outlet of the rotary calciner wet scrubber.

C.1.15.2 <u>Plant P1--Industry Test</u>. Figure C-30 is a schematic of he system tested. Particulate and SO_2 emission tests were conducted at he outlet of the ESP controlling emissions from a rotary calciner oducing TiO_2 by the sulfate process. The calciner operated at percent of design capacity and was fired by natural gas. The ESP was preceded by a conditioning tower and was followed by a wet scrubber. No process upsets are noted in the report.

C.1.15.3 Plant P2--EPA Test. Particulate emission tests were conducted at the outlet of the fabric filter controlling emissions from a spray dryer at Plant P2. Four particle size distribution tests were conducted at the fabric filter outlet. However, the results of the first run were not reported because the impactor stages were loaded incorrectly with the filter media. Visible emission observations were made at the fabric filter exhaust stack. The 6-minute average opacities ranged from 0 to 0.8 percent. A trace metals analysis was also performed on the Method 5 particulate catch. No process upsets were noted. All information regarding process operation during testing is presented in the Confidential Addendum to this document.

C.1.15.4 Plant P3--Industry Test. Particulate emission tests were conducted at the outlet of a wet scrubber controlling emissions from a flash dryer. The dryer operated at 93 percent of capacity during the tests and was fired by natural gas. There were no process upsets noted in the test report. Actual operating parameters for the wet scrubber are given in the Confidential Addendum to this document.

C.1.16 Vermiculite

C.1.16.1 Plant Q1--Industry Test. Figure C-31 is a schematic of the system tested. Particulate emission tests were conducted on the outlet of a wet scrubber controlling emissions from a rotary dryer. The dryer operated at 86 percent of capacity during the tests and was fired by No. 4 fuel oil. Inclement weather prevented measurement of VE's during the test series. Actual operating parameters for the wet scrubber were not reported. The design pressure drop for the wet scrubber is 1.2 kPa (5 in. w.c.). No process upsets were noted in the test report.

C.2 SUMMARY OF TEST DATA

The EPA-conducted and EPA-approved test data are summarized in this section. Metric/English conversions and test series averages may not convert exactly due to independent rounding of data. Test data collected at each plant are presented in the following tables and figures:

Plant A1: Tables C-1 to C-2

Plant A2: Tables C-3 to C-5
Plant B1: Table C-6
Plant C1: Tables C-7 to C-11, and Figure C-31
Plant C3: Table C-12
Plant D1: Table C-13
Plant E1: Table C-14
Plant E2: Table C-15
Plant E3: Table C-16
Plant F1: Tables C-17 to C-29, and Figures C-32 to C-35
Plant F2: Tables C-30 to C-31, and Figure C-36
Plant F3: Tables C-32 to C-39, and Figures C-37 to C-39
Plant G1: Table C-40
Plant H1: Tables C-41 to C-47, and Figure C-40
Plant H2: Tables C-48 to C-51, and Figures C-41 to C-42
Plant H3: Tables C-52 to C-53, and Figures C-43 to C-44
Plant H4: Tables C-54 to C-55, and Figures C-45 to C-46
Plant H5: Tables C-56 and C-57
Plant I1: Tables C-58 to C-65, and Figures C-47 to C-50
Plant I2: Table C-66
Plant I3: Table C-67
Plant I4: Table C-68
Plant J1: Tables C-69 to C-74, and Figures C-51 to C-53
Plant J2: Tables C-75 to C-76
Plant J3: Table C-77
Plant J4: Table C-78
Plant K1: Tables C-79 to C-86, and Figures C-54 to C-56
Plant K2: Tables C-87 to C-91, and Figure C-57
Plant K3: Tables C-92 to C-94
Plant K4: Table C-95
Plant K5: Tables C-96 to C-97
Plant K6: Tables C-98 to C-103, and Figure C-58
Plant L1: Table C-104
Plant L2: Table C-105
Plant L3: Table C-106
Plant L4: Table C-107
Plant M1: Tables C-108 to C-115, and Figure C-59
Plant M2: Tables C-116 to C-119
Plant M3: Table C-120
Plant N1: Table C-121
Plant P1: Tables C-122 to C-137, and Figures C-60 to C-63
Plant P2: Tables C-138 to C-142
Plant P3: Table C-143
Plant Q1: Table C-144

.3 TEST DATA NOT USED IN DATA BASE

Emission data from five EPA-conducted source tests were not used in he data base. The reasons for the exclusion of these data are explained low.

Data from emission tests at gypsum Plants H2 and H6 were excluded because the process unit operating capacity was below the acceptable level (at least 80 percent) selected as representative of normal operating conditions.

Data from the scrubber outlet at lightweight aggregate Plant K2 were excluded because the scrubber mist eliminator did not function properly during testing. Therefore, the outlet data are not representative of normal scrubber performance.

Data from emission tests at lightweight aggregate Plant K7 were not used because the scrubber water pump malfunctioned during testing. Therefore, the test data are not representative of normal scrubber operation.

Data from the baghouse outlet on the No. 2 spray dryer at titanium dioxide Plant P1 were excluded because the measured outlet concentration of 4 gr/dscf is not considered representative of a well operated baghouse. Because of the ductwork configuration at this plant, VE's from the baghouse outlet cannot be observed; but due to high outlet concentrations, some bags must have been torn or broken.

C.4 SCRUBBER MODELING

Venturi scrubber performance modeling was performed to predict the operating pressure drop required to achieve the particulate emission levels of RA I, II, and III, for process units for which EPA-approved emission test data on venturi scrubbers are unavailable. Table C-145 summarizes the input variables selected for each unit and the pressure drop required to achieve the emission levels of RA I, II, and III as determined by the computer model.

For some process units, inlet mass loading and/or particle size distribution data were unavailable. In these cases, product particle size sieve analyses and process unit controllabilities (as indicated by outlet data) were compared with units for which inlet data were available, and the input variables were estimated. Table C-146 summarizes the product particle size sieve analysis data.

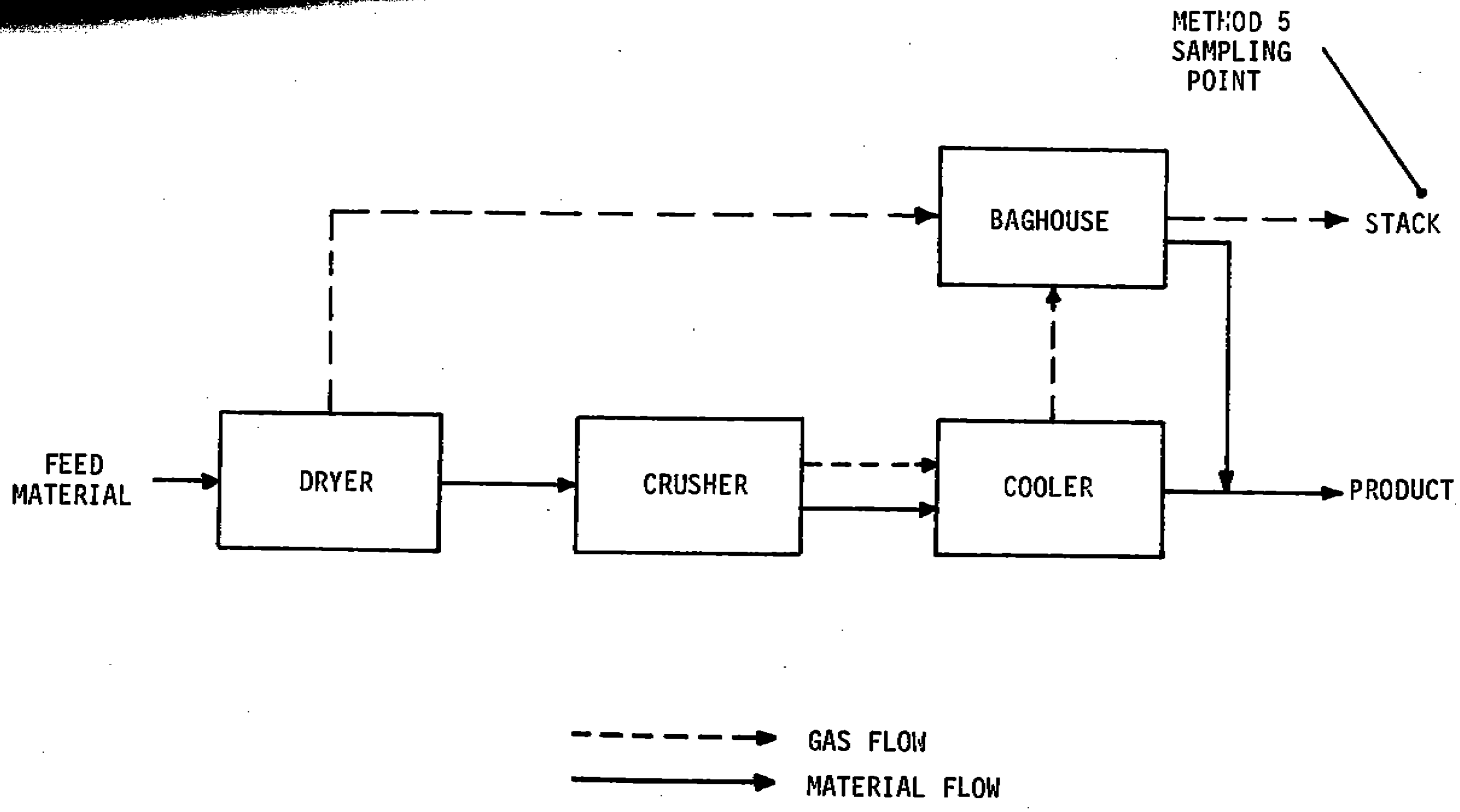


Figure C-1. Process schematic and sampling points--Plant B1.

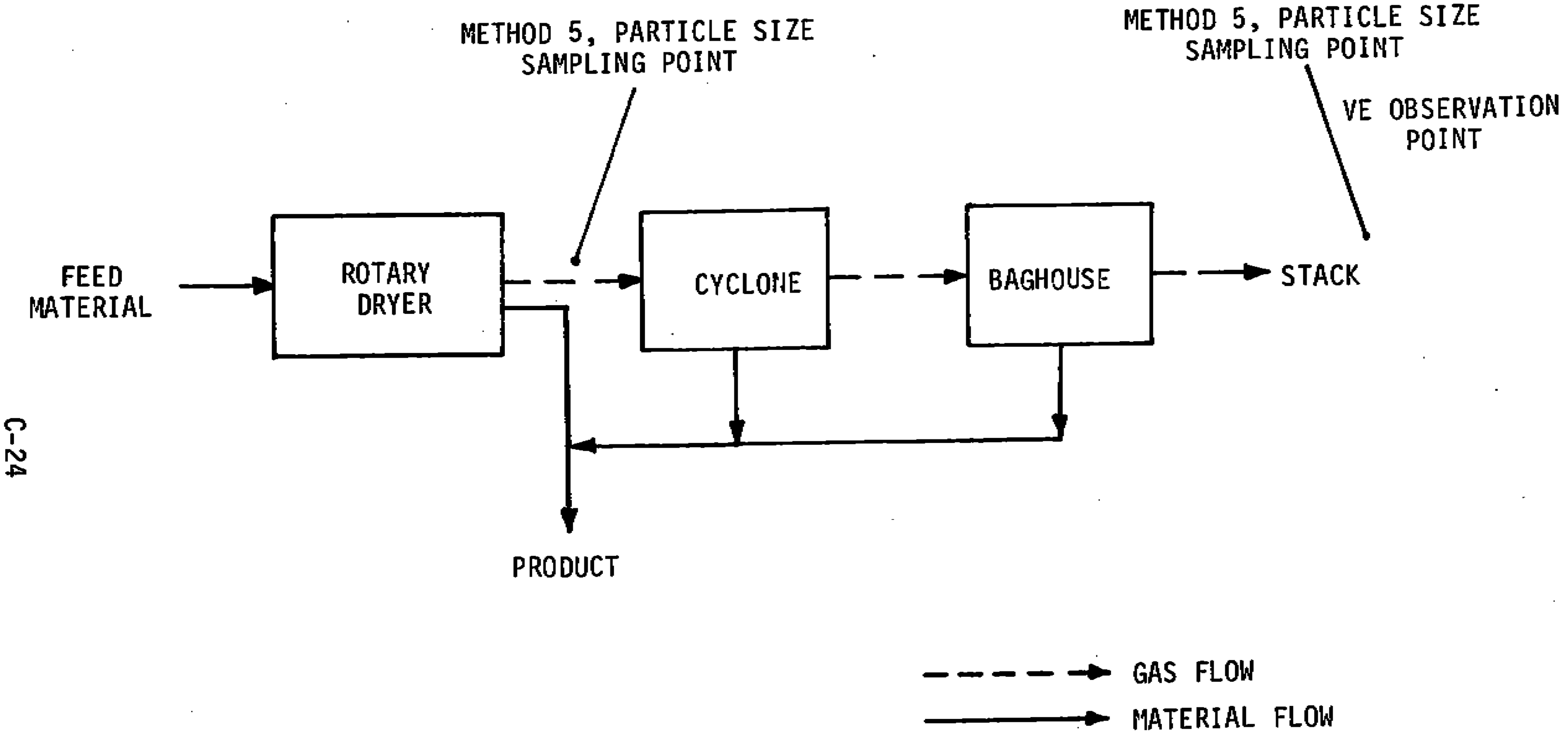


Figure C-2. Process schematic and sampling points--Plant C1.

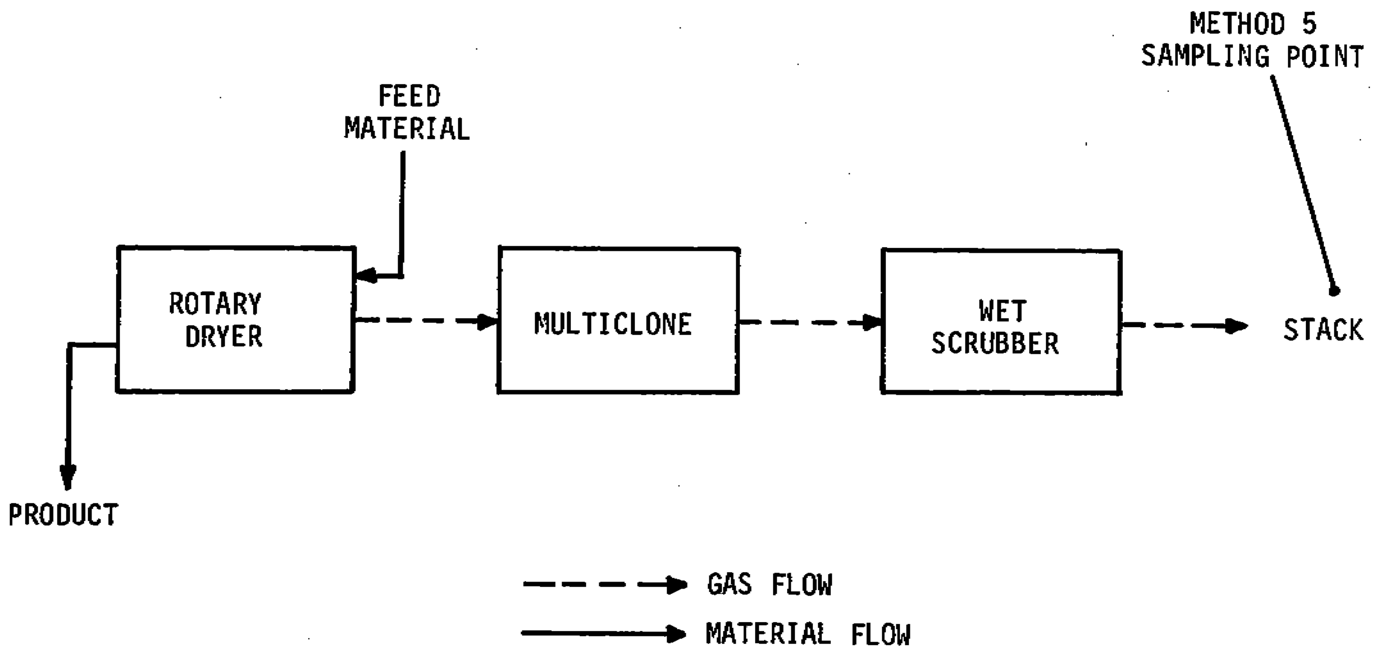


Figure C-3. Process schematic and sampling points--Plant E2.

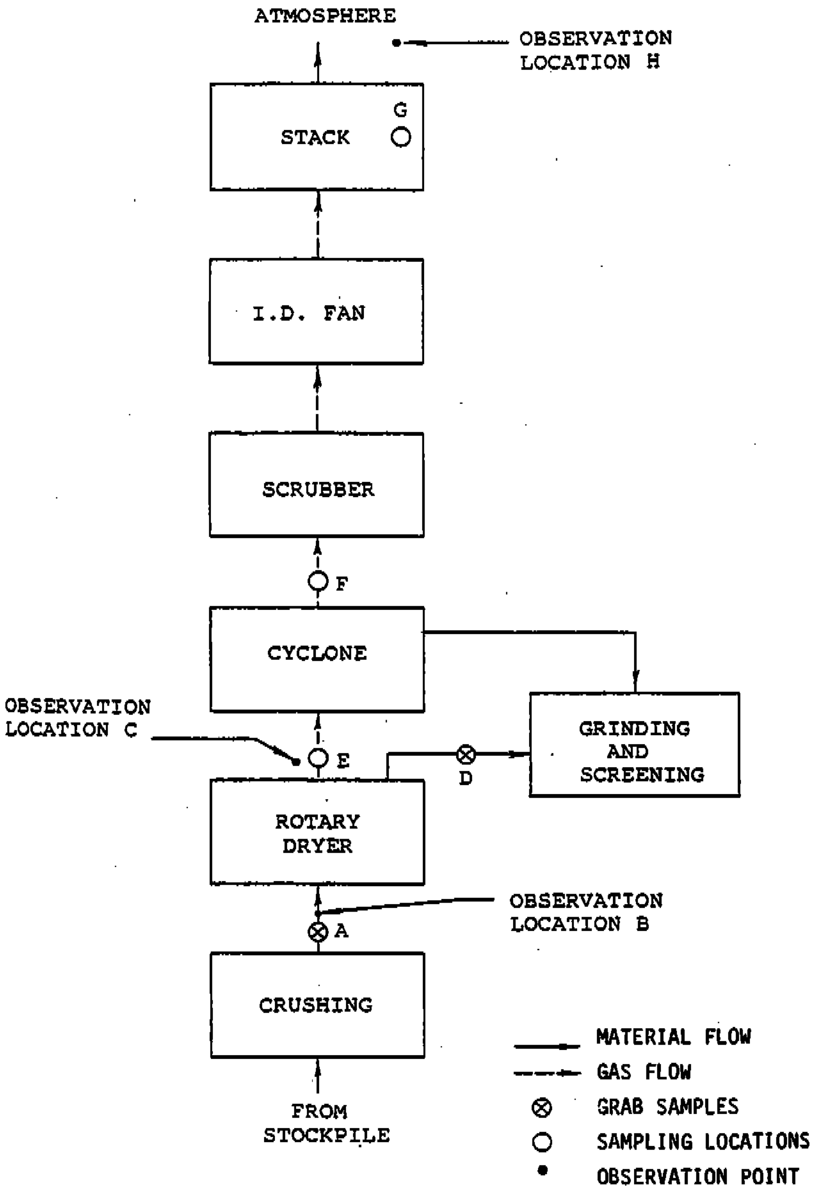


Figure C-4. Process schematic and sampling points--Plant F1.

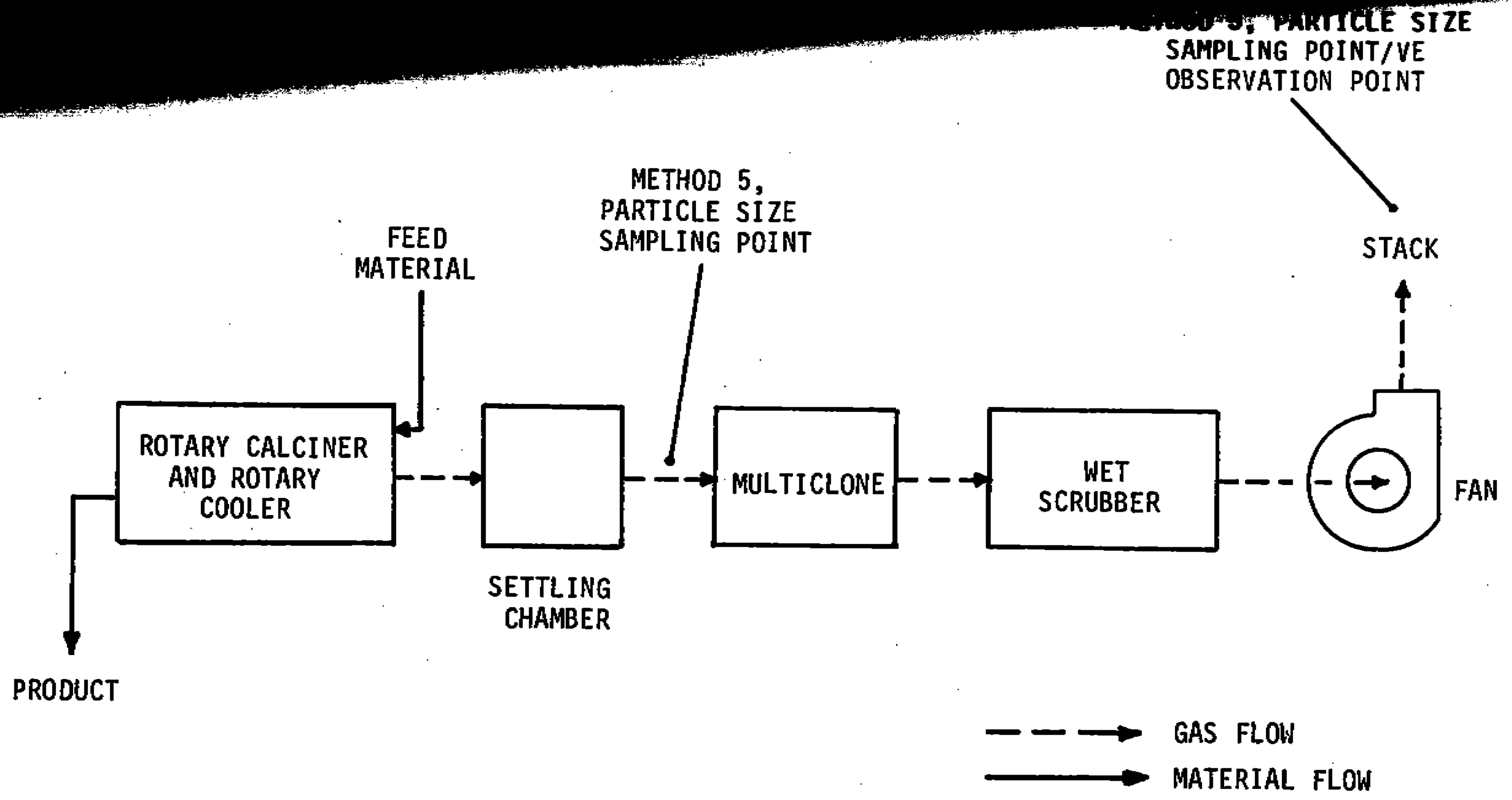


Figure C-5. Process schematic and sampling points--Plant F2.

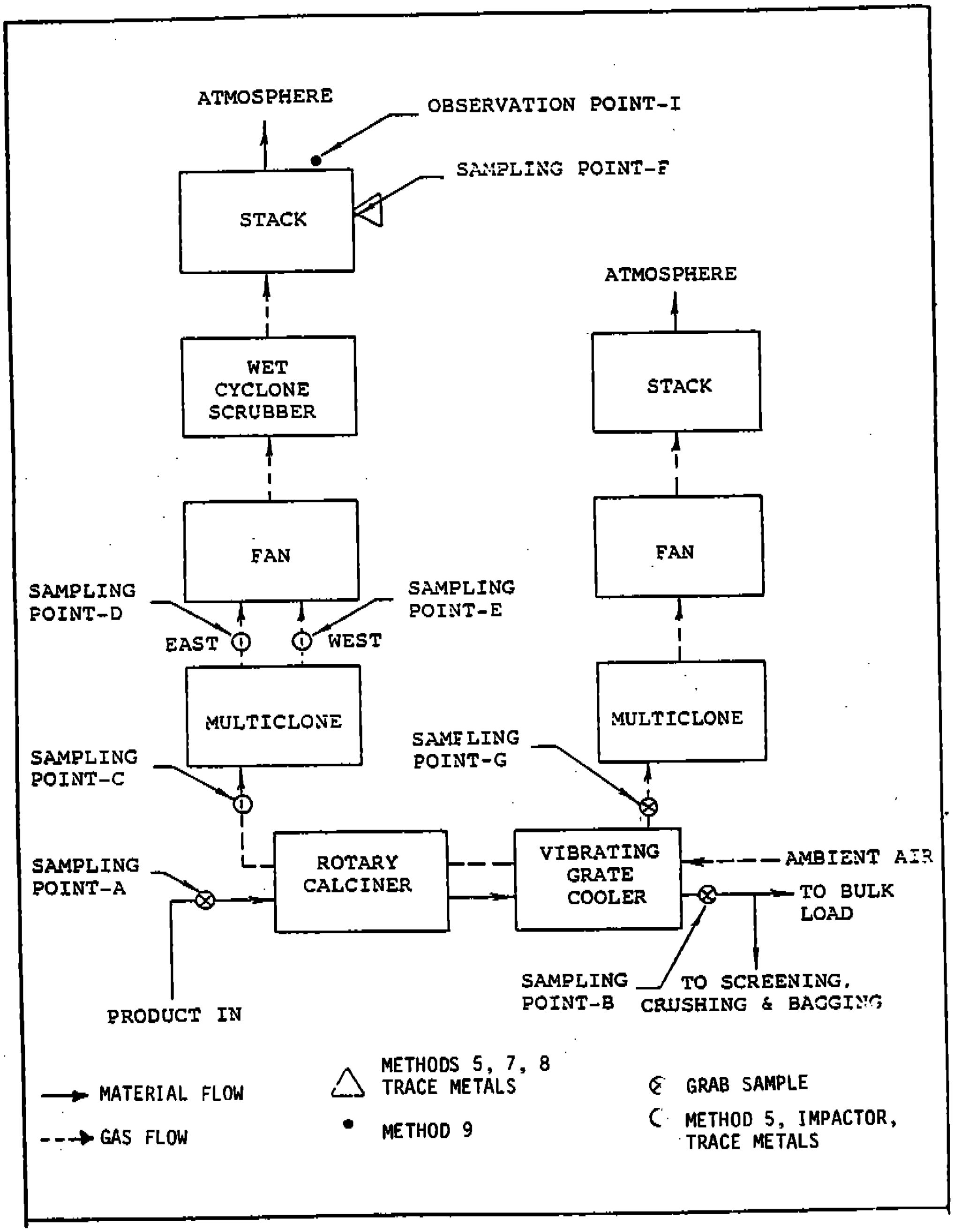


Figure C-6. Process schematic and sampling points--Plant F3.

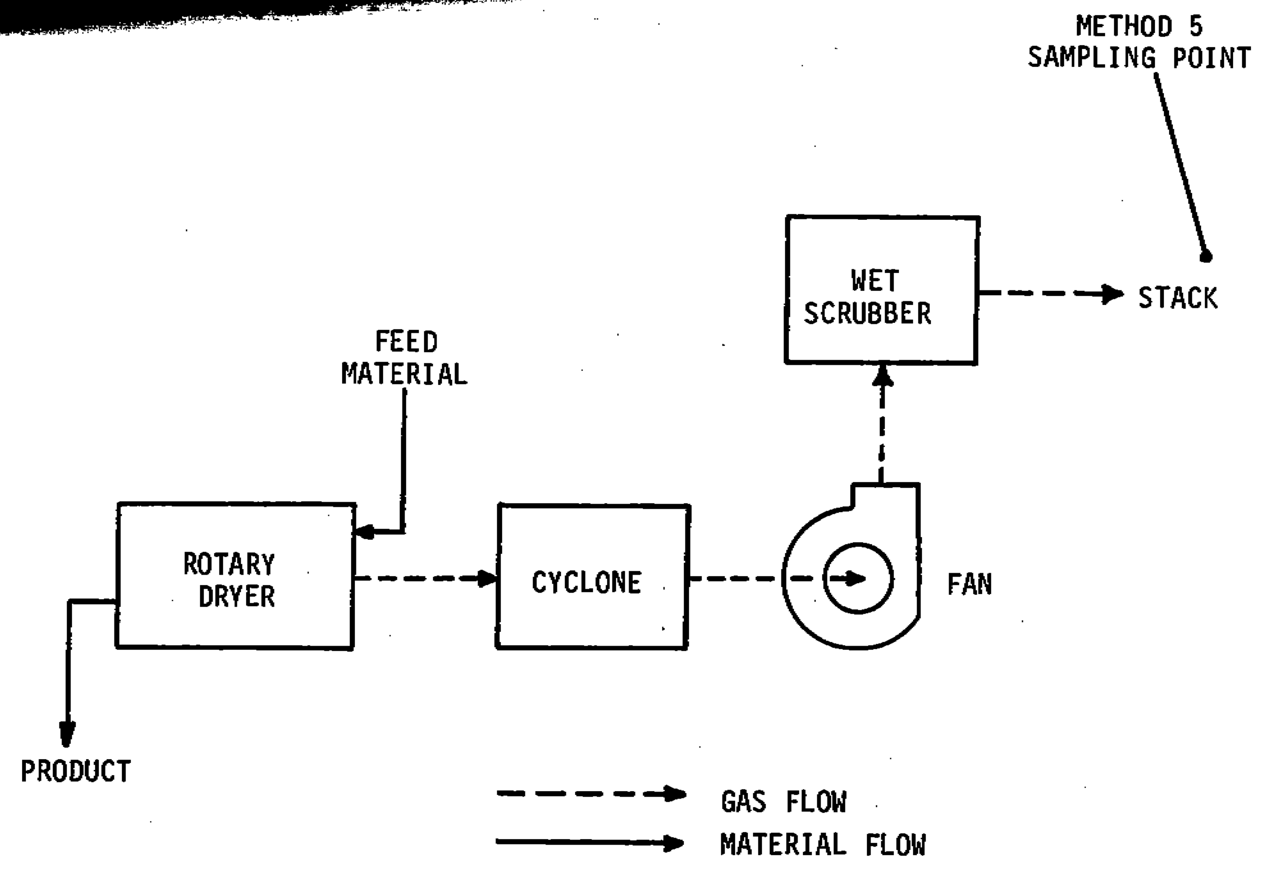


Figure C-7. Process schematic and sampling points--Plant G1.

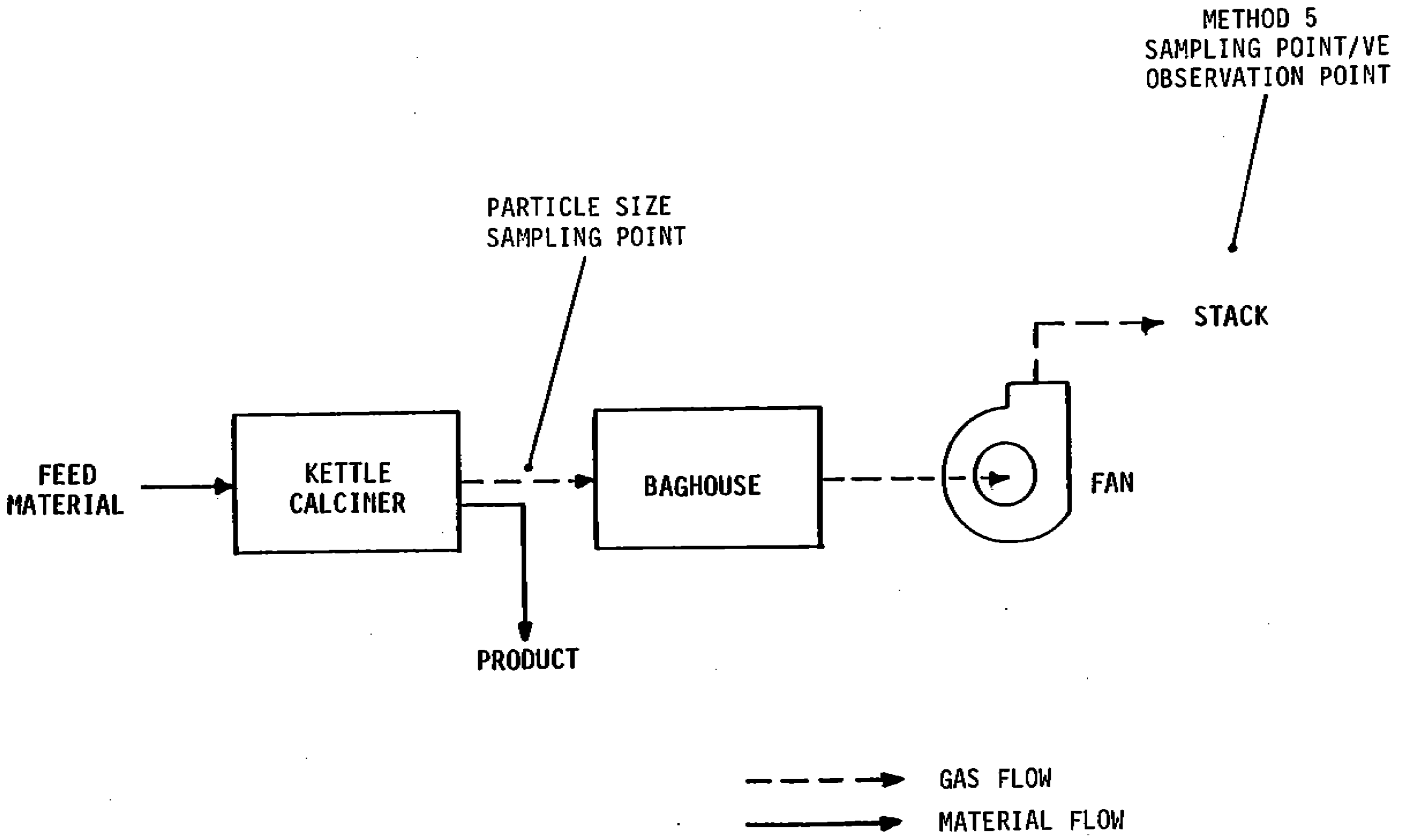


Figure C-8. Process schematic and sampling points--Plant H1.

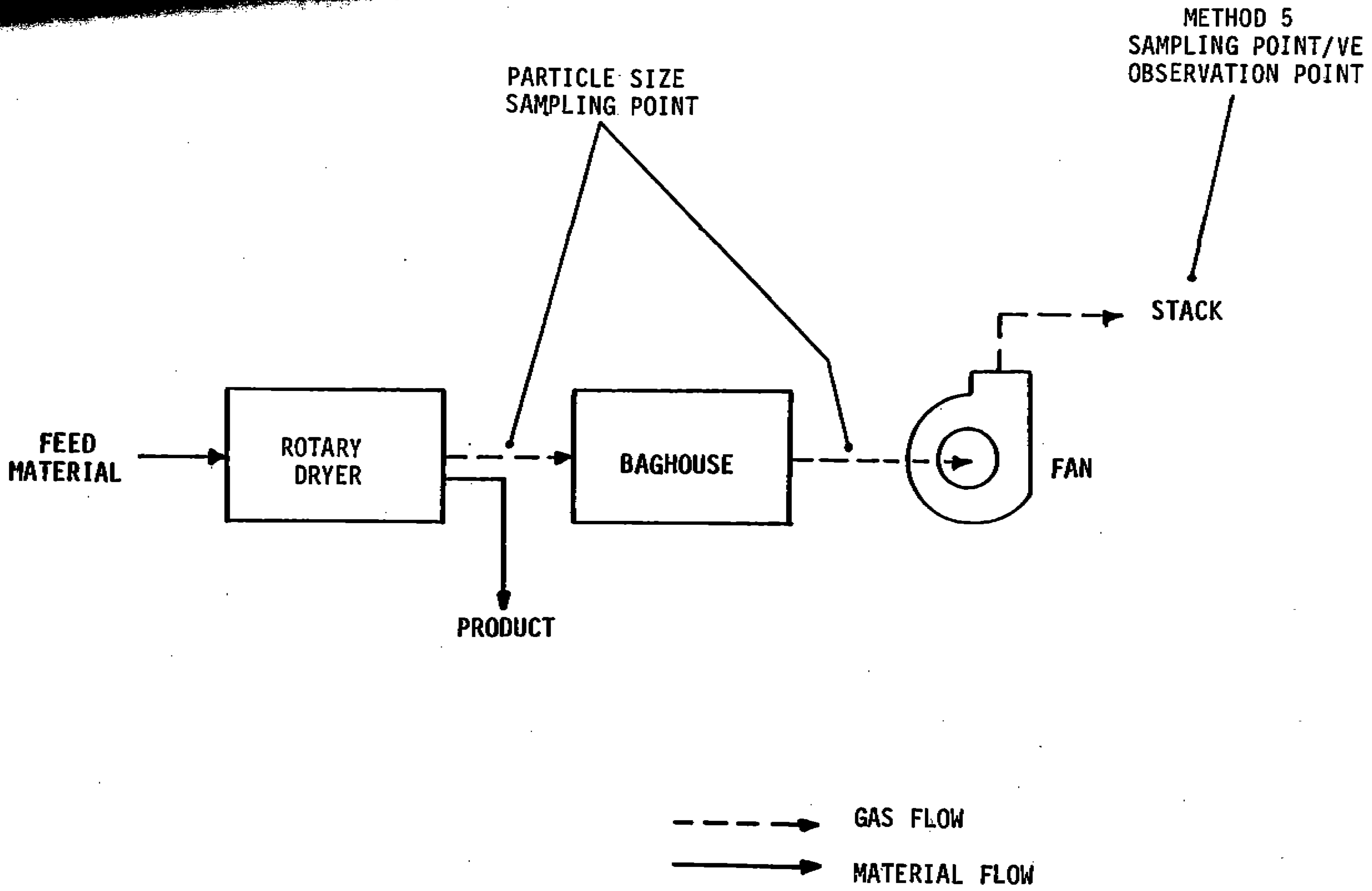


Figure C-9. Process schematic and sampling points--Plant H1.

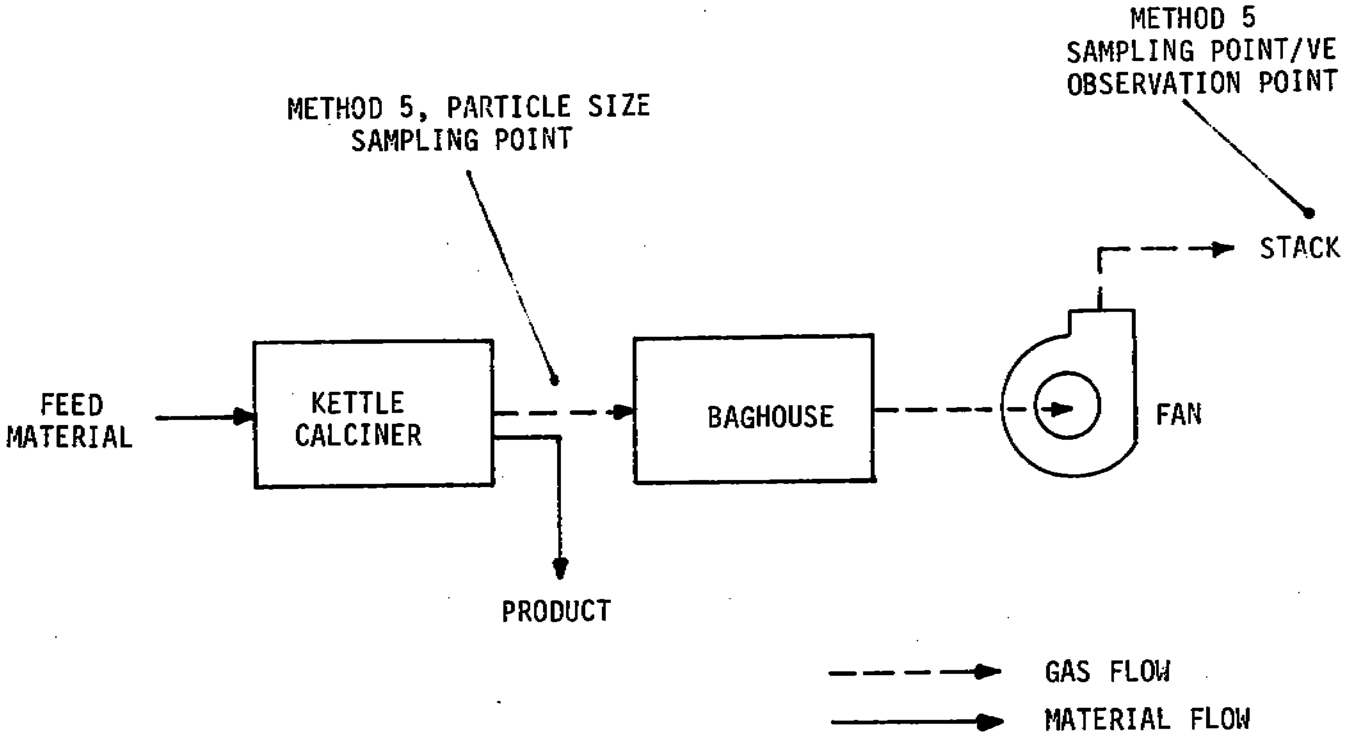


Figure C-10. Process schematic and sampling points--Plant H3.

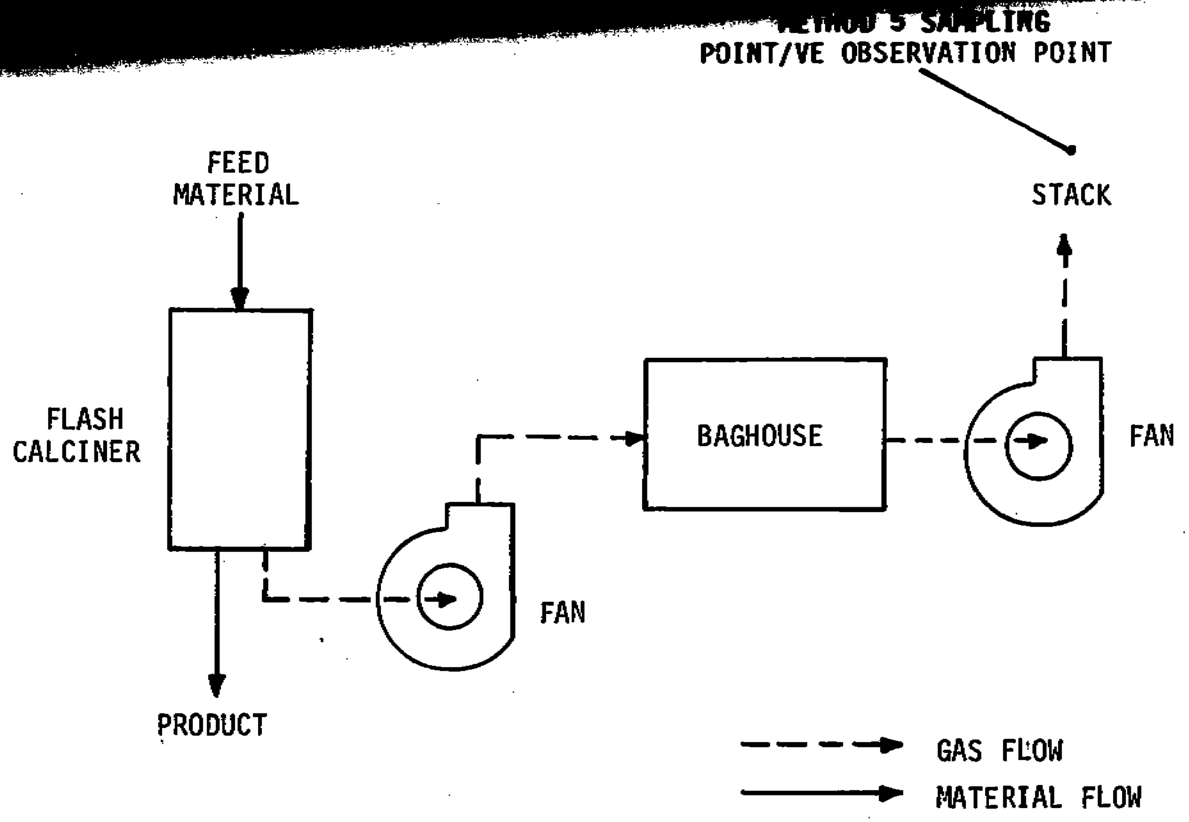


Figure C-11. Process schematic and sampling points--Plant H5.

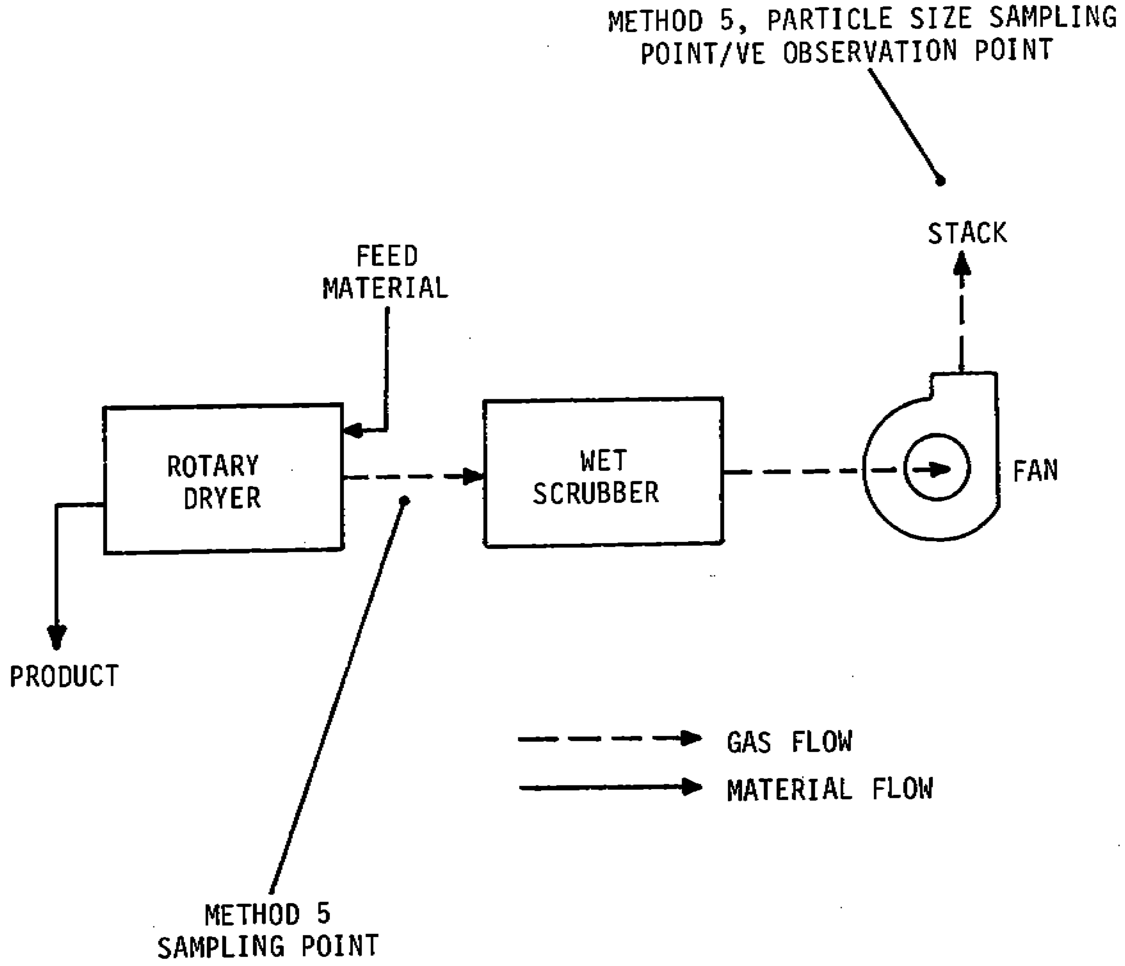


Figure C-12. Process schematic and sampling points--Plant I1.

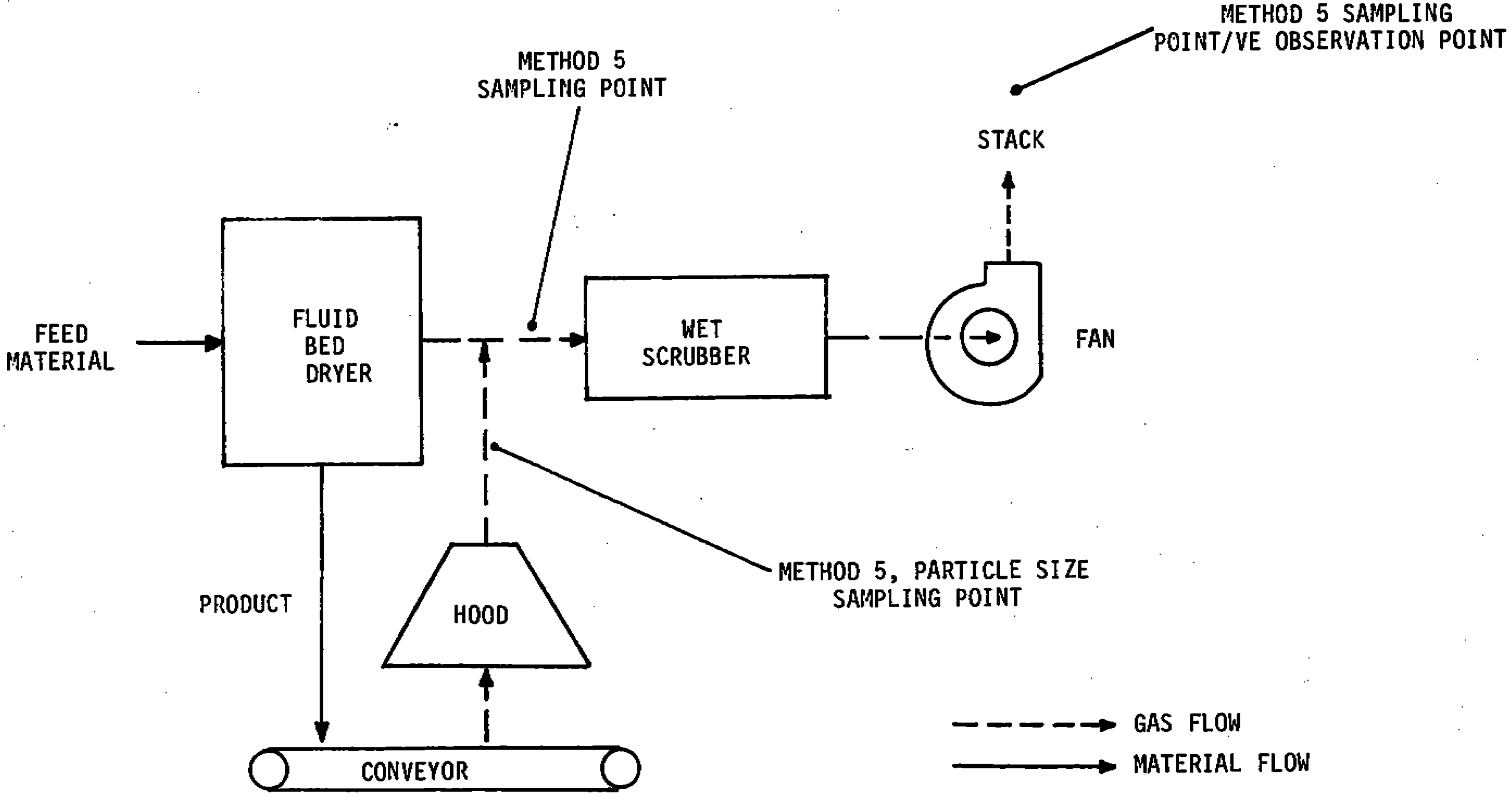


Figure C-13. Process schematic and sampling points--Plant I1.

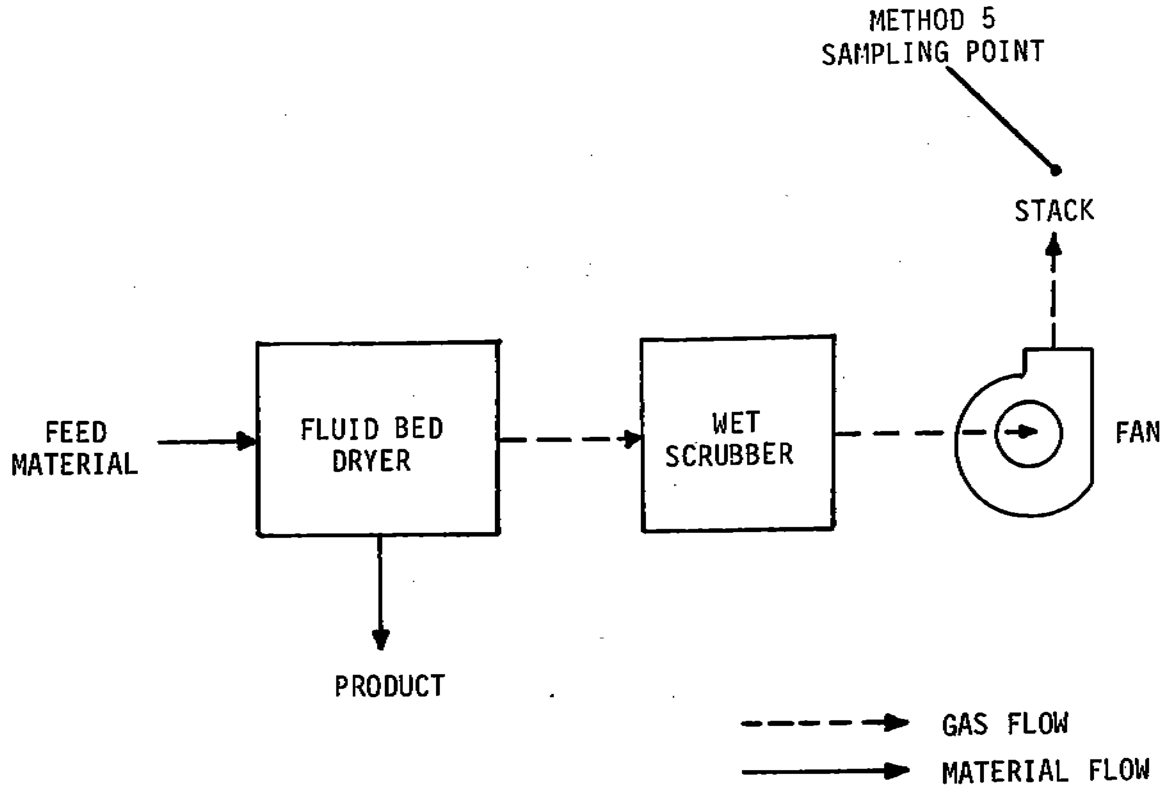


Figure C-14. Process schematic and sampling points--Plant I2.

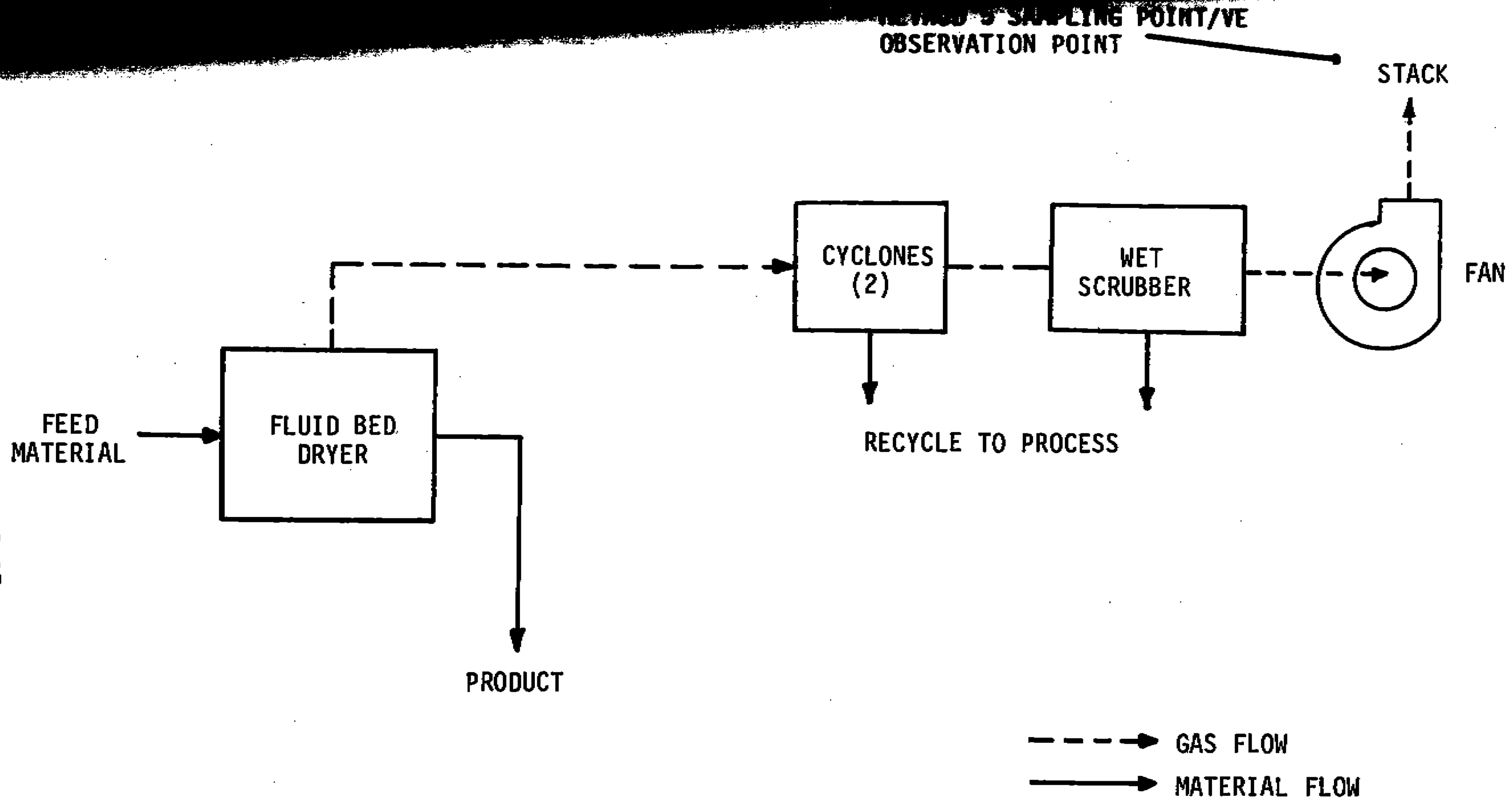


Figure C-15. Process schematic and sampling points--Plant I4.

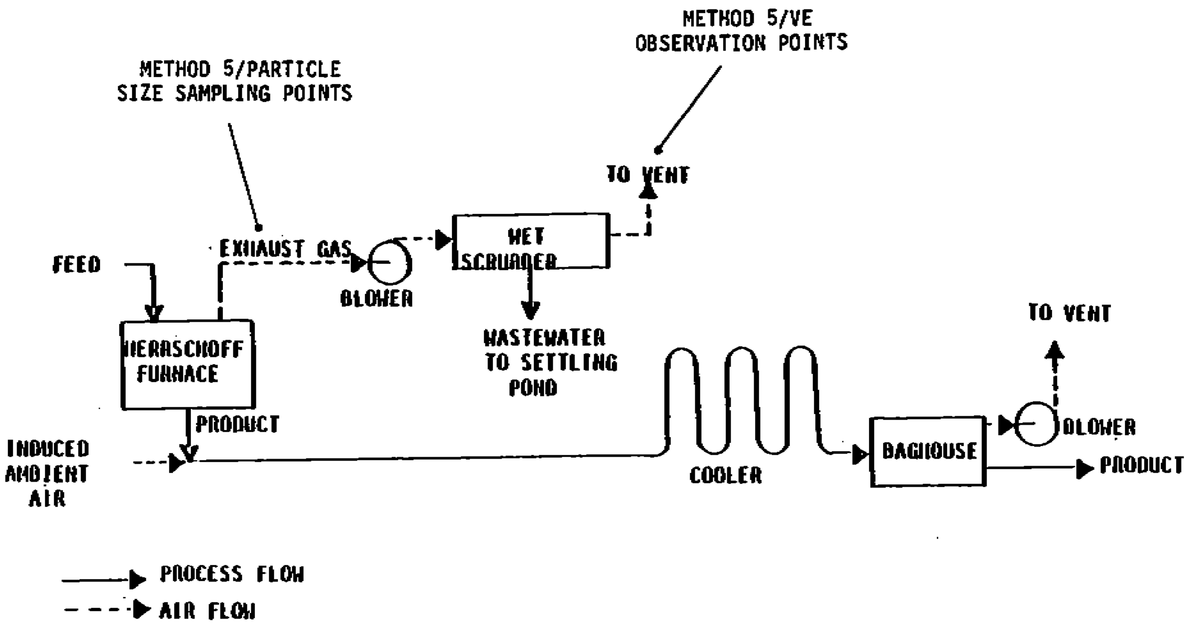


Figure C-16. Process schematic and sampling points--Plant J1.

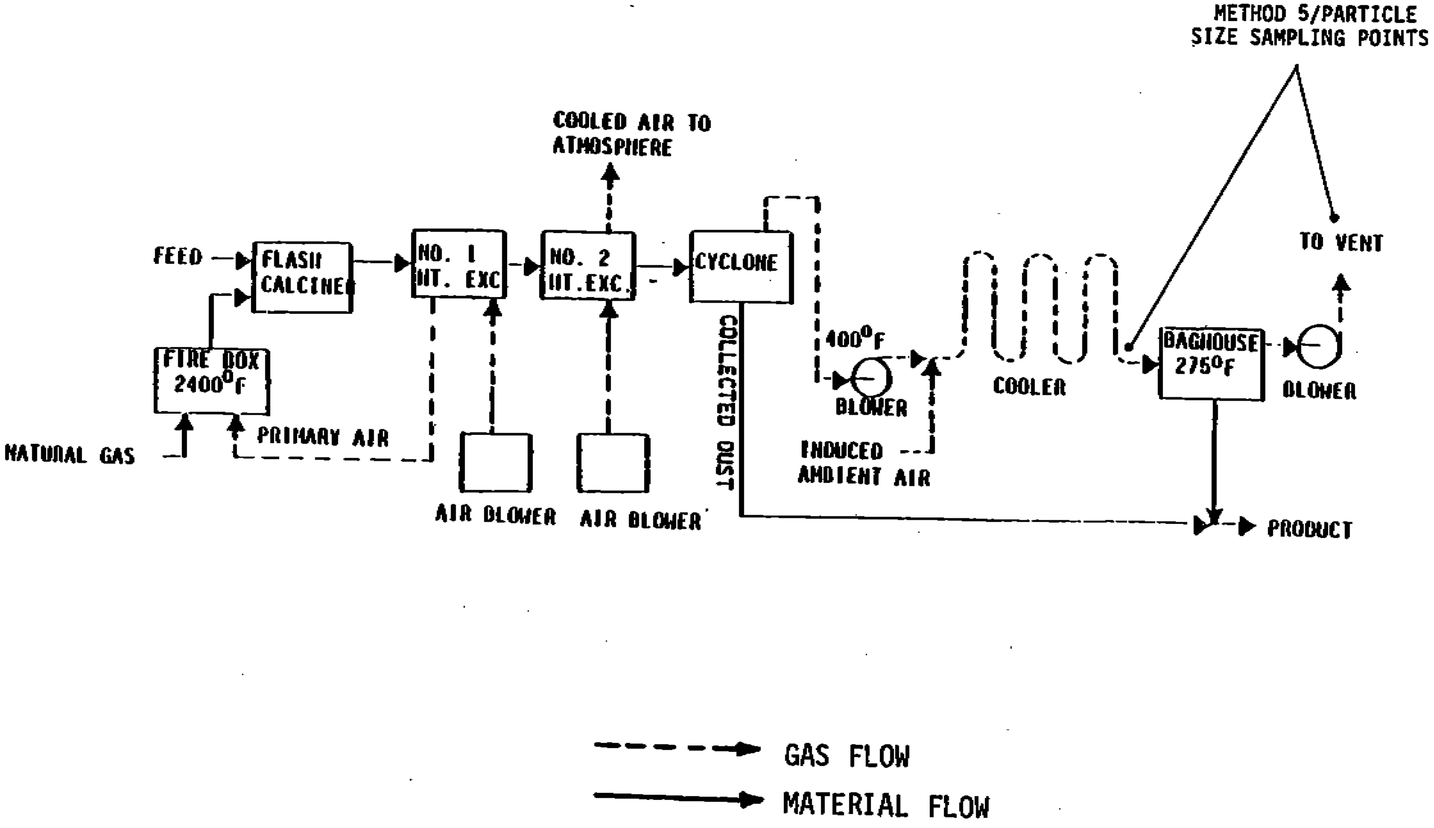


Figure C-17. Process schematic and sampling points--Plant J1.

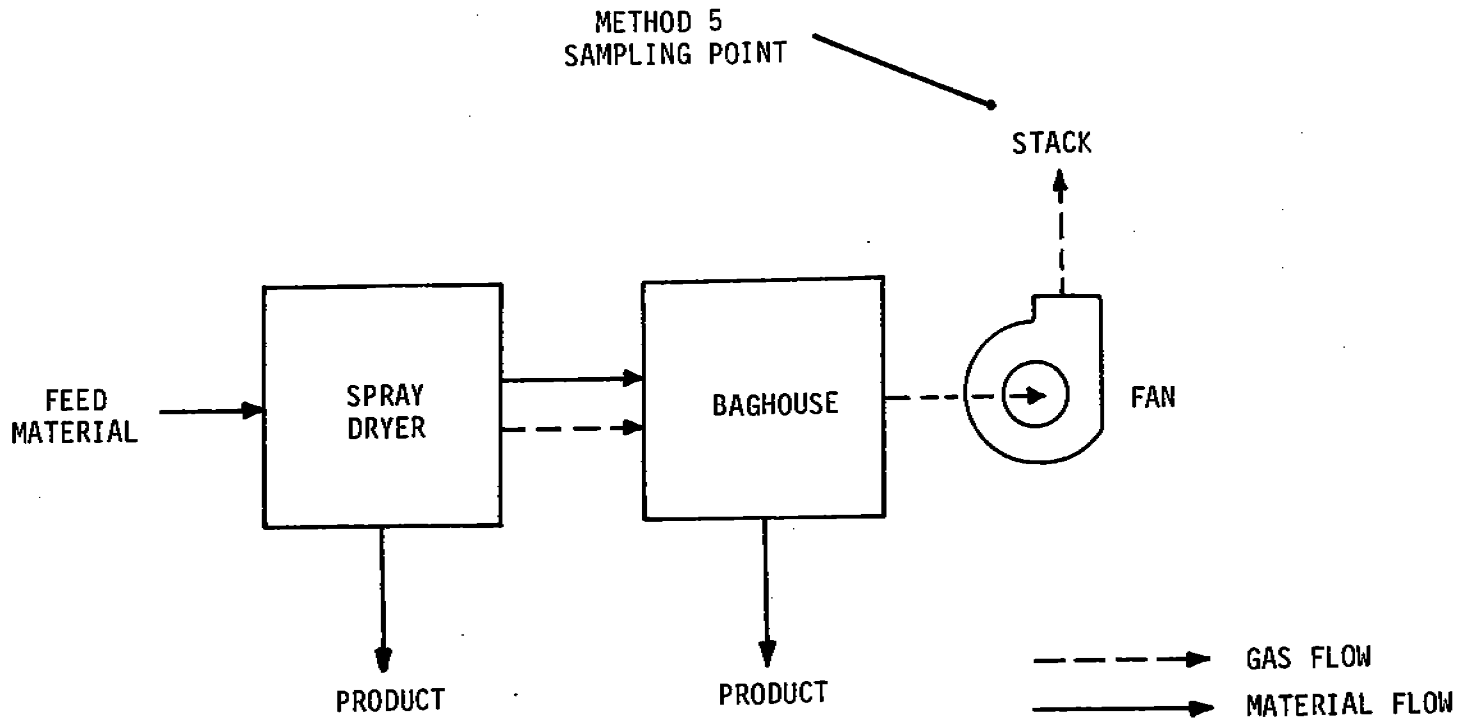


Figure C-18. Process schematic and sampling points--Plants J2, J3, and J4.

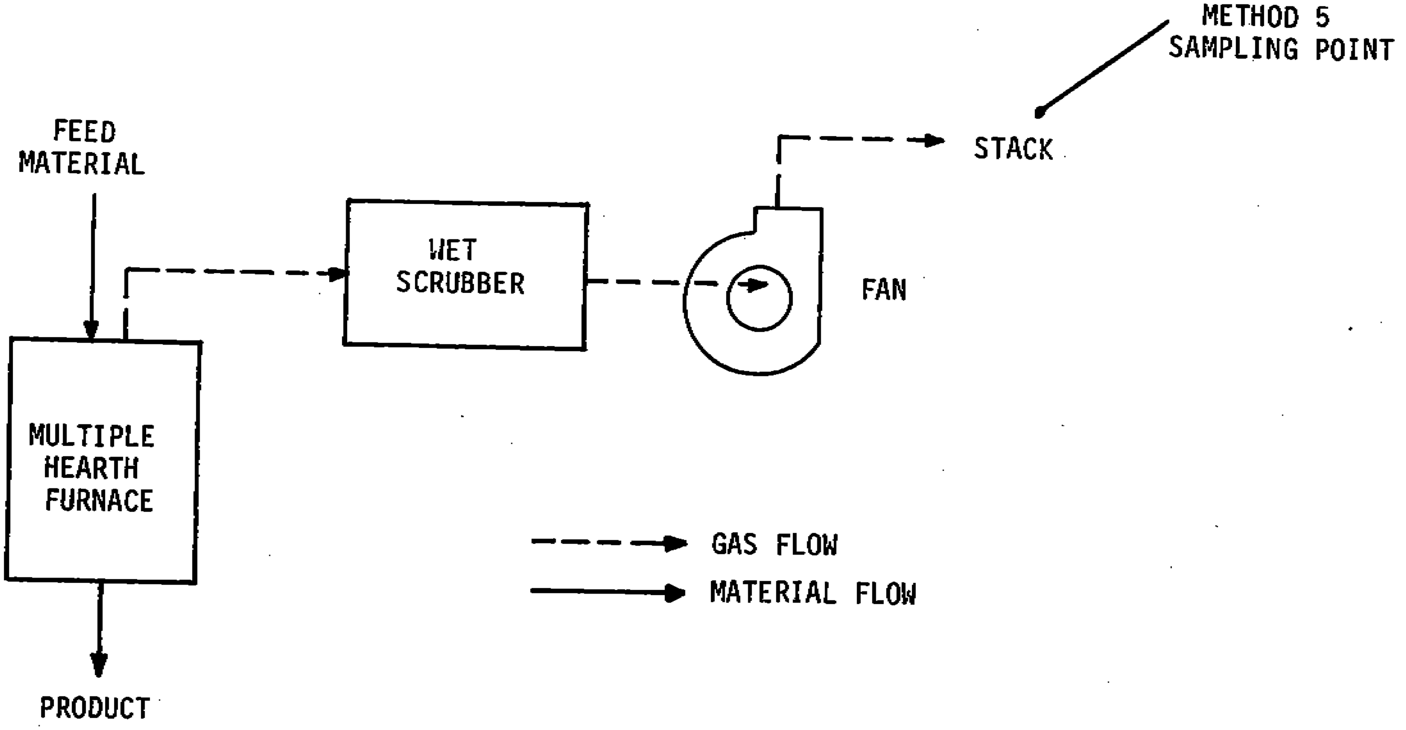


Figure C-19. Process schematic and sampling points--Plant J2.

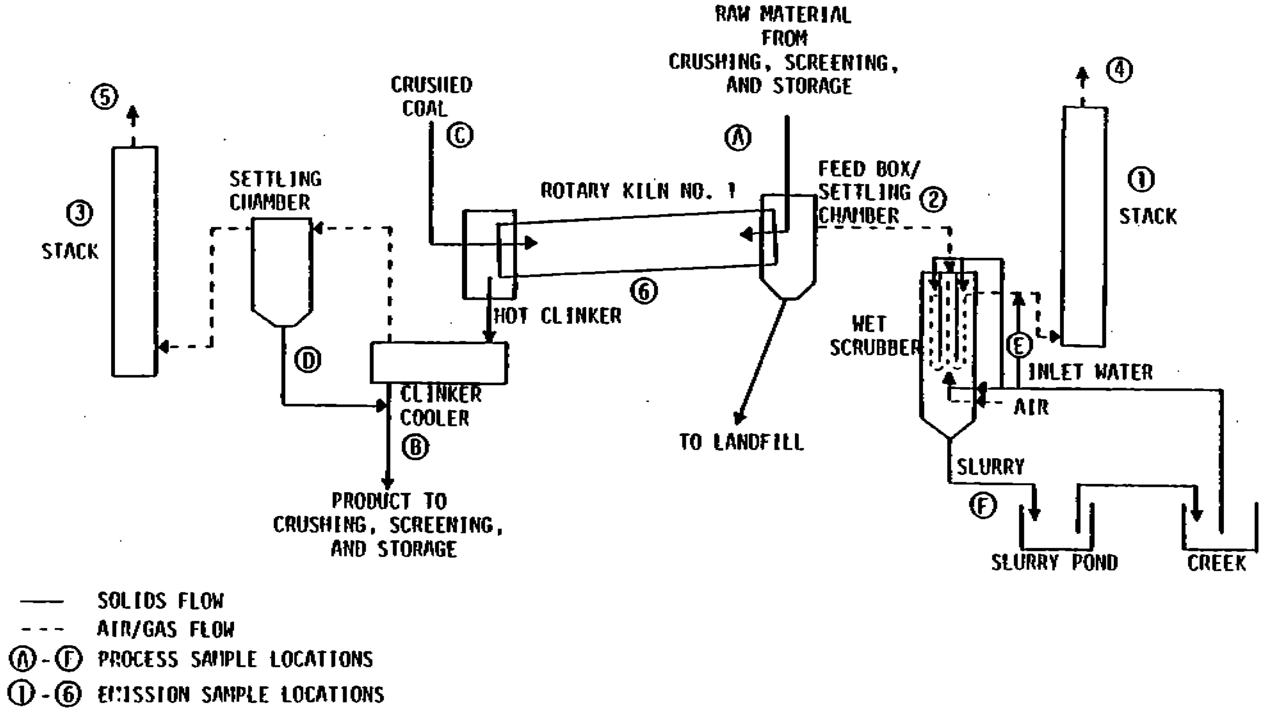
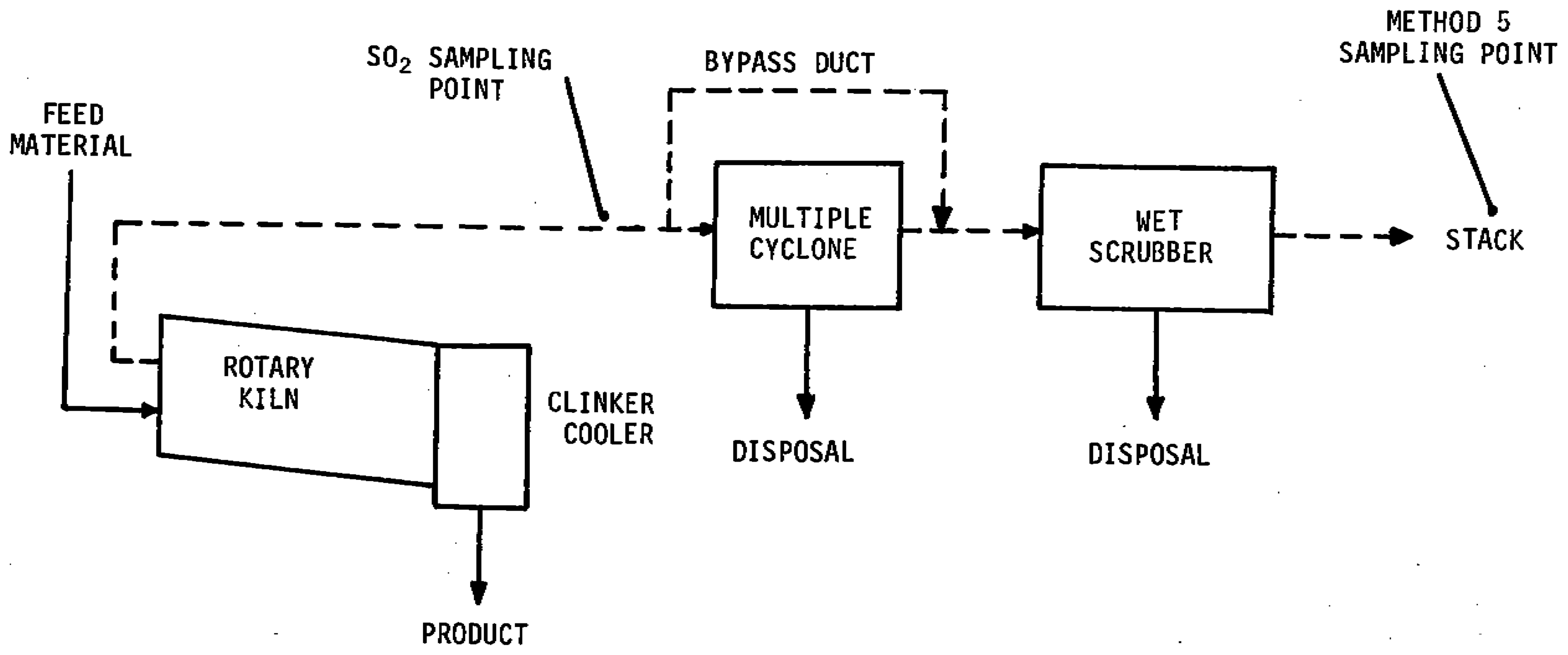


Figure C-20. Process schematic and sampling points--Plants K1 and K2.



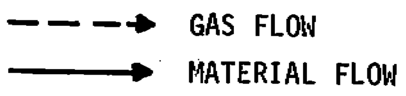


Figure C-21. Process schematic and sampling points--Plant K3.

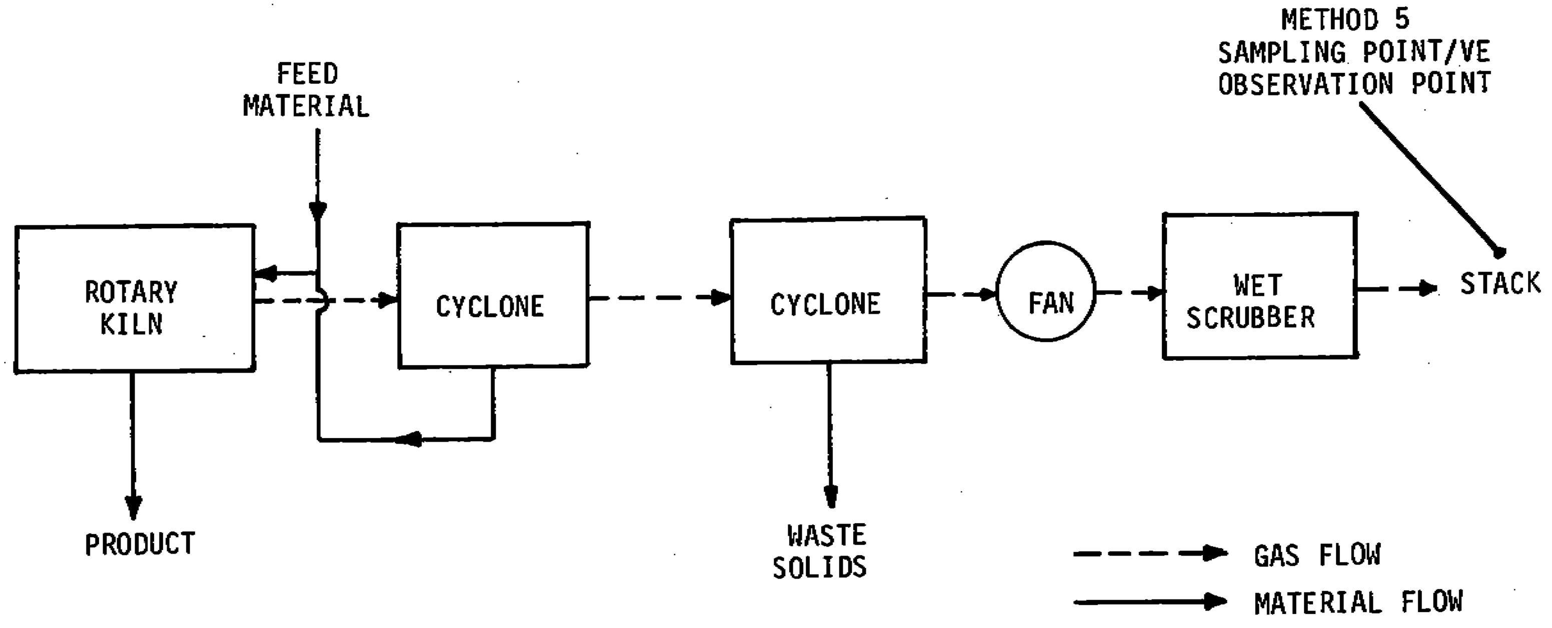


Figure C-22. Process schematic and sampling points--Plant K4.

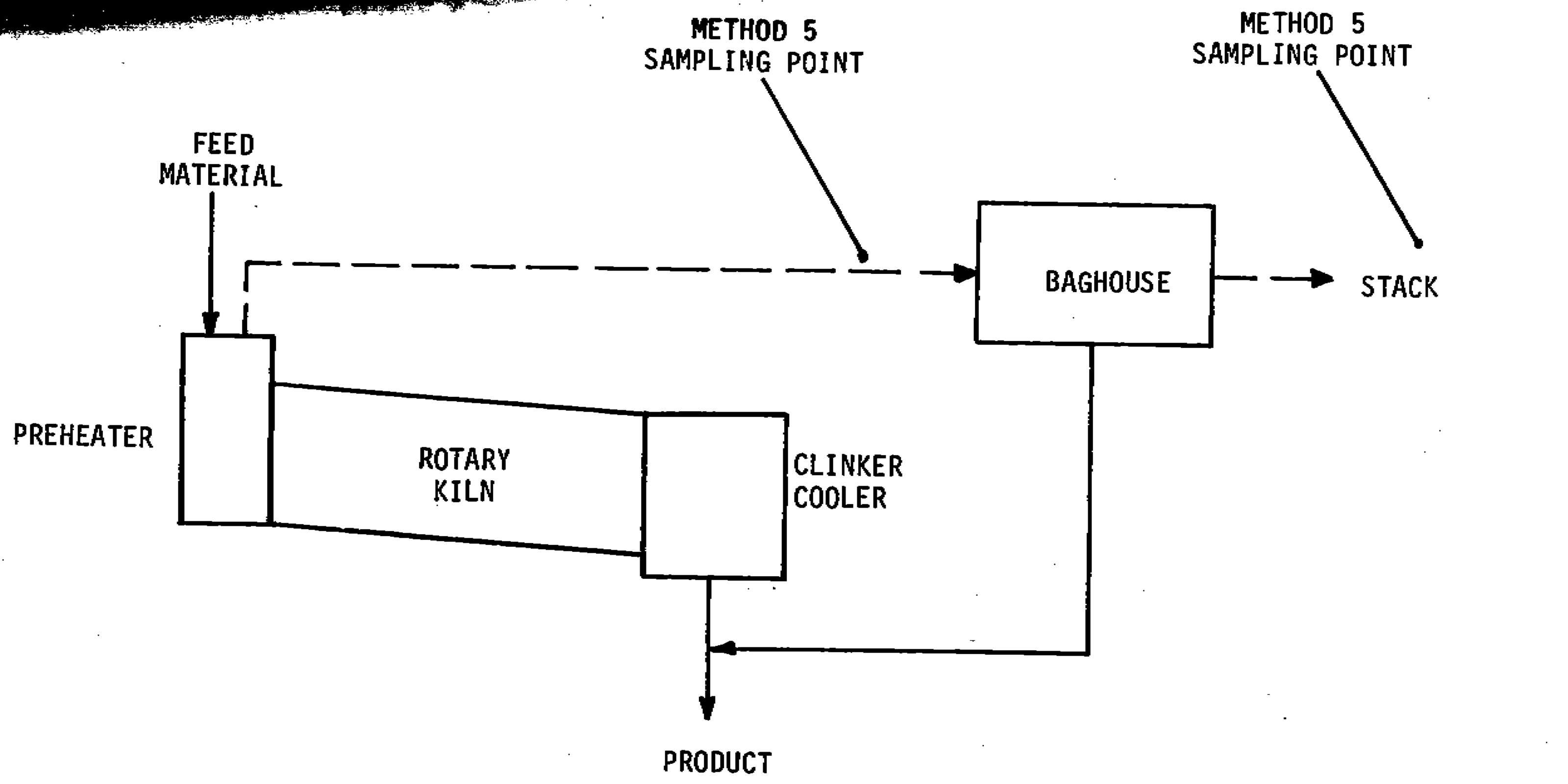


Figure C-23. Process schematic and sampling points--Plant K5.

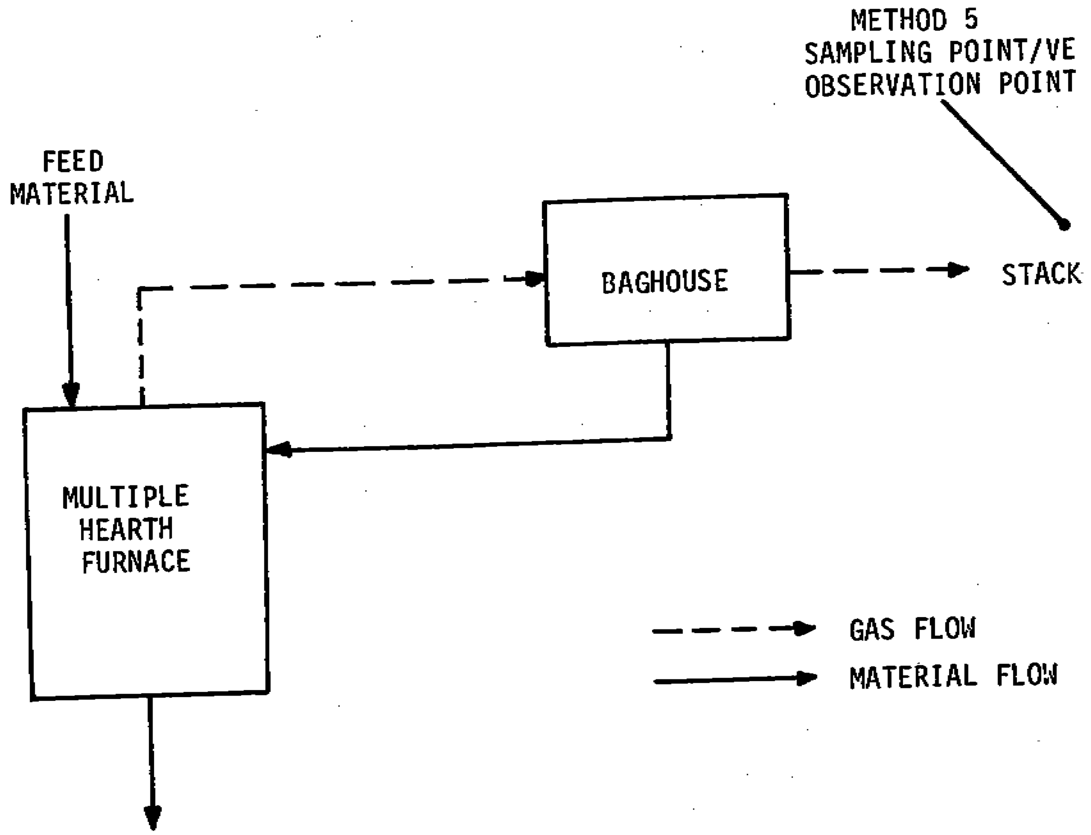


Figure C-24. Process schematic and sampling points--Plant L1.

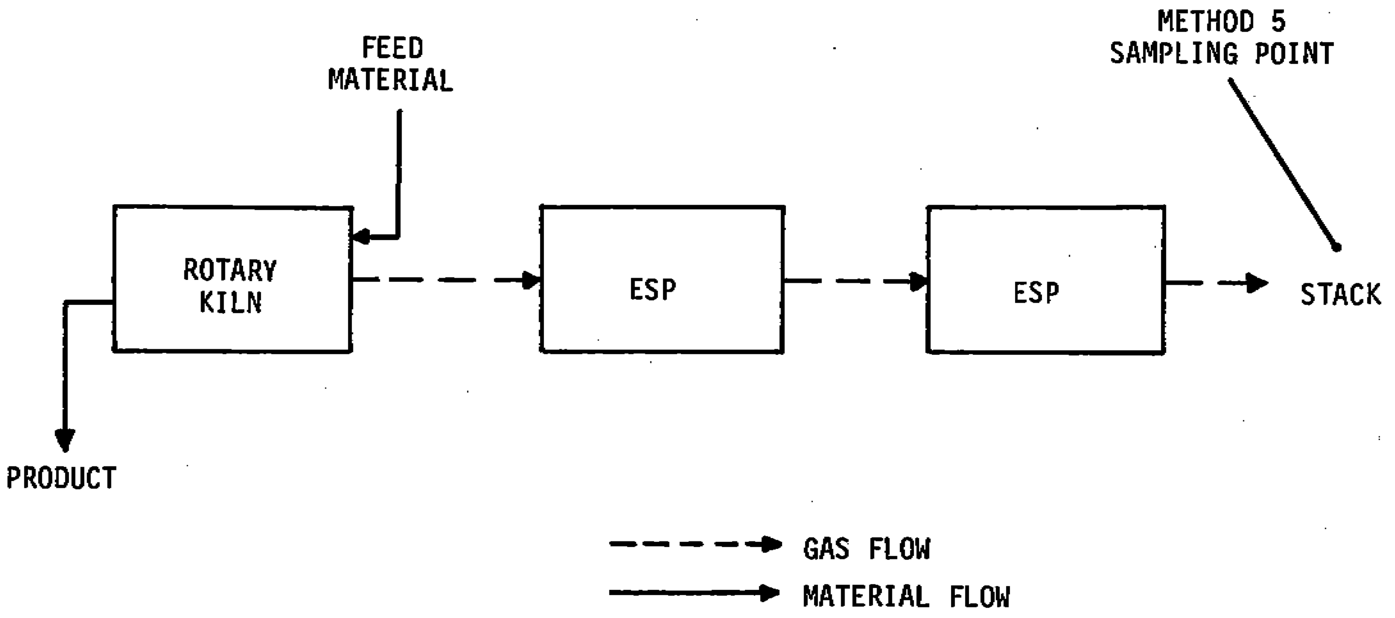


Figure C-25. Process schematic and sampling points--Plant L2.

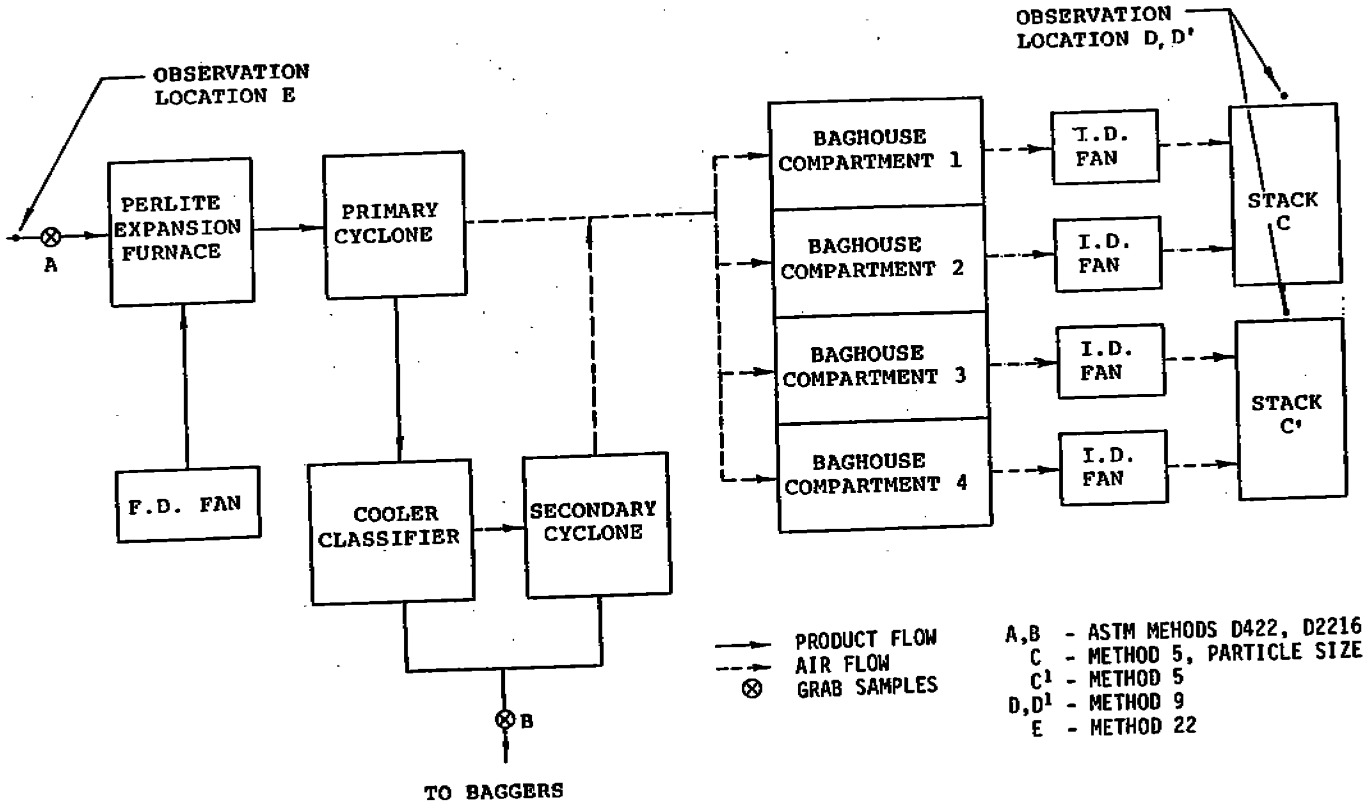


Figure C-26. Process schematic and sampling points--Plant M1.

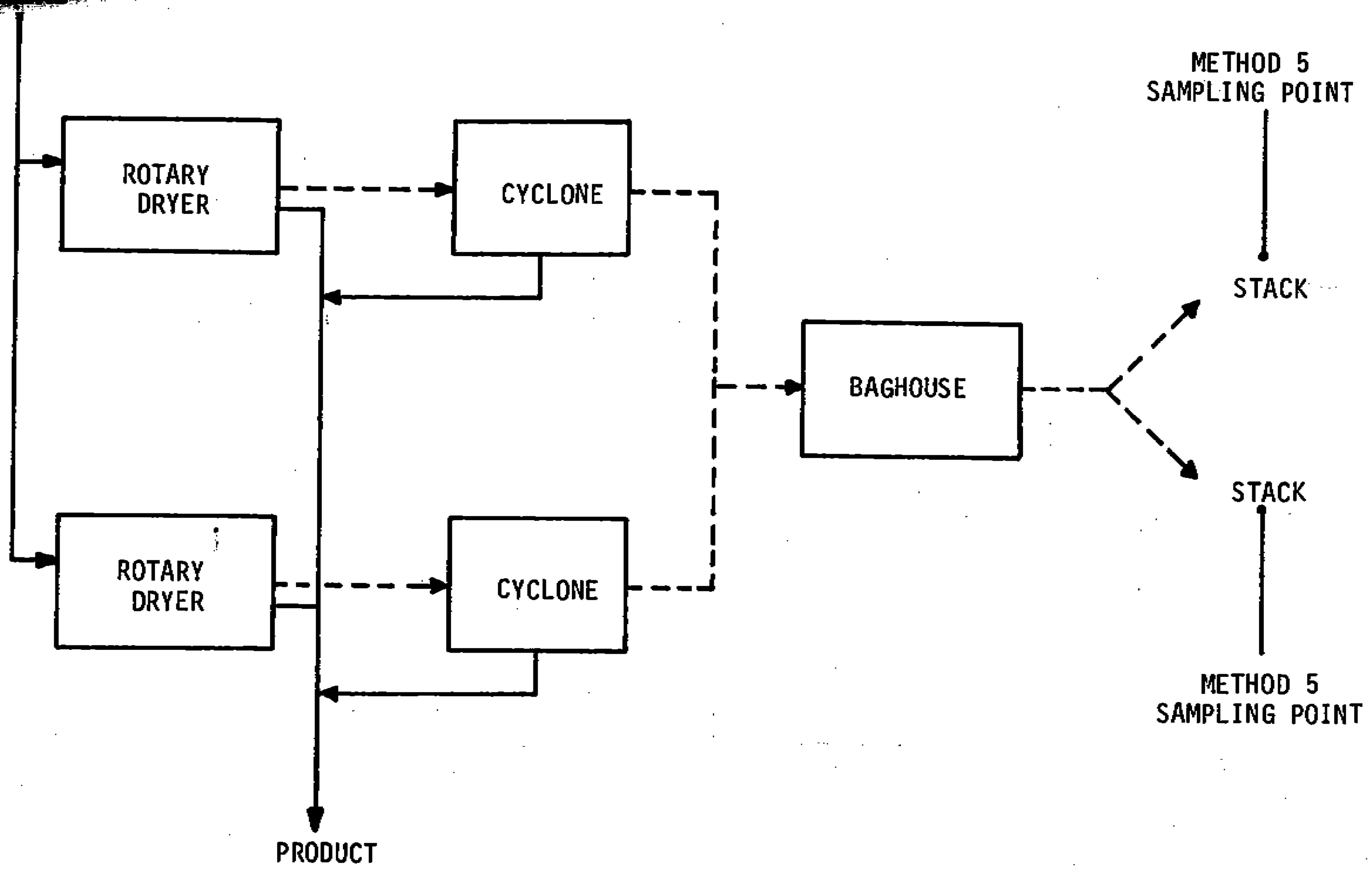


Figure C-27. Process schematic and sampling points--Plant M2.

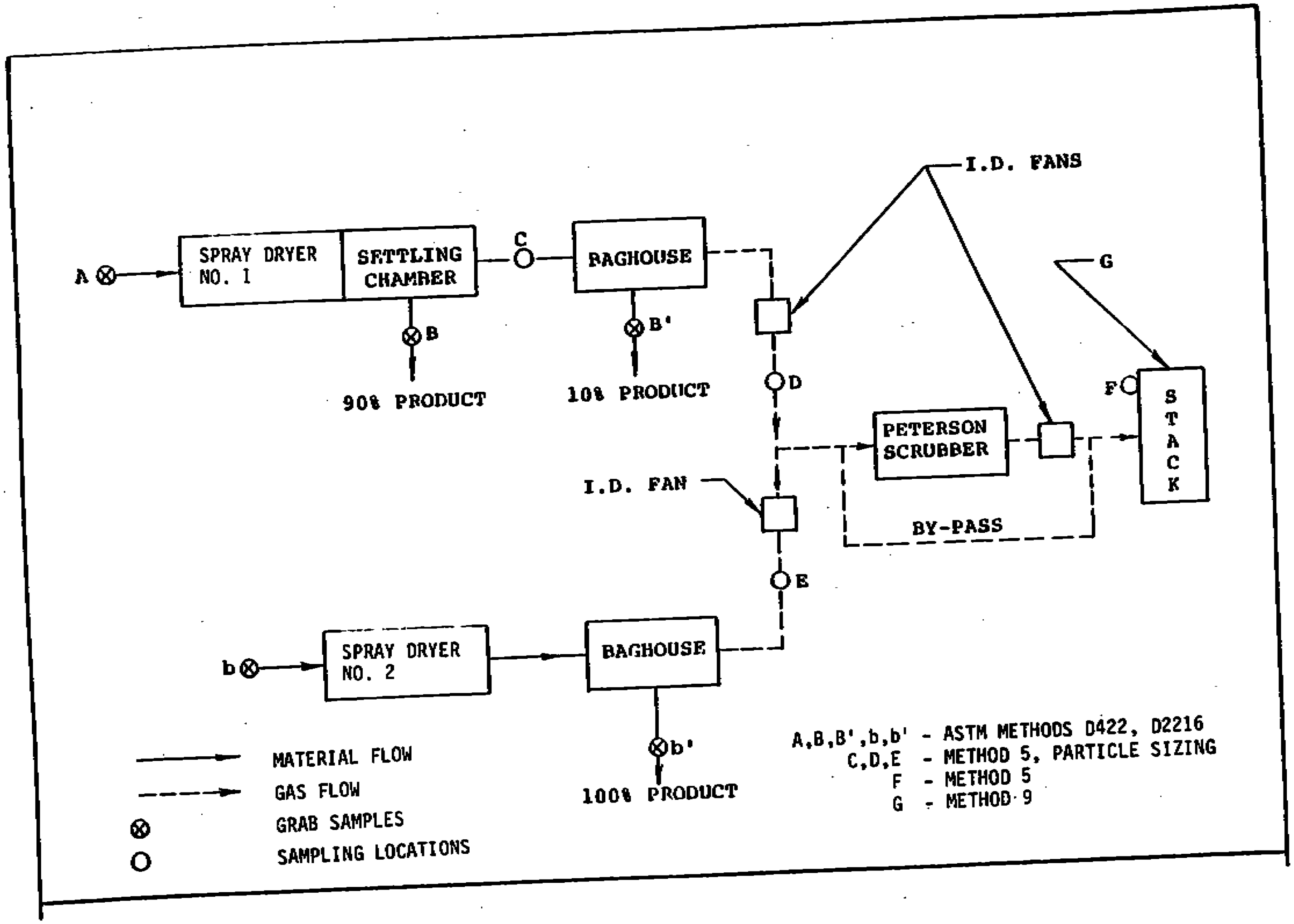


Figure C-28. Process schematic and sampling points--Plant P1.

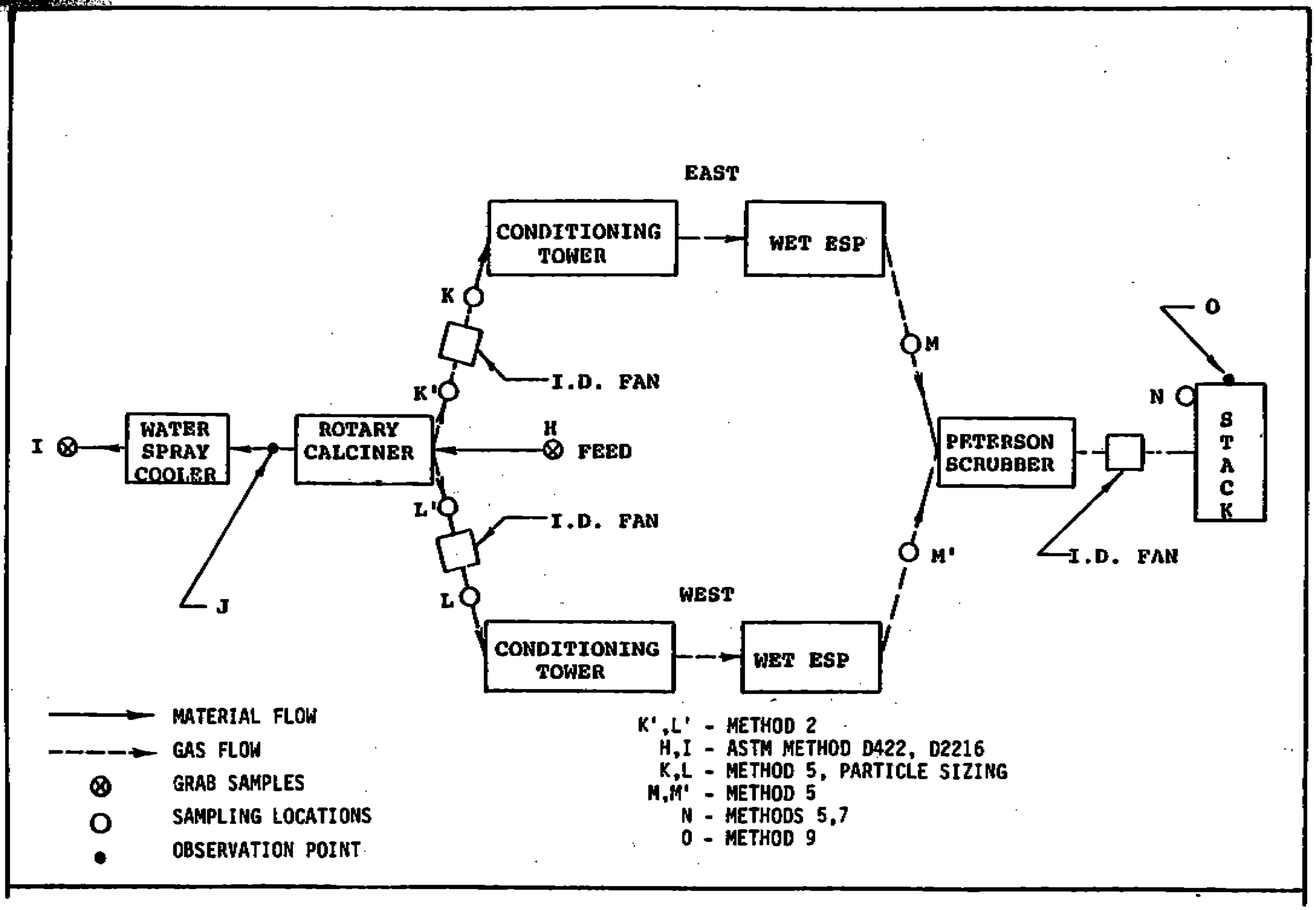


Figure C-29. Process schematic and sampling points--Plant P1.

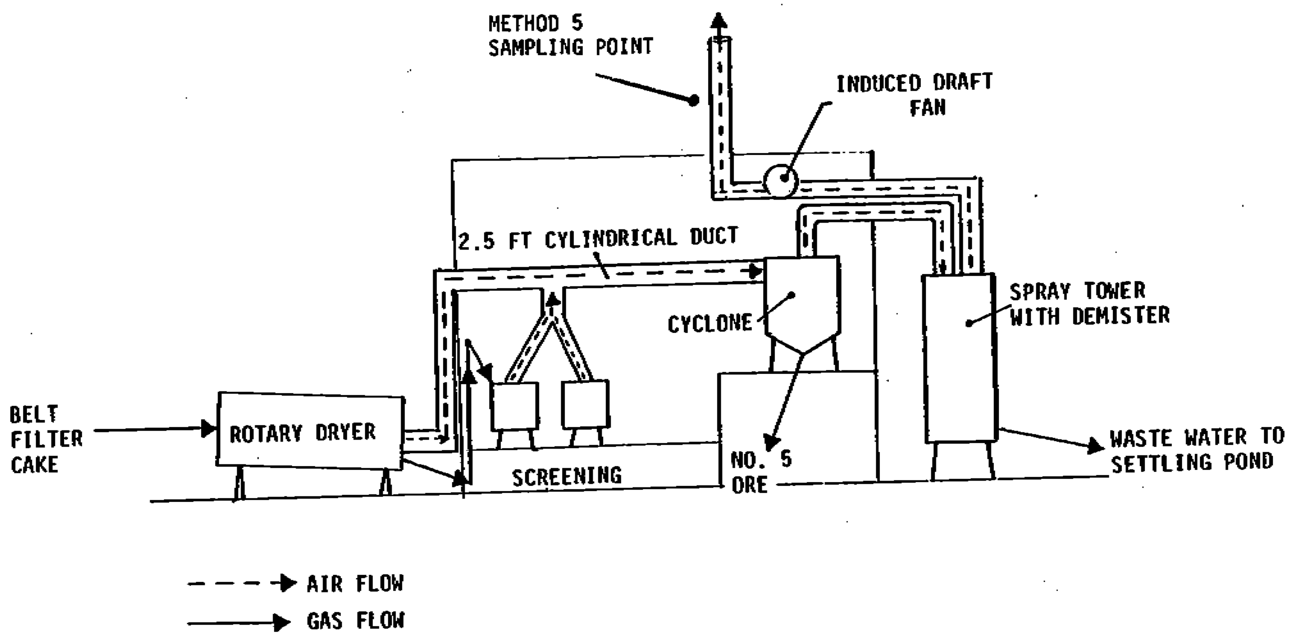


Figure C-30. Process schematic and sampling points--Plant Q1.

SUMMARY OF EMISSION TEST RESULTS--PLANT A1

Industry: Alumina
Process unit: Flash calciner
Emission source: ESP outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	8/19/81	8/20/81	8/20/81	--
Sampling time, minutes	108	108	108	--
Isokinetic ratio, percent	93	110	100	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent	90	90	90	90
Gas stream data				
Temperature, °C (°F)	a	a	a	a
Moisture, percent	a	a	a	a
Flow rate, m^3/s (acfm)	a	a	a	a
Flow rate, dsm^3/s (dscfm)	a	a	a	a
Particulate emissions				
g/dsm^3 (gr/dscf)	0.059 (0.026)	0.046 (0.020)	0.064 (0.028)	0.056 (0.025)
kg/h (lb/h)	a	a	a	a
kg/Mg (lb/ton)	a	a	a	a

[a] Confidential data.

TABLE C-2. SUMMARY OF VISIBLE EMISSIONS--PLANT A1[a]

Date	8/19-20/81
Industry	Alumina
Process unit	Flash calciner
Location of discharge	ESP outlet
Height of observation point, ft	--
Height of point of discharge, ft	120
Distance from observer to discharge point, ft	200; 300; 200
Direction of observer from discharge point	W; E; W
Description of background	Sky
Description of sky	Partly cloudy and hazy; partly cloudy; cloudy
Wind direction	NNW; N;N
Wind velocity, mph	20; 25; 20
Color of plume	White; white; white;
Duration of observation, min:s	5:15; 5:15; 5:15
Period of observation	
8/19/81	1255-1300:15
8/20/81	1015-1020:15
	1640-1645:15
Highest single reading, percent	10
Highest 6-minute average opacity, percent	6.7

[a] Data based on 5 minute, 15 second periods of observation during 3 runs.

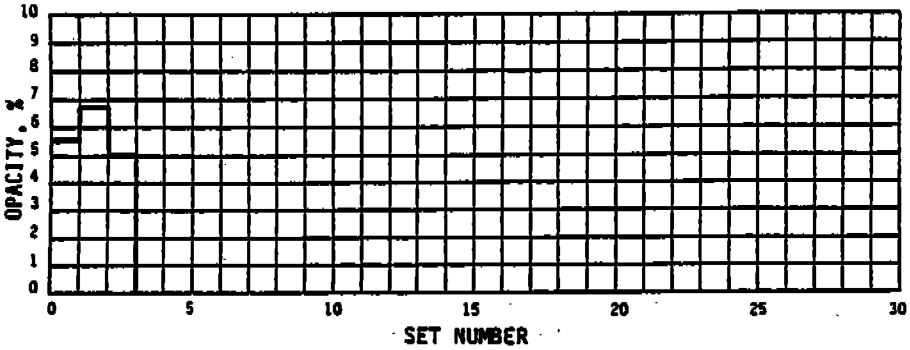


TABLE C-[illegible]. SUMMARY OF EMISSION TEST RESULTS--PLANT A2

Industry: Alumina
Process unit: Rotary calciner No. 1
Emission source: ESP No. 1 outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	10/6/76	10/6/76	10/6/76	--
Sampling time, minutes	120	120	120	--
Isokinetic ratio, percent	97	99	98	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent	105	105	105	105
Gas stream data				
Temperature, °C (°F)	a	a	a	a
Moisture, percent	a	a	a	a
Flow rate, m^3/s	a	a	a	a
(acfm)				
Flow rate, dsm^3/s (dscfm)	a	a	a	a
Particulate emissions				
g/dsm^3	0.028	0.075	0.130	0.078
(gr/dscf)	(0.012)	(0.033)	(0.057)	(0.034)
kg/h (lb/h)	a	a	a	a
kg/Mg (lb/ton)	a	a	a	a

---

[a] Confidential data.

TABLE C-4. SUMMARY OF EMISSION TEST RESULTS--PLANT A2

Industry: Alumina
Process unit: Rotary calciner No. 2
Emission source: ESP No. 2 outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	10/8/76	10/8/76	10/8/76	--
Sampling time, minutes	120	120	120	--
Isokinetic ratio, percent	91	90	99	--
Production rate, Mg/h (tons/h)	[a]	[a]	[a]	[a]
Capacity utilization, percent	117	117	117	117
Gas stream data				
Temperature, °C (°F)	[a]	[a]	[a]	[a]
Moisture, percent	[a]	[a]	[a]	[a]
Flow rate, m^3/s (acfm)	[a]	[a]	[a]	[a]
Flow rate, dsm^3/s (dscfm)	[a]	[a]	[a]	[a]
Particulate emissions				
g/dsm^3	0.038	0.035	0.036	0.036
(gr/dscf)	(0.017)	(0.015)	(0.016)	(0.016)
kg/h	[a]	[a]	[a]	[a]
(lb/h)				
kg/Mg	[a]	[a]	[a]	[a]
(lb/ton)				

[a] Confidential data.

TABLE C-5. SUMMARY OF EMISSION TEST RESULTS--PLANT A2

Industry: Alumina
Process unit: Rotary calciner Nos. 1 and 2
Emission source: ESP Nos. 3 and 4 outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	10/5/76	10/5/76	10/5/76	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	98	99	107	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent	117	117	117	117
Gas stream data				
Temperature, °C (°F)	a	a	a	a
Moisture, percent	a	a	a	a
Flow rate, m³/s	a	a	a	a
(acfm)	a	a	a	a
Flow rate, dsm³/s (dscfm)	a	a	a	a
Particulate emissions				
g/dsm³	0.064	0.023	0.027	0.038
(gr/dscf)	(0.028)	(0.010)	(0.012)	(0.017)
kg/h (lb/h)	a	a	a	a
kg/Mg (lb/ton)	a	a	a	a

---

[a] Confidential data.

TABLE C-6. SUMMARY OF EMISSION TEST RESULTS--PLANT B1

Industry: Ball clay
Process unit: Vibrating-grate dryer
Emission source: Baghouse outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	4/3/79	4/3/79	4/4/79	--
Sampling time, minutes	72	60	60	--
Isokinetic ratio, percent	105	110	109	--
Production rate, Mg/h	7.3	7.3	7.3	7.3
(tons/h)	(8.1)	(8.1)	(8.1)	(8.1)
Capacity utilization, percent	81	81	81	81
Gas stream data				
Temperature, °C	71	71	71	71
(°F)	(160)	(160)	(160)	(160)
Moisture, percent	4.17	4.81	4.55	4.51
Flow rate, m^3/s	11	11	11	11
(acfm)	(23,300)	(23,800)	(22,900)	(23,300)
Flow rate, dsm^3/s	8.9	8.9	8.6	8.8
(dscfm)	(18,800)	(18,900)	(18,200)	(18,700)
Particulate emissions				
g/dsm^3	0.026	0.017	0.006	0.016
(gr/dscf)	(0.011)	(0.008)	(0.003)	(0.007)
kg/h	0.82	0.56	0.19	0.52
(lb/h)	(1.80)	(1.23)	(0.41)	(1.15)
kg/Mg	0.11	0.076	0.026	0.071
(lb/ton)	(0.22)	(0.15)	(0.051)	(0.14)

TABLE C-7. SUMMARY OF EMISSION TEST RESULTS--PLANT C1

Industry: Bentonite
Process unit: Rotary dryer
Emission source: Cyclone inlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	9/20/83	9/21/83	9/22/83	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	104	102	103	--
Production rate, Mg/h	24.5	24.5	24.5	24.5
(tons/h)	(27)	(27)	(27)	(27)
Capacity utilization, percent	87	87	87	87
Gas stream data				
Temperature, °C	80	77	76	78
(°F)	176	(171)	(168)	(172)
Moisture, percent	22.5	23.9	27.1	24.5
Flow rate, m^3/s	7.4	6.7	6.8	7.0
(acfm)	(15,700)	(14,300)	(14,400)	(14,800)
Flow rate, dsm^3/s	4.1	3.7	3.6	3.8
(dscfm)	(8,620)	(7,780)	(7,542)	(7,980)
Particulate emissions				
g/dsm^3	254	269	254	259
(gr/dscf)	(111)	(117)	(111)	(113)
kg/h	3,719	3,551	3,261	3,510
(lb/h)	(8,192)	(7,821)	(7,183)	(7,732)
kg/Mg	150	140	130	140
(lb/ton)	(300)	(290)	(270)	(290)

TABLE C-8. SUMMARY OF EMISSION TEST RESULTS--PLANT C1

Industry: Bentonite
Process unit: Rotary dryer
Emission source: Baghouse outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	9/20/83	9/21/83	9/22/83	--
Sampling time, minutes	108	180	180	--
Isokinetic ratio, percent	103	105	105	--
Production rate, Mg/h	24.5	24.5	24.5	24.5
(tons/h)	(27)	(27)	(27)	(27)
Capacity utilization, percent	87	87	87	87
Gas stream data				
Temperature, °C	64	67	68	67
(°F)	(148)	(153)	(154)	(152)
Moisture, percent	13.2	13.8	14.9	14.0
Flow rate, m^3/s	11	12	11	11
(acfm)	(23,400)	(24,900)	(24,300)	(24,200)
Flow rate, dsm^3/s	7.1	7.5	7.2	7.2
(dscfm)	(15,100)	(15,800)	(15,200)	(15,400)
Particulate emissions				
g/dsm^3	0.031	0.045	0.064	0.047
(gr/dscf)	(0.013)	(0.020)	(0.028)	(0.020)
kg/h	0.79	1.22	1.66	1.22
(lb/h)	(1.74)	(2.68)	(3.65)	(2.69)
kg/Mg	0.032	0.050	0.068	0.050
(lb/ton)	(0.06)	(0.10)	(0.14)	(0.10)

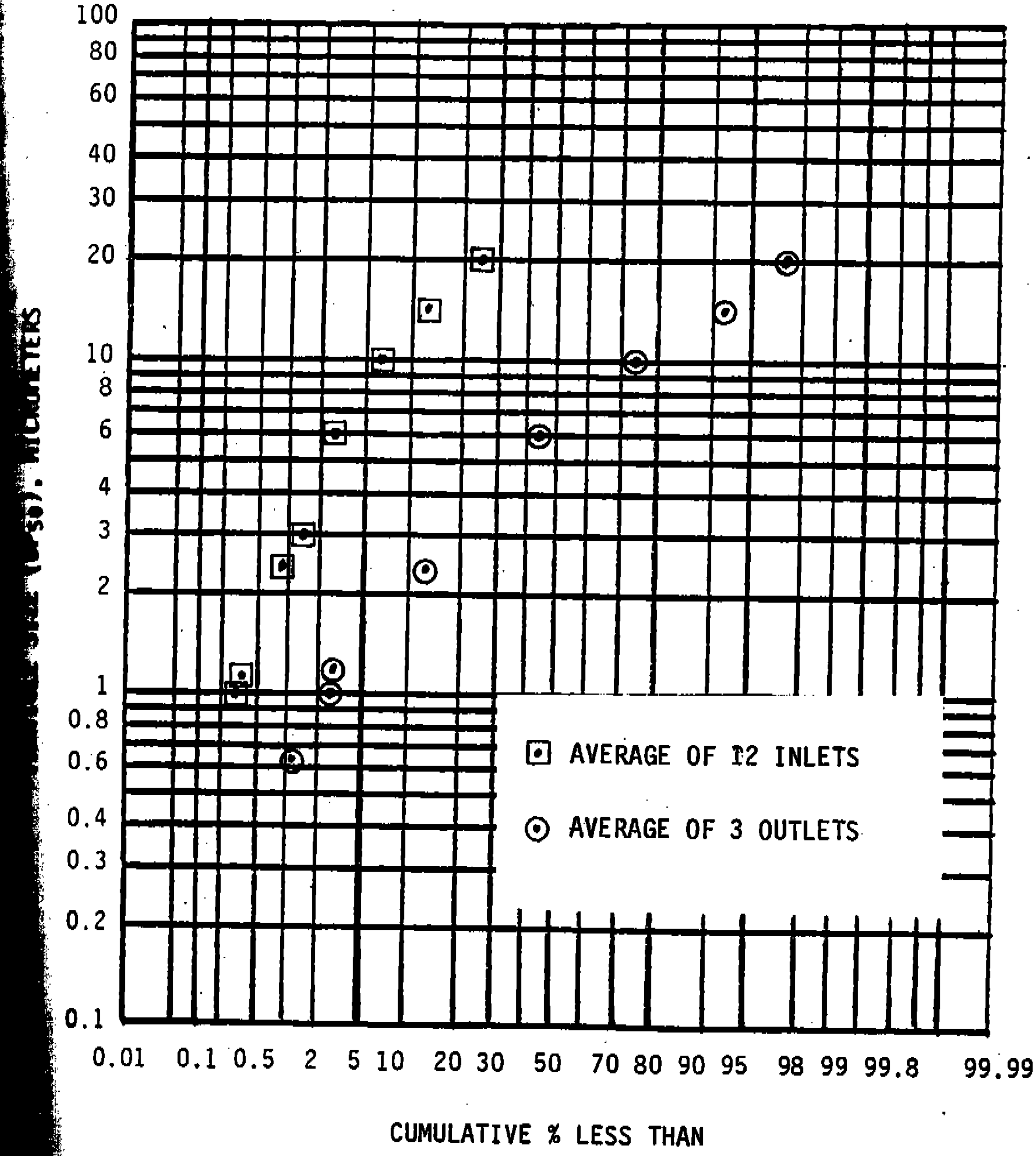


Figure C-31. Particle size distribution data: rotary dryer--Plant C1.

TABLE C-9. SUMMARY OF VISIBLE EMISSIONS--PLANT C1

Date	9/20/83
Industry	Bentonite
Process unit	Rotary dryer
Location of discharge	Baghouse outlet
Height of observation point, ft	45
Height of point of discharge, ft	45
Distance from observer to discharge point, ft	50
Direction of observer from discharge point	--
Description of background	Side of grey building
Description of sky	Partly cloudy
Wind direction	NW
Wind velocity, mph	10-15
Color of plume	White
Duration of observation, min	120
Period of observation	1300-1633
Highest single reading, percent	10.0
Highest 6-minute average opacity, percent	2.5

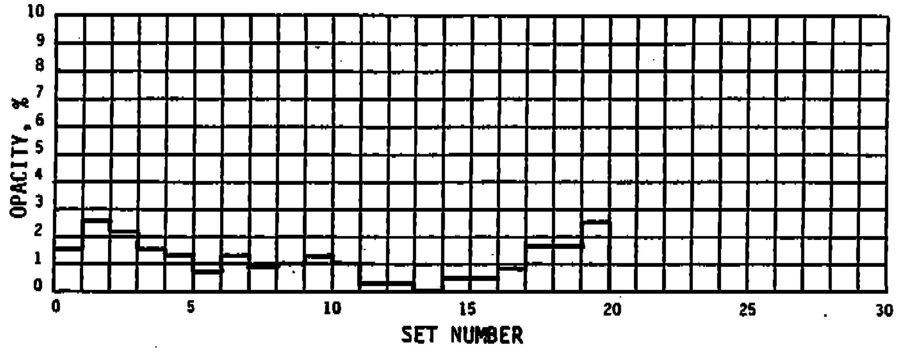
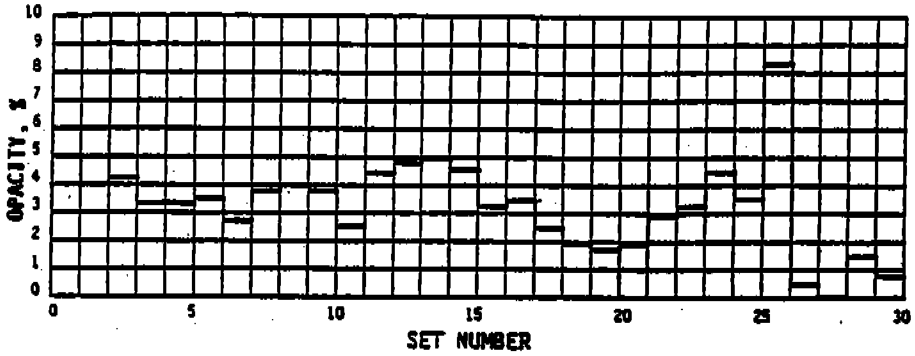


TABLE C-10. SUMMARY OF VISIBLE EMISSIONS--PLANT C1

te	9/21/83
dustry	Bentonite
ocess unit	Rotary dryer
cation of discharge	Baghouse outlet
ight of observation point, ft	45
ight of point of discharge, ft	45
stance from observer to discharge point, ft	50
rection of observer from discharge point	--
scription of background	Building
scription of sky	Partly cloudy
d direction	W
d velocity, mph	10-15
or of plume	White
ation of observation, min	210
iod of observation	1545-1915
est single reading, percent	10.0
est 6-minute average opacity, percent	8.3



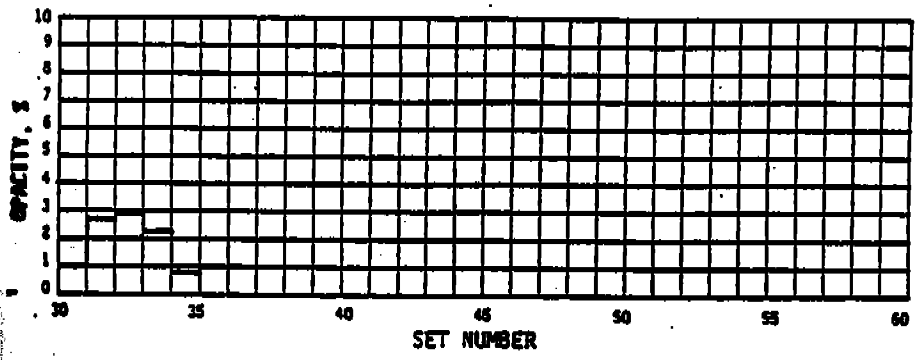
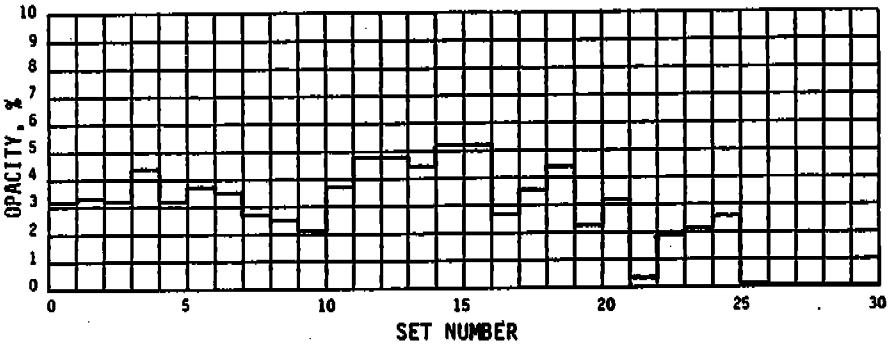


TABLE C-11. SUMMARY OF VISIBLE EMISSIONS--PLANT C1

Date	9/22/83
Industry	Bentonite
Process unit	Rotary dryer
Location of discharge	Baghouse outlet
Height of observation point, ft	45
Height of point of discharge, ft	45
Distance from observer to discharge point, ft	50
Direction of observer from discharge point	--
Description of background	Building
Description of sky	Clear
Wind direction	W
Wind velocity, mph	5-10
Color of plume	White
Duration of observation, min	204
Period of observation	1030-1354
Highest single reading, percent	10.0
Highest 6-minute average, percent	5.2



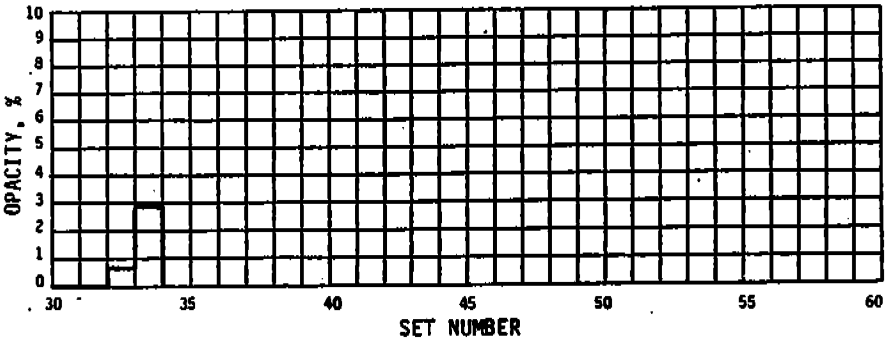


TABLE C-12. SUMMARY OF EMISSION TEST RESULTS--PLANT C3

Industry: Bentonite
Process unit: Rotary dryer
Emission source: ESP outlet

Data	Run No. 2[a]	Run No. 3	Run No. 4	Average for test series
General				
Date	11/4/81	11/4/81	11/5/81	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	92	97	101	--
Production rate, Mg/h	40.0	40.0	50.8	43.6
(tons/h)	(44)	(44)	(56)	(48)
Capacity utilization, percent	88	88	112	96
Gas stream data				
Temperature, °C	75	72	68	72
(°F)	(165)	(160)	(153)	(159)
Moisture, percent	14.8	12.9	15.3	14.4
Flow rate, m^3/s	22	21	23	22
(acfm)	(47,500)	(44,400)	(48,200)	(46,700)
Flow rate, dsm^3/s	14	14	15	14
(dscfm)	(29,700)	(28,600)	(30,800)	(29,700)
Particulate emissions				
g/dsm^3	0.025	0.006	0.010	0.014
(gr/dscf)	(0.011)	(0.003)	(0.004)	(0.006)
kg/h	1.25	0.31	0.52	0.69
(lb/h)	(2.75)	(0.69)	(1.14)	(1.53)
kg/Mg	0.031	0.078	0.010	0.016
(lb/ton)	(0.062)	(0.016)	(0.020)	(0.033)

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[a] Isokinetic ratio for Run No. 1 not within allowable limits; data were not included in average. Test data for Run No. 1 were not given in the test report.

TABLE C-13. SUMMARY OF EMISSION TEST RESULTS--PLANT D1

Industry: Diatomite
Process unit: Rotary calciner
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	6/3/82	6/3/82	6/3/82	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	96	100	102	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent	89-104	89-104	89-104	96
Gas stream data				
Temperature, °C (°F)	a	a	a	a
Moisture, percent	12.0	11.0	12.9	12.0
Flow rate, m^3/s (acfm)	a	a	a	a
Flow rate, dsm^3/s (dscfm)	a	a	a	a
Particulate emissions				
g/dsm^3 (gr/dscf)	0.089 (0.039)	0.085 (0.037)	0.098 (0.043)	0.091 (0.040)
kg/h (lb/h)	a	a	a	a
kg/Mg (lb/ton)	a	a	a	a

[a] Confidential data

SUMMARY OF EMISSION TEST RESULTS--PLANT E1

Industry: Feldspar
Process unit: Rotary dryer
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	9/1/81	9/1/81	9/2/81	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	98	97	102	--
Production rate, Mg/h	a	a	a	a
(tons/h)				
Capacity utilization, percent	90	90	90	90
Gas stream data				
Temperature, °C	51	51	48	50
(°F)	(123)	(123)	(118)	(121)
Moisture, percent	12.5	12.5	11.1	12.0
Flow rate, m^3/s	7.4	7.4	7.3	7.3
(acfm)	(15,600)	(15,600)	(15,400)	(15,500)
Flow rate, dsm^3/s	6.0	6.0	6.0	6.0
(dscfm)	(12,700)	(12,800)	(12,600)	(12,700)
Particulate emissions				
g/dsm^3	0.051	0.052	0.063	0.055
(gr/dscf)	(0.022)	(0.023)	(0.027)	(0.024)
kg/h	1.09	1.12	1.35	1.19
(lb/h)	(2.42)	(2.46)	(2.97)	(2.62)
kg/Mg	a	a	a	a
(lb/ton)				

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[a] Confidential data.

TABLE C-15. SUMMARY OF EMISSION TEST RESULTS--PLANT E2

Industry: Feldspar
Process unit: Rotary dryer
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	5/16/79	5/16/79	5/16/79	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	98	97	98	--
Production rate, Mg/h	a	a	a	a
(tons/h)				
Capacity utilization, percent	100	100	100	100
Gas stream data				
Temperature, °C	35	37	38	37
(°F)	(95)	(99)	(100)	(98)
Moisture, percent	5.1	5.1	5.5	5.2
Flow rate, m^3/s	6.0	5.9	5.9	5.9
(acfm)	(12,700)	(12,500)	(12,600)	(12,600)
Flow rate, dsm^3/s	5.0	4.9	4.9	4.9
(dscfm)	(10,600)	(10,400)	(10,400)	(10,500)
Particulate emissions				
g/dsm^3	0.035	0.032	0.047	0.038
(gr/dscf)	(0.015)	(0.014)	(0.021)	(0.017)
kg/h	0.63	0.57	0.84	0.68
(lb/h)	(1.39)	(1.25)	(1.85)	(1.50)
kg/Mg	a	a	a	a
(lb/ton)				

[a] Confidential data

TABLE C-10. SUMMARY OF EMISSION TEST RESULTS--PLANT E3

Industry: Feldspar
Process unit: Rotary dryer
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	10/25/78	10/25/78	10/25/78	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	102	105	105	--
Production rate, Mg/h	18.1	18.1	18.1	18.1
(tons/h)	(20)	(20)	(20)	(20)
Capacity utilization, percent	100	100	100	100
Gas stream data				
Temperature, °C	43	47	43	44
(°F)	(110)	(116)	(110)	(112)
Moisture, percent	9.2	9.5	7.7	8.8
Flow rate, m^3/s	3.9	3.9	4.0	4.0
(acfm)	(8,270)	(8,210)	(8,430)	(8,300)
Flow rate, dsm^3/s	3.3	3.2	3.3	3.3
(dscfm)	(6,940)	(6,820)	(7,070)	(6,940)
Particulate emissions				
g/dsm^3	0.011	0.008	0.012	0.010
(gr/dscf)	(0.005)	(0.004)	(0.005)	(0.004)
kg/h	0.11	0.09	0.13	0.11
(lb/h)	(0.25)	(0.19)	(0.29)	(0.25)
kg/Mg	0.0063	0.0048	0.0073	0.0061
(lb/ton)	(0.013)	(0.095)	(0.015)	(0.012)

TABLE C-17. SUMMARY OF EMISSION TEST RESULTS--PLANT F1

Industry: Fire clay
Process unit: Rotary dryer--Plastic clay
Emission source: Cyclone inlet

Data	Run No. 1	Run No. 11	Run No. 12	Average for test series
General				
Date	3/12/84	3/15/84	3/15/84	--
Sampling time, minutes	30	24	24	--
Isokinetic ratio, percent	103	103	103	--
Production rate, Mg/h	25.6	28.8	31.4	28.6
(tons/h)	(28.2)	(31.7)	(34.6)	(31.5)
Capacity utilization, percent[a]	100	100	100	100
Gas stream data				
Temperature, °C	71	59	59	63
(°F)	(160)	(139)	(138)	(146)
Moisture, percent	15.9	19.4	19.0	18.1
Flow rate, m^3/s	3.5	3.2	3.1	3.3
(acfm)	(7,410)	(6,860)	(6,610)	(6,960)
Flow rate, dsm^3/s	2.5	2.3	2.2	2.3
(dscfm)	(5,290)	(4,790)	(4,630)	(4,900)
Particulate emissions				
g/dsm^3	96	136	115	116
(gr/dscf)	(42)	(59)	(50)	(50)
kg/h	865	1,100	902	957
(lb/h)	(1,910)	(2,440)	(1,990)	(2,110)
kg/Mg	34	38	29	34
(lb/ton)	(68)	(77)	(58)	(67)

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[a] The dryer was operated at maximum capacity at all times to achieve the desired product quality.

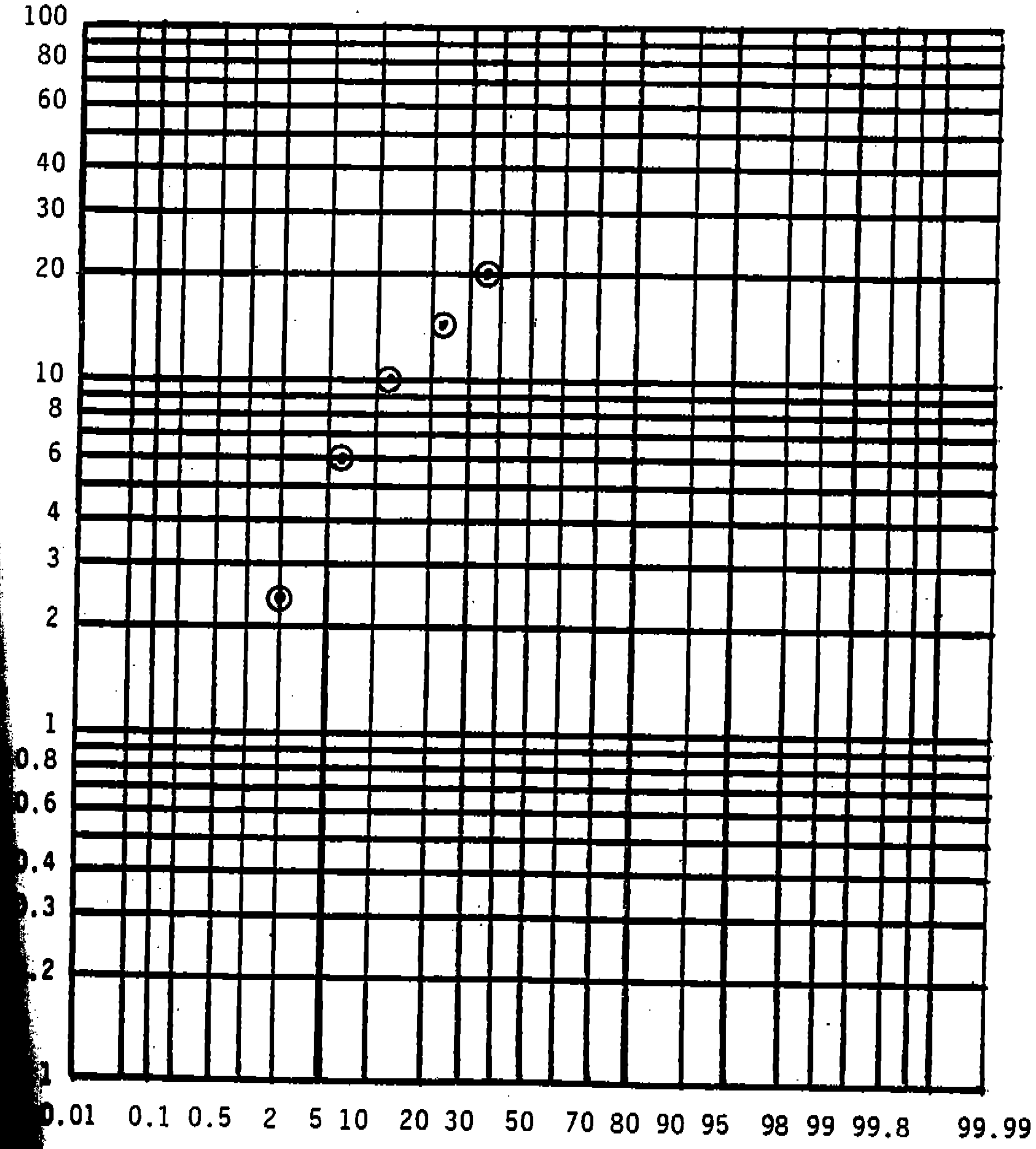

Figure C-32. Particle size distribution data: rotary dryer cyclone inlet (plastic clay)--Plant F1.

TABLE C-18. SUMMARY OF EMISSION TEST RESULTS--PLANT F1

Industry: Fire clay
Process unit: Rotary dryer--Plastic clay
Emission source: Scrubber inlet

Data	Run No. 4	Run No. 14	Run No. 15	Average for test series
General				
Date	3/12/84	3/15/84	3/15/84	--
Sampling time, minutes	63	40	40	--
Isokinetic ratio, percent	100	99	98	--
Production rate, Mg/h	25.6	28.8	31.4	28.6
(tons/h)	(28.2)	(31.7)	(34.6)	(31.5)
Capacity utilization, percent[a]	100	100	100	100
Gas stream data				
Temperature, °C	56	56	56	56
(°F)	(132)	(132)	(133)	(132)
Moisture, percent	16.0	16.4	16.6	16.3
Flow rate, m^3/s	4.8	4.6	4.7	4.7
(acfm)	(10,110)	(9,780)	(9,960)	(9,950)
Flow rate, dsm^3/s	3.4	3.3	3.4	3.4
(dscfm)	(7,260)	(7,090)	(7,180)	(7,170)
Particulate emissions				
g/dsm^3	14.3	12.9	7.3	11.5
(gr/dscf)	(6.26)	(5.65)	(3.19)	(5.03)
kg/h	177	156	89	141
(lb/h)	(390)	(343)	(196)	(310)
kg/Mg	6.9	5.4	2.8	5.0
(lb/ton)	(14)	(11)	(5.7)	(10)

[a] The dryer was operated at maximum capacity at all times to achieve the desired product quality.

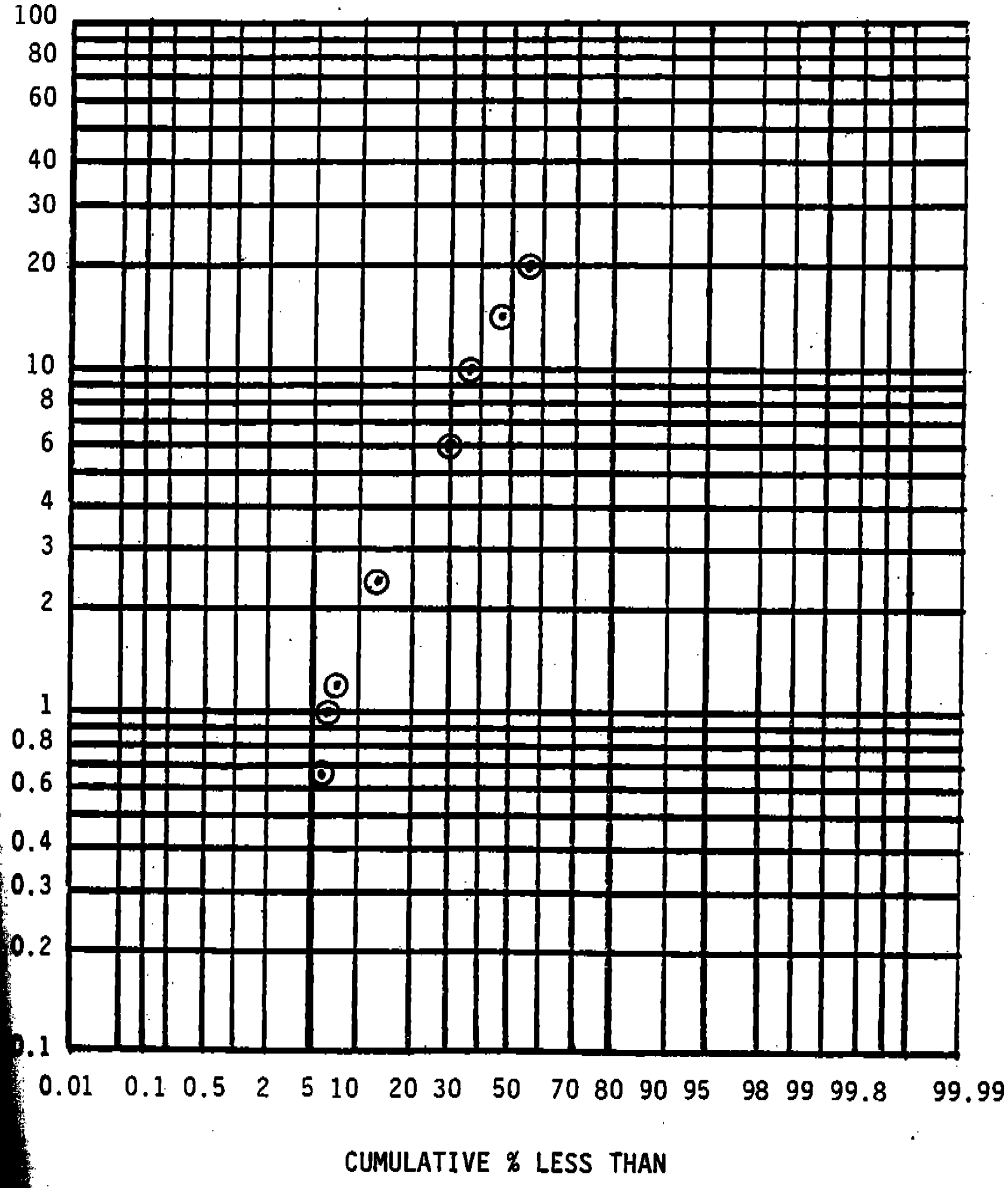

Figure C-33. Particle size distribution data: rotary dryer scrubber inlet (plastic clay)--Plant F1.

TABLE C-19. SUMMARY OF EMISSION TEST RESULTS--PLANT F1

Industry: Fire clay
Process unit: Rotary dryer--Plastic clay
Emission source: Scrubber outlet

Data	Run No. 7[a]	Run No. 17	Run No. 18	Average for test series
General				
Date	3/12/84	3/15/84	3/15/84	--
Sampling time, minutes	125	100	100	--
Isokinetic ratio, percent	114	111	105	--
Production rate, Mg/h	25.6	28.8	31.4	30.1
(tons/h)	(28.2)	(31.7)	(34.6)	(33.2)
Capacity utilization, percent[b]	100	100	100	100
Gas stream data				
Temperature, °C	54	57	56	57
(°F)	(130)	(134)	(132)	(133)
Moisture, percent	12.7	13.1	12.3	12.7
Flow rate, m^3/s	5.1	4.9	5.0	5.0
(acfm)	(10,700)	(10,400)	(10,700)	(10,500)
Flow rate, dsm^3/s	3.9	3.7	3.9	3.8
(dscfm)	(8,260)	(7,900)	(8,240)	(8,070)
Particulate emissions				
g/dsm^3	0.116	0.086	0.054	0.070
(gr/dscf)	(0.051)	(0.038)	(0.024)	(0.031)
kg/h	1.62	1.16	0.76	0.96
(lb/h)	(3.57)	(2.55)	(1.67)	(2.11)
kg/Mg	0.063	0.040	0.024	0.032
(lb/ton)	(0.13)	(0.080)	(0.048)	(0.086)

[a] Isokinetic ratio not within allowable limits; data not included in average.

[b] The dryer was operated at maximum capacity at all times to achieve the desired product quality.

TABLE C-20. SUMMARY OF VISIBLE EMISSIONS--PLANT F1

Date	3/13/84
Industry	Fire clay
Process unit	Rotary dryer-Flint clay
Location of discharge	Scrubber outlet
Height of observation point, ft	--
Height of point of discharge, ft	60
Distance from observer to discharge point, ft	150
Direction of observer from discharge point	--
Description of background	Light grey
Description of sky	Overcast
Wind direction	E
Wind velocity, mph	0-5
Color of plume	White
Duration of observation, min	164
Period of observation	1445-1645 1647-1731
Highest single reading, percent	10
Highest 6-minute average, percent	3.5

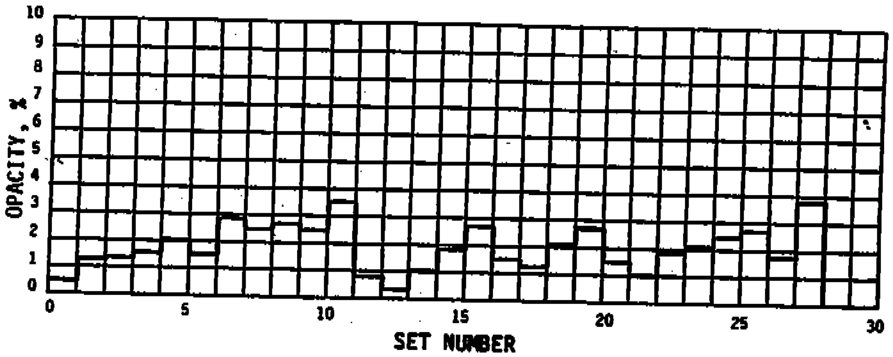

TABLE C-21. SUMMARY OF VISIBLE EMISSIONS--PLANT F1

Date	3/14/84
Industry	Fire clay
Process unit	Rotary dryer-Flint clay
Location of discharge	Scrubber outlet
Height of observation point, ft	--
Height of point of discharge, ft	60
Distance from observer to discharge point, ft	150
Direction of observer from discharge point	--
Description of background	Light grey
Description of sky	Overcast
Wind direction	N
Wind velocity, mph	5-10
Color of plume	White
Duration of observation, min:s	114
Period of observation	1315-1349:15 1420-1545
Highest single reading, percent	5
Highest 6-minute average, percent	3.5

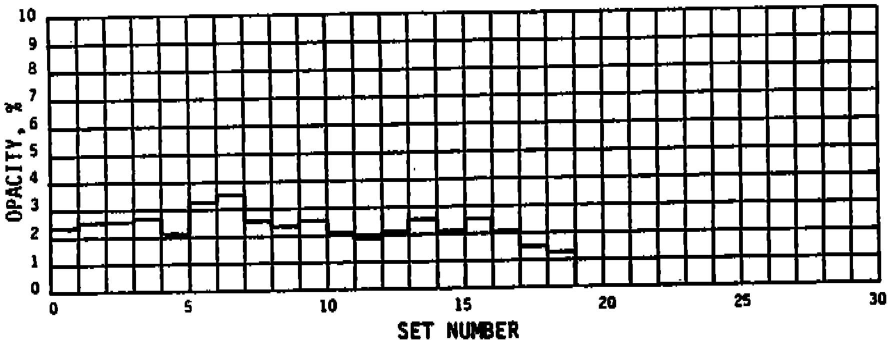

TABLE C-22. TRACE METALS CONCENTRATIONS AND ANALYTICAL RESULTS--PLANT F1

Industry: Fire clay
Process unit: Rotary dryer--Plastic clay
Sample source: Method 5 particulate catch

Element	Run No. 11: Cyclone inlet[a]	Run No. 14: Scrubber inlet[a]	Run No. 17: Scrubber outlet[a]
Aluminum	2,310 (7,439)	442 (848)	13.9 (7.15)
Beryllium	0.080 (0.771)	0.012 (0.0690)	BDL[b]
Calcium	70.5 (153)	12.6 (16.3)	5.23 (1.81)
Chromium	5.42 (9.0557)	1.09 (1.08)	0.036 (0.096)
Fluorine	c	c	c
Iron	190 (296)	32.3 (29.9)	1.46 (0.363)
Lead	0.898 (0.377)	0.171 (0.0427)	0.0217 (0.00145)
Magnesium	8.29 (29.6)	8.56 (18.2)	1.68 (0.959)
Manganese	BDL[d]	BDL[d]	0.012 (0.00303)
ercury	0.0195 (0.00845)	0.005 (0.00129)	0.0024 (0.000166)
ckel	2.80 (4.14)	0.816 (0.719)	0.042 (0.00992)
licon	c	c	c
tanium	2.5 (4.54)	0.67 (0.724)	0.22 (0.0637)
nium	c	c	c
adium	3.560 (6.07)	0.702 (0.713)	0.021 (0.00572)
	2.060 (2.74)	0.288 (0.228)	0.113 (0.0240)

(ppm) of impinger solution.
ow detection limit of 0.001 mg.
reported.
w detection limit of 0.02 mg.

TABLE C-23. SUMMARY OF EMISSION TEST RESULTS--PLANT F1
Industry: Fire clay
Process unit: Rotary dryer--Flint clay
Emission source: Cyclone inlet

Data	Run No. 2	Run No. 3	Run No. 10	Average for test series
General				
Date	3/13/84	3/14/84	3/14/84	--
Sampling time, minutes	24	24	24	--
Isokinetic ratio, percent	104	107	101	--
Production rate, Mg/h	27.6	24.3	13.9	22.0
(tons/h)	(30.4)	(26.8)	(15.3)	(24.2)
Capacity utilization, percent[a]	100	100	100	100
Gas stream data				
Temperature, °C	66	67	65	66
(°F)	(150)	(153)	(149)	(151)
Moisture, percent	14.8	19.5	17.5	17.3
Flow rate, m^3/s	3.2	3.1	3.3	3.2
(acfm)	(6,780)	(6,570)	(6,950)	(6,770)
Flow rate, dsm^3/s	2.3	2.1	2.3	2.2
(dscfm)	(4,900)	(4,480)	(4,890)	(4,750)
Particulate emissions				
g/dsm^3	84	54	88	75
(gr/dscf)	(37)	(24)	(38)	(33)
kg/h	700	411	730	614
(lb/h)	(1,540)	(910)	(1,610)	(1,350)
kg/Mg	25	17	53	32
(lb/ton)	(51)	(34)	(100)	(63)

[a] The dryer was operated at maximum capacity at all times to achieve the desired product quality.

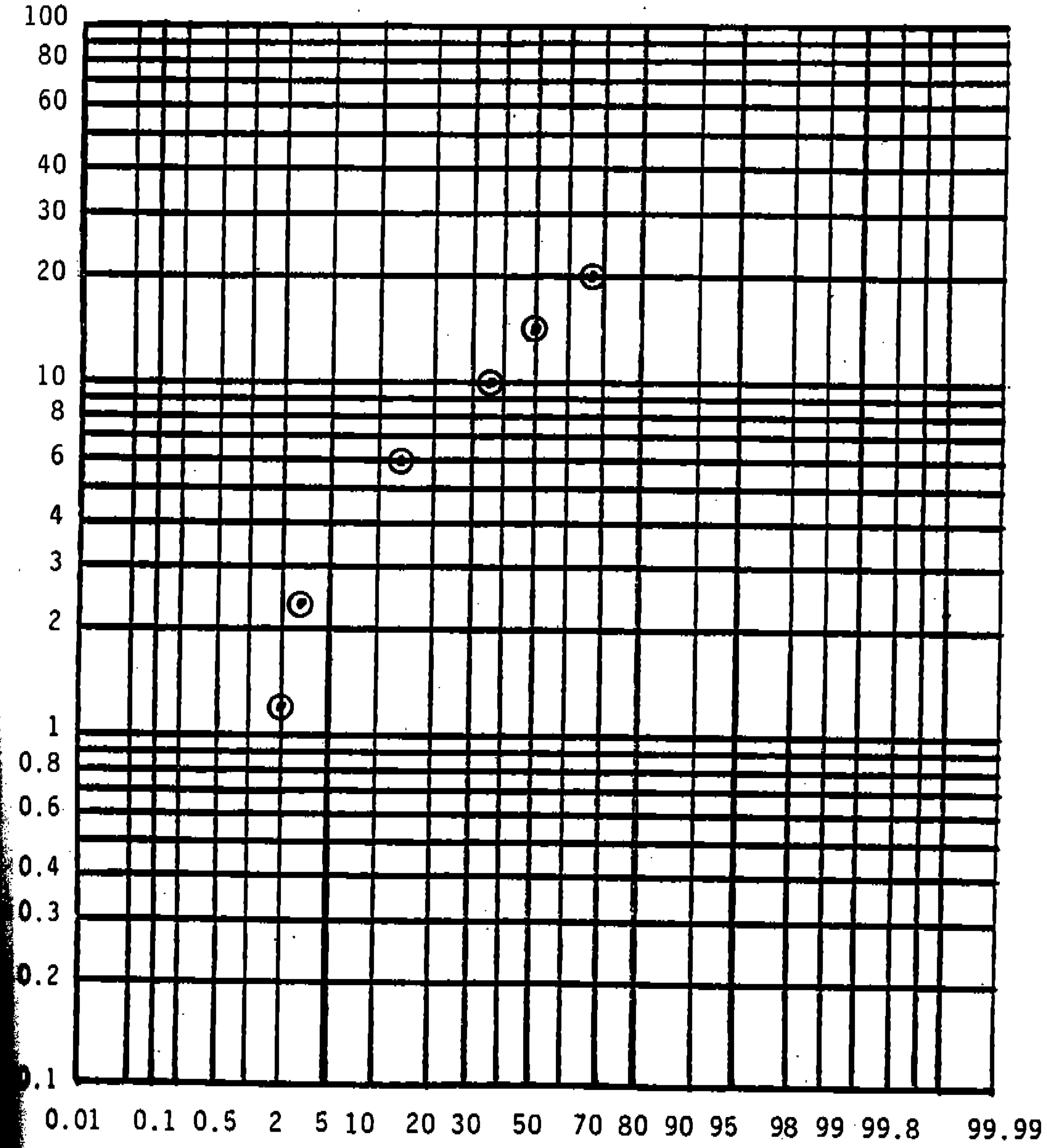

Figure C-34. Particle size distribution data: rotary dryer cyclone inlet (flint clay)--Plant F1.

TABLE C-24. SUMMARY OF EMISSION TEST RESULTS--PLANT F1
Industry: Fire clay
Process unit: Rotary dryer--Flint clay
Emission source: Scrubber inlet

Data	Run No. 5	Run No. 6	Run No. 13	Average for test series
General				
Date	3/13/84	3/14/84	3/14/84	--
Sampling time, minutes	62.5	62.5	40	--
Isokinetic ratio, percent	107	104	101	--
Production rate, Mg/h	27.6	24.3	13.9	22.0
(tons/h)	(30.4)	(26.8)	(15.3)	(24.2)
Capacity utilization, percent[a]	100	100	100	100
Gas stream data				
Temperature, °C	58	60	63	60
(°F)	(136)	(140)	(145)	(140)
Moisture, percent	17.0	18.7	18.3	18.0
Flow rate, m^3/s	4.5	4.5	4.8	4.6
(acfm)	(9,440)	(9,510)	(10,100)	(9,690)
Flow rate, dsm^3/s	3.2	3.1	3.3	3.2
(dscfm)	(6,740)	(6,630)	(7,020)	(6,800)
Particulate emissions				
g/dsm^3	6.91	5.79	14.6	9.11
(gr/dscf)	(3.02)	(2.53)	(6.40)	(3.98)
kg/h	79	65	175	106
(lb/h)	(175)	(144)	(385)	(234)
kg/Mg	2.9	2.7	13	6.1
(lb/ton)	(5.7)	(5.4)	(25)	(12)

[a] The dryer was operated at maximum capacity at all times to achieve the desired product quality.

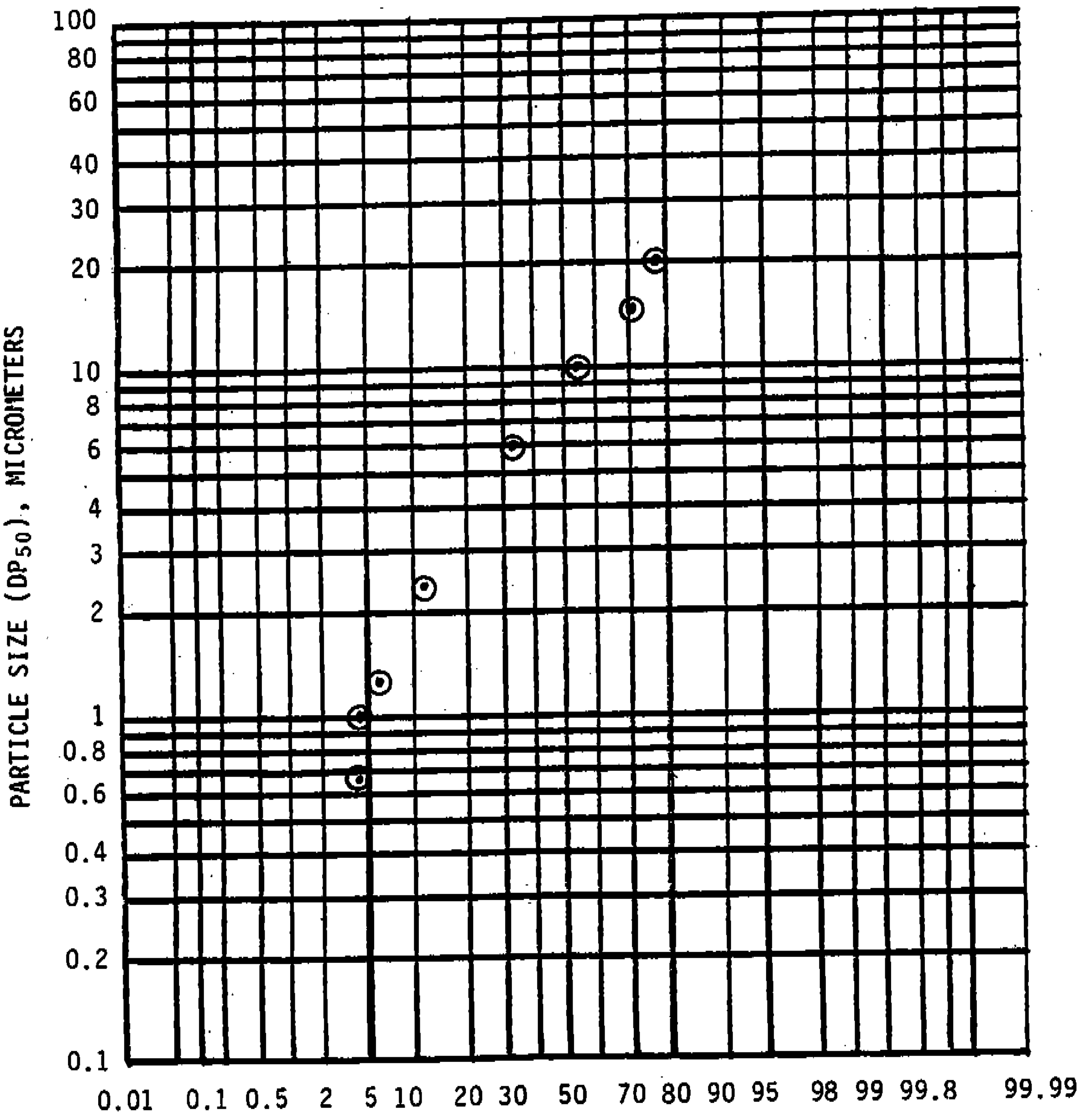

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Figure C-35. Particle size distribution data: rotary dryer scrubber inlet (flint clay)--Plant F1.

TABLE C-25. SUMMARY OF EMISSION TEST RESULTS--PLANT F1

Industry: Fire clay
Process unit: Rotary dryer--Flint clay
Emission source: Scrubber outlet

Data	Run No. 8	Run No. 9	Run No. 16	Average for test series
General				
Date	3/13/84	3/14/84	3/14/84	--
Sampling time, minutes	112	100	75	--
Isokinetic ratio, percent	109	108	101	--
Production rate, Mg/h	27.6	24.3	13.9	21.9
(tons/h)	(30.4)	(26.8)	(15.3)	(24.2)
Capacity utilization, percent[a]	100	100	100	100
Gas stream data				
Temperature, °C	57	56	56	56
(°F)	(134)	(132)	(133)	(133)
Moisture, percent	14.8	19.5	17.5	17.3
Flow rate, m^3/s	5.0	4.8	5.1	5.0
(acfm)	(10,700)	(10,300)	(10,900)	(10,600)
Flow rate, dsm^3/s	3.8	3.7	3.8	3.7
(dscfm)	(7,960)	(7,760)	(8,100)	(7,930)
Particulate emissions				
g/dsm^3	0.068	0.090	0.105	0.088
(gr/dscf)	(0.030)	(0.039)	(0.046)	(0.038)
kg/h	0.92	1.18	1.44	1.18
(lb/h)	(2.03)	(2.61)	(3.18)	(2.61)
kg/Mg	0.033	0.048	0.10	0.54
(lb/ton)	(0.067)	(0.10)	(0.21)	(0.13)

[a] The dryer was operated at maximum capacity at all times to achieve the desired product quality.

TABLE C-26. SUMMARY OF VISIBLE EMISSIONS--PLANT F1

Date	3/14/84
Industry	Fire clay
Process unit	Rotary dryer-Flint clay
Location of discharge	Scrubber outlet
Height of observation point, ft	--
Height of point of discharge, ft	60
Distance from observer to discharge point, ft	150
Direction of observer from discharge point	--
Description of background	Light grey
Description of sky	Overcast
Wind direction	N
Wind velocity, mph	10-15
Color of plume	White
Duration of observation, min	78
Period of observation	1615-1645 1715-1803
Highest single reading, percent	5
Highest 6-minute average, percent	3.3

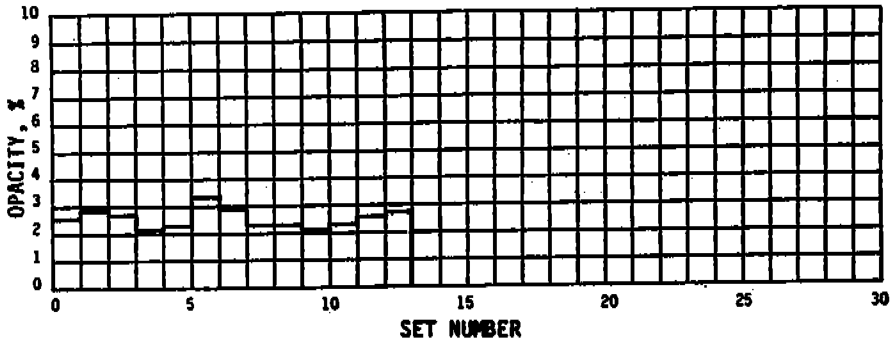

TABLE C-27. SUMMARY OF VISIBLE EMISSIONS--PLANT F1

Date	3/15/84
Industry	Fire clay
Process unit	Rotary dryer-Plastic clay
Location of discharge	Scrubber outlet
Height of observation point, ft	--
Height of point of discharge, ft	60
Distance from observer to discharge point, ft	--
Direction of observer from discharge point	--
Description of background	Grey
Description of sky	Overcast
Wind direction	N
Wind velocity, mph	5-10
Color of plume	White
Duration of observation, min	120
Period of observation	1100-1155 1245-1345
Highest single reading, percent	5
Highest 6-minute average, percent	3.0

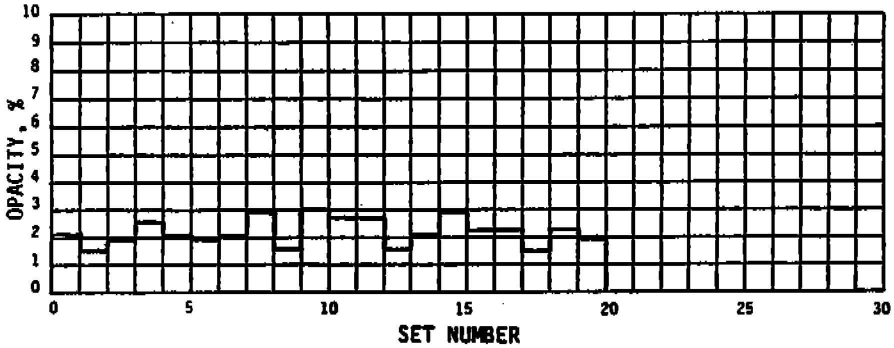

TABLE C-28. SUMMARY OF VISIBLE EMISSIONS--PLANT F1

e	3/15/84
ustry	Fire clay
cess unit	Rotary dryer-Plastic clay
ation of discharge	Scrubber outlet
ght of observation point, ft	--
ght of point of discharge, ft	60
tance from observer to discharge point, ft	150
ection of observer from discharge point	--
cription of background	Grey
cription of sky	Overcast
d direction	NNE
d velocity, mph	5-10
or of plume	White
ation of observation, min	108
iod of observation	1415-1600
hest single reading, percent	5
hest 6-minute average, percent	3.5

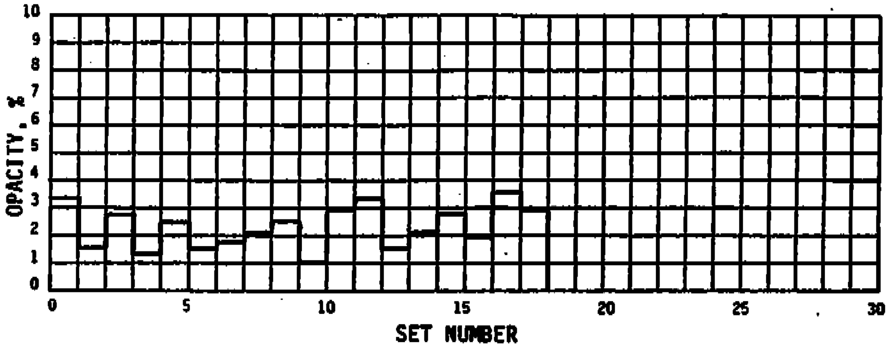

TABLE C-29. TRACE METALS CONCENTRATIONS AND ANALYTICAL RESULTS--PLANT F1
Process unit: Rotary dryer--Flint clay
Sample source: Method 5 particulate catch

Element	Run No. 3: Cyclone inlet[a]	Run No. 6: Scrubber inlet[a]	Run No. 9: Scrubber outlet[a]
Aluminum	955 (3,160)	209 (261)	13.5 (7.23)
Beryllium	0.010 (0.099)	BDL[b]	BDL[b]
Calcium	9.51 (21.2)	2.79 (2.34)	2.16 (0.780)
Chromium	2.72 (4.67)	0.356 (0.231)	0.044 (0.0122)
Fluorine	c	c	c
Iron	105 (168)	28.4 (17.1)	2.08 (0.539)
Lead	0.484 (2.08)	0.156 (0.0254)	0.0228 (0.00159)
Magnesium	17.1 (62.8)	3.71 (5.14)	0.50 (0.298)
Manganese	0.750 (1.22)	BDL[d]	0.016 (0.00421)
Mercury	0.005 (0.00213)	0.003 (0.000571)	0.002 (0.000144)
Nickel	5.460 (8.30)	0.206 (0.118)	0.028 (0.00690)
Silicon	c	c	c
Titanium	1.29 (2.40)	0.68 (0.478)	0.31 (0.0997)
Uranium	c	c	c
Vanadium	0.990 (1.73)	0.262 (0.173)	0.028 (0.00795)
Zinc	4.99 (6.81)	0.192 (0.0990)	0.076 (0.0168)

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[a] mg (ppm) of impinger solution.
[b] Below detection limit of 0.001 mg.
[c] Not reported.
[d] Below detection limit of 0.01 mg.

TABLE C-30. SUMMARY OF EMISSION TEST RESULTS--PLANT F2
Industry: Fire clay
Process unit: Rotary calciner
Emission source: Multiple cyclone collector inlet

Data	Run No. 1[a]	Run No. 2	Run No. 3	Run No. 4	Average for test series
General					
Date	10/18/83	10/20/83	10/21/83	10/21/83	--
Sampling time, minutes	98	112	112	112	--
Isokinetic ratio, percent	119	106	107	102	--
Production rate, Mg/h	7.2	7.2	7.2	7.2	7.2
(tons/h)	(8)	(8)	(8)	(8)	(8)
Capacity utilization, percent	100	100	100	100	100
Gas stream data					
Temperature, °C	456	450	455	447	451
(°F)	(853)	(842)	(851)	(837)	(843)
Moisture, percent	18.5	21.1	21.8	20.6	21.2
Flow rate, m^3/s	19	19	19	20	20
(acfm)	(40,000)	(41,000)	(41,000)	(40,000)	(41,300)
Flow rate, dsm^3/s	6.1	6.1	6.1	6.1	6.1
(dscfm)	(13,000)	(13,000)	(13,000)	(13,000)	(13,000)
Particulate emissions					
g/dsm^3	11.3	24.0	20.7	17.8	20.8
(gr/dscf)	(7.87)	(10.5)	(9.03)	(7.77)	(9.10)
kg/h	394	522	438	397	452
(lb/h)	(870)	(1,150)	(964)	(875)	(997)
kg/Mg	49	73	61	55	63
(lb/ton)	(110)	(140)	(120)	(110)	(120)

[a] Isokinetic ratio not within allowable limits; data not included in average.

TABLE C-31. SUMMARY OF EMISSION TEST RESULTS--PLANT F2

Industry: Fire clay
Process unit: Rotary calciner
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	10/18/83	10/20/83	10/21/83	--
Sampling time, minutes	192	192	204	--
Isokinetic ratio, percent	108	102	102	--
Production rate, Mg/h	7.2	7.2	7.2	7.2
(tons/h)	(8)	(8)	(8)	(8)
Capacity utilization, percent	100	100	100	100
Gas stream data				
Temperature, °C	62	62	63	62
(°F)	(143)	(144)	(145)	(144)
Moisture, percent	20.2	19.4	19.8	19.8
Flow rate, m^3/s	8.0	8.0	8.5	8.2
(acfm)	(17,000)	(17,000)	(18,000)	(17,300)
Flow rate, dsm^3/s	5.7	5.7	5.7	5.7
(dscfm)	(12,000)	(12,000)	(12,000)	(12,000)
Particulate emissions				
g/dsm^3	0.028	0.013	0.012	0.018
(gr/dscf)	(0.012)	(0.006)	(0.005)	(0.008)
kg/h	0.56	0.26	0.26	0.36
(lb/h)	(1.23)	(0.57)	(0.57)	(0.79)
kg/Mg	0.078	0.036	0.036	0.050
(lb/ton)	(0.15)	(0.071)	(0.071)	(0.10)

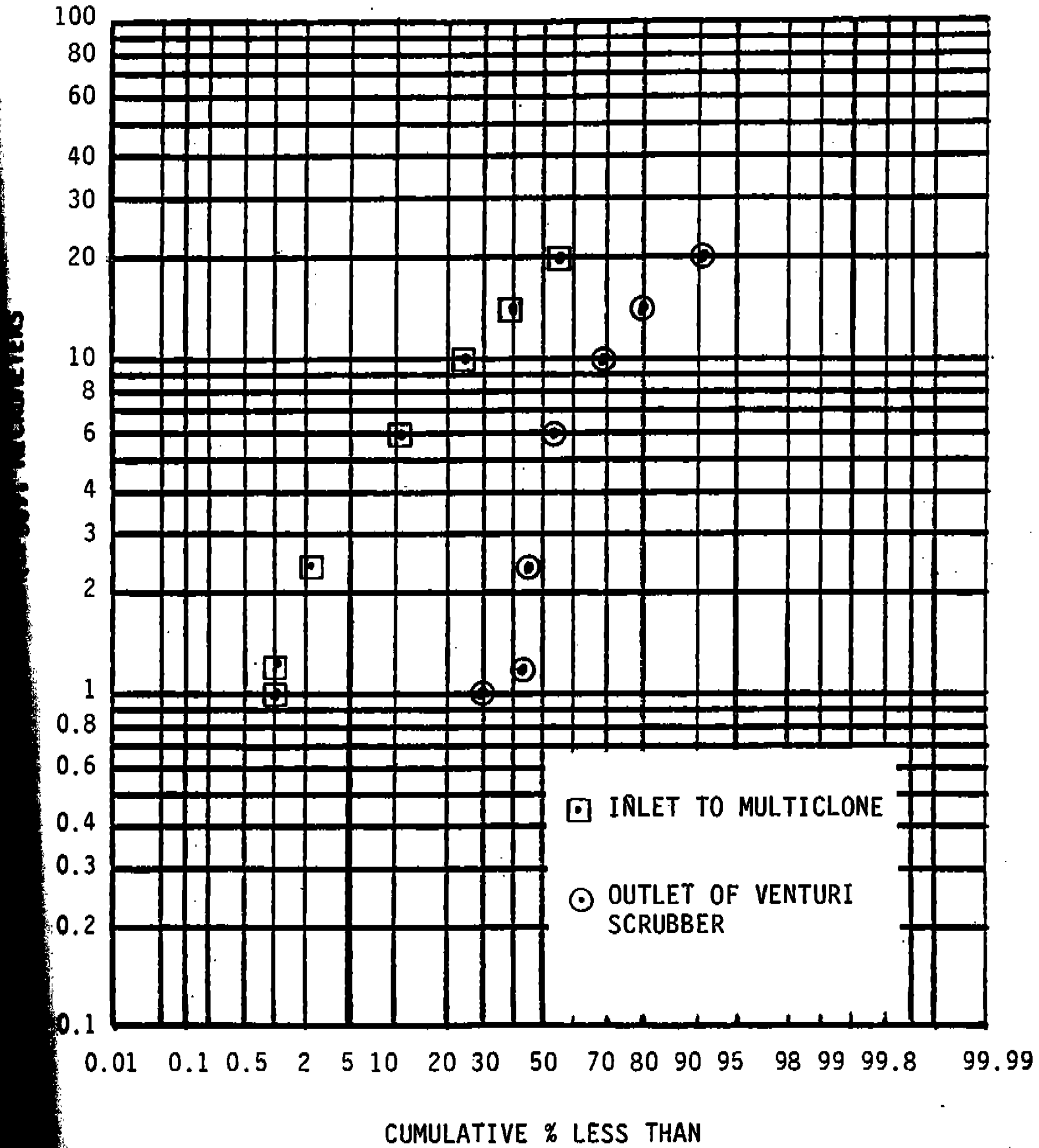

Figure C-36. Particle size distribution data: rotary calciner--Plant F2.

TABLE C-32. SUMMARY OF EMISSION TEST RESULTS--PLANT F3

Industry: Fire clay
Process unit: Rotary calciner
Emission source: Multiple cyclone collector inlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	4/17/84	4/17/84	4/17/84	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	108	104	110	--
Production.rate, Mg/h	a	a	a	a
(tons/h)				
Capacity utilization, percent	98	98	98	98
Gas stream data				
Temperature, °C	312	316	317	315
(°F)	(593)	(601)	(602)	(599)
Moisture, percent	12.3	12.2	11.6	12.0
Flow rate, m^3/s	37	37	35	36
(acfm)	(78,900)	(78,100)	(73,400)	(76,800)
Flow rate, dsm^3/s	16	16	15	16
(dscfm)	(34,000)	(33,400)	(31,700)	(33,000)
Particulate emissions				
g/dsm^3	17.2	18.9	16.4	17.5
(gr/dscf)	(7.52)	(8.24)	(7.17)	(7.64)
kg/h	1,000	1,100	900	1,000
(lb/h)	(2,200)	(2,400)	(2,000)	(2,200)
kg/Mg	a	a	a	a
(lb/ton)				

[a] [redacted]

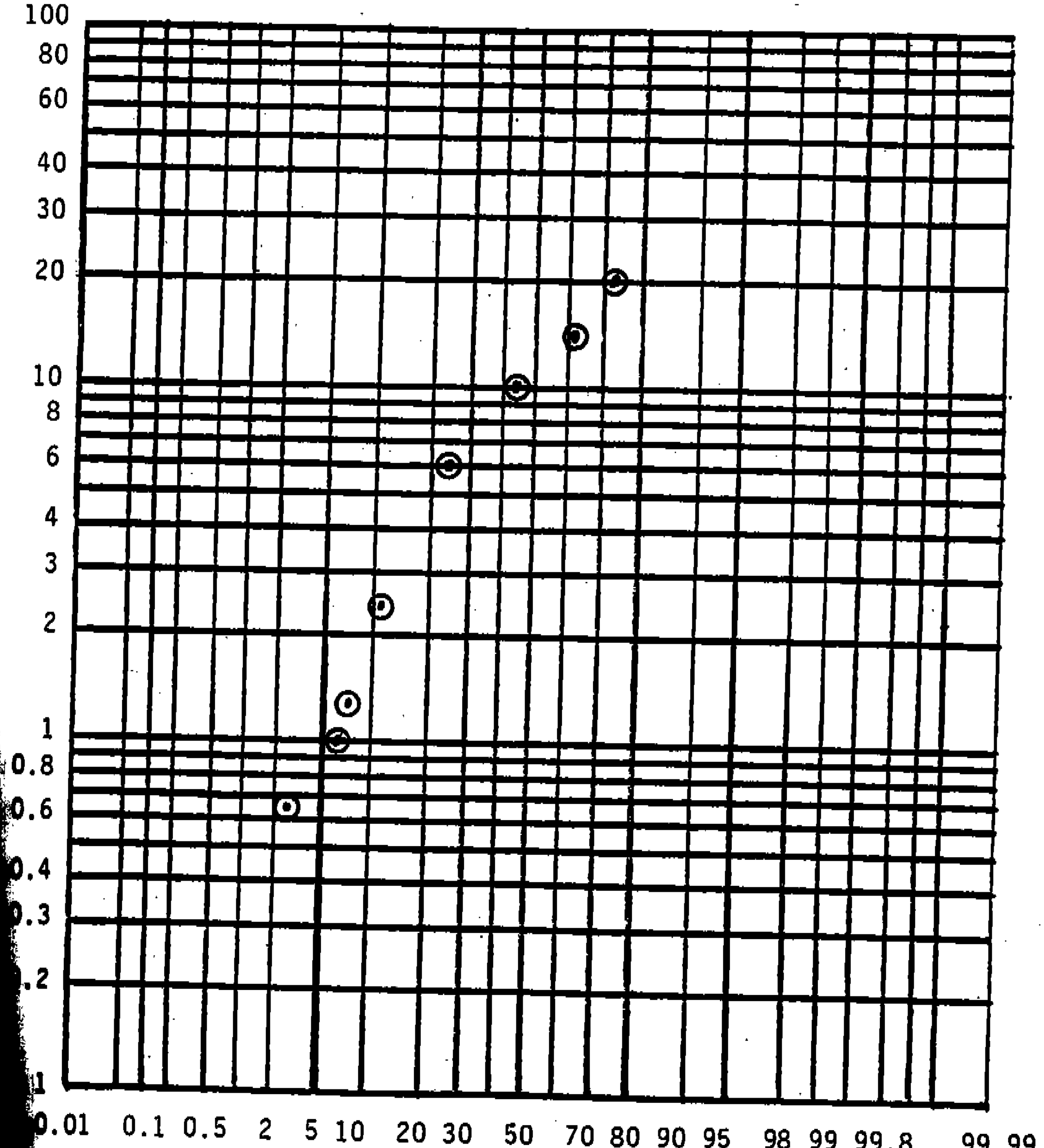

Figure C-37. Particle size distribution data: rotary calciner multiple cyclone inlet--Plant F3.

TABLE C-33. SUMMARY OF EMISSION TEST RESULTS--PLANT F3

Industry: Fire clay
Process unit: Rotary calciner
Emission source: I.D. Fan Inlet--East (Scrubber Inlet)

Data	Run No. 4	Run No. 5	Run No. 6	Average for test series
General				
Date	4/17/84	4/17/84	4/18/84	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	102	107	104	--
Production rate, Mg/h	a	a	a	a
(tons/h)				
Capacity utilization, percent	98	98	98	98
Gas stream data				
Temperature, °C	287	285	291	288
(°F)	(549)	(545)	(555)	(550)
Moisture, percent	13.1	13.4	11.8	12.8
Flow rate, m^3/s	16	16	16	16
(acfm)	(33,300)	(34,000)	(35,000)	(34,000)
Flow rate, dsm^3/s	7.0	7.1	7.3	7.1
(dscfm)	(14,700)	(15,000)	(15,500)	(15,100)
Particulate emissions				
g/dsm^3	10.1	10.0	9.50	9.86
(gr/dscf)	(4.39)	(4.39)	(4.15)	(4.31)
kg/h	250	260	250	250
(lb/h)	(550)	(570)	(550)	(560)
kg/Mg	a	a	a	a
(lb/ton)				

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[a] Confidential data

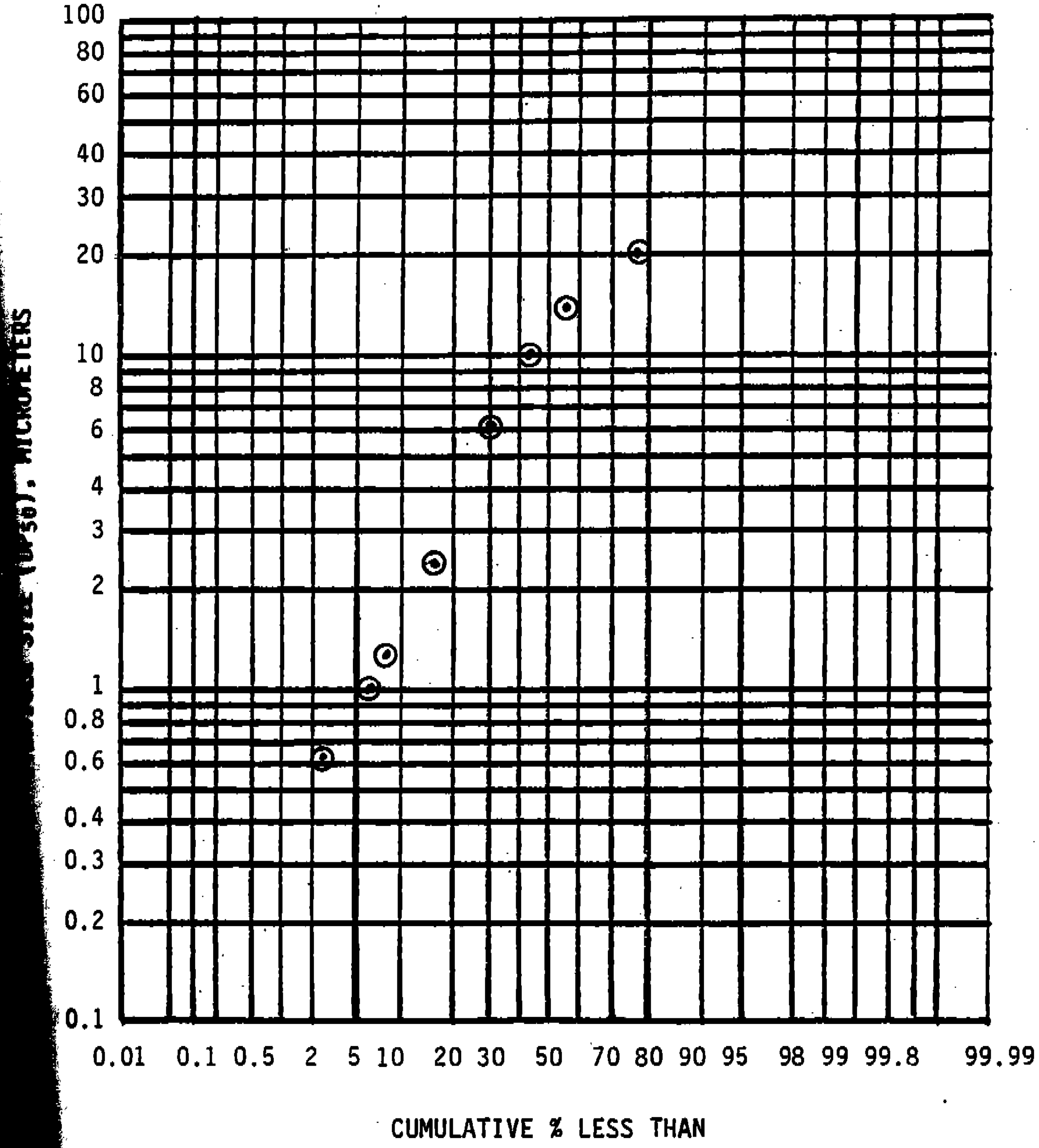

Figure C-38. Particle size distribution data: rotary calciner scrubber inlet (East)--Plant F3.

TABLE C-34. SUMMARY OF EMISSION TEST RESULTS--PLANT F3
Industry: Fire clay
Process unit: Rotary calciner
Emission source: I.D. Fan Inlet--West (Scrubber Inlet)

Data	Run No. 7	Run No. 8	Run No. 9	Average for test series
General				
Date	4/17/84	4/17/84	4/18/84	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	106	102	103	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent	98	98	98	98
Gas stream data				
Temperature, °C	284	282	285	283
(°F)	(543)	(539)	(545)	(542)
Moisture, percent	13.3	13.9	13.6	13.6
Flow rate, m^3/s	16	16	15	16
(acfm)	(33,200)	(33,300)	(32,200)	(33,000)
Flow rate, dsm^3/s	7.0	7.0	6.7	6.9
(dscfm)	(14,700)	(14,700)	(14,300)	(14,600)
Particulate emissions				
g/dsm^3	8.38	8.54	8.57	8.50
(gr/dscf)	(3.66)	(3.73)	(3.75)	(3.71)
kg/h	210	210	210	210
(lb/h)	(460)	(470)	(460)	(470)
kg/Mg (lb/ton)	a	a	a	a

[a] Confidential data.

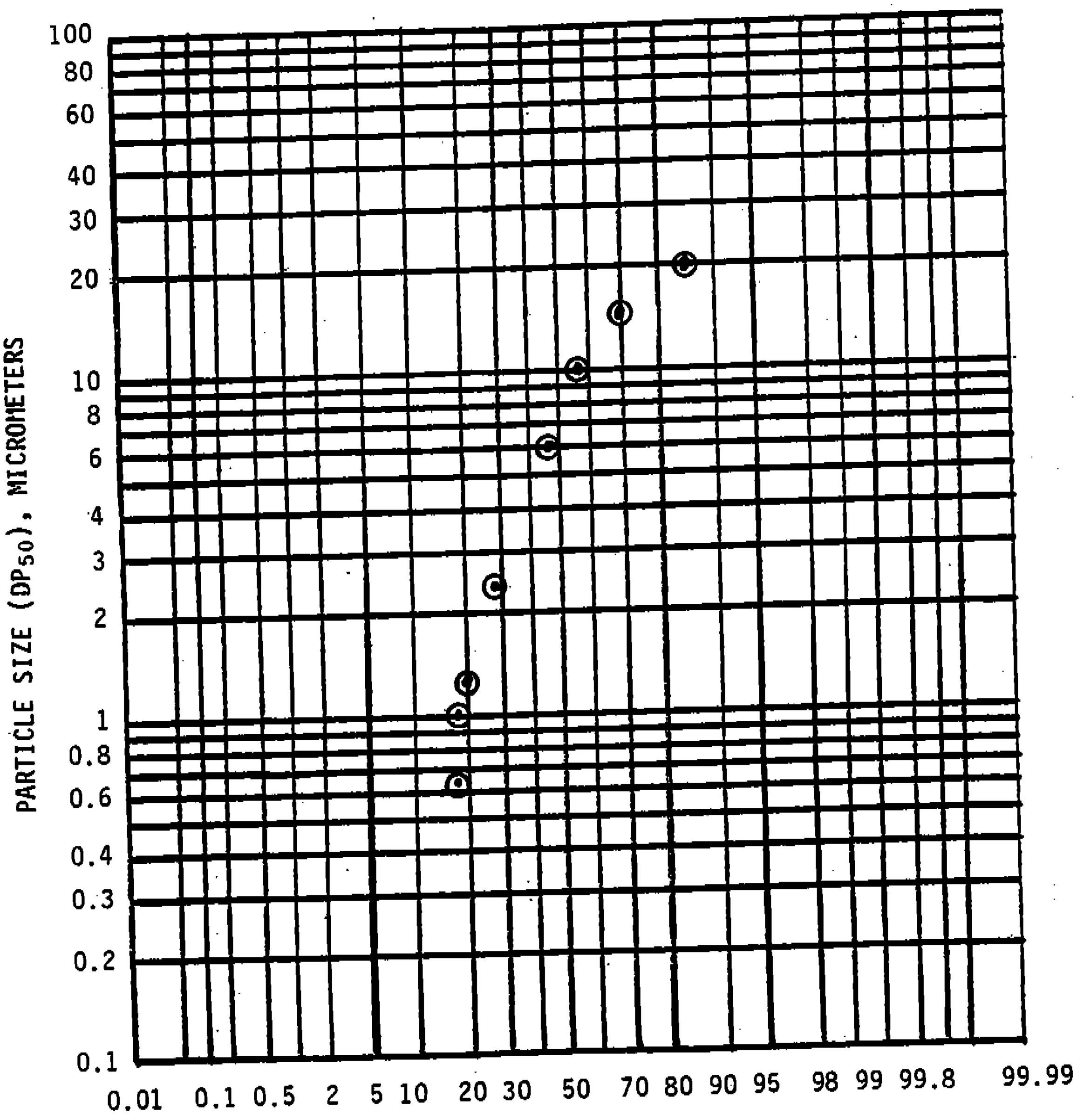

Figure C-39. Particle size distribution data: rotary calciner scrubber inlet (West)--Plant F3.

TABLE C-35. SUMMARY OF EMISSION TEST RESULTS--PLANT F3

Industry: Fire clay
Process unit: Rotary calciner
Emission source: Scrubber outlet

Data	Run No. 10	Run No. 11	Run No. 12	Average for test series
General				
Date	4/17/84	4/17/84	4/18/84	--
Sampling time, minutes	120	120	120	--
Isokinetic ratio, percent	99	100	98	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent	98	98	98	98
Gas stream data				
Temperature, °C	60	60	61	60
(°F)	(140)	(140)	(141)	(140)
Moisture, percent	19.9	19.9	19.0	19.6
Flow rate, m^3/s	20	20	21	20
(acfm)	(42,000)	(43,200)	(43,600)	(43,000)
Flow rate, dsm^3/s	14	14	14	14
(dscfm)	(29,100)	(29,900)	(30,400)	(29,800)
Particulate emissions				
g/dsm^3	0.077	0.072	0.079	0.076
(gr/dscf)	(0.034)	(0.032)	(0.034)	(0.033)
kg/h	3.8	3.7	4.1	3.9
(lb/h)	(8.4)	(8.1)	(9.0)	(8.5)
kg/Mg (lb/ton)	a	a	a	a

[a] Confidential data.

TABLE C-36. TRACE METALS CONCENTRATIONS AND ANALYTICAL RESULTS--PLANT F3
Industry: Fire clay
Process unit: Rotary calciner
Sample source: Method 5 particulate catch

Element	Run No. 2: Multiclone inlet[a]	Run No. 11: Scrubber outlet[a]
Aluminum	774 (817)	8.3 (2.84)
Beryllium	0.018 (0.0569)	BDL[b]
Calcium	18 (12.8)	2.07 (0.477)
Chromium	1.58 (0.865)	0.02 (0.00356)
Fluorine	c	c
Iron	69.8 (35.6)	0.88 (0.146)
Lead	0.431 (0.0592)	0.0276 (0.00123)
Magnesium	5.49 (6.43)	0.22 (0.0837)
Manganese	0.162 (0.084)	BDL[d]
Mercury	0.0318 (0.00451)	0.003 (0.000138)
Nickel	1.17 (0.567)	0.028 (0.00441)
Silicon	c	c
Titanium	9.13 (5.43)	0.27 (0.0521)
Uranium	c	c
Vanadium	1.11 (0.62)	0.056 (0.01)
Zinc	4.43 (1.93)	0.067 (0.00947)

[a] mg (ppm) of impinger solution.
[b] Below detection limit of 0.010 mg.
[c] Not reported.
[d] Below detection limit of 0.01 mg.

TABLE C-37. TRACE METALS CONCENTRATIONS AND ANALYTICAL RESULTS--PLANT F3

Industry: Fire clay
Process unit: Rotary calciner
Sample source: Method 5 particulate catch

Element	Run No. 5: I. D. fan inlet East[a]	Run No. 8: I. D. fan inlet West[a]
Aluminum	511 (598)	27 (527)
Beryllium	0.02 (0.07)	0.016 (0.0566)
Calcium	12.6 (9.92)	12.5 (9.95)
Chromium	0.44 (0.267)	0.392 (0.240)
Fluorine	b	b
Iron	44.8 (25.3)	39.7 (22.7)
Lead	0.292 (0.0445)	0.27 (0.0416)
Magnesium	5.00 (6.49)	4.34 (5.69)
Manganese	0.088 (0.051)	0.056 (0.0325)
Mercury	0.0098 (0.00154)	0.0132 (0.0021)
Nickel	0.376 (0.202)	0.428 (0.233)
Silicon	b	b
Titanium	6.90 (4.54)	4.5 (3)
Uranium	b	b
Vanadium	0.76 (0.471)	0.7 (0.438)
Zinc	0.332 (0.160)	0.430 (0.210)

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[a] mg (ppm) of impinger solution.
[b] Not reported.

TABLE C-38. SUMMARY OF SULFUR DIOXIDE EMISSIONS DATA--PLANT F3

Industry: Fire clay
Process unit: Rotary calciner
Location of discharge: Scrubber outlet

Test location	Date, 1984	Concentration, g/dsm^3 (ppm)	Mass emission rate, kg/h (lb/h)	Temp., °C (°F)
Scrubber outlet				
Run No. 10	4/17	1.15 (432)	56.8 (125)	60 (140)
Run No. 11	4/17	1.16 (434)	58.7 (130)	60 (140)
Run No. 12	4/18	1.07 (402)	55.2 (122)	61 (141)
Average	--	1.13 (423)	56.9 (126)	60 (140)

TABLE C-39. SUMMARY OF NITROGEN OXIDE EMISSIONS DATA--PLANT F3

Industry: Fire clay
Process unit: Rotary calciner
Location of discharge: Scrubber outlet

Test location	Date, 1984	Concentration, g/dsm³ (ppm)	Mass emission rate, kg/h (lb/h)
<u>Scrubber outlet</u>			
Sample No. 10A	4/17	0.520 (272)	25.6 (56.5)
Sample No. 10B	4/17	0.526 (275)	25.9 (57.2)
Sample No. 10C	4/17	0.503 (263)	24.8 (54.6)
Sample No. 10D	4/17	0.483 (253)	23.8 (52.5)
Average	--	0.508 (266)	25.0 (55.2)
Sample No. 11A	4/17	0.572 (299)	29.0 (64.0)
Sample No. 11B	4/17	0.566 (296)	28.7 (63.3)
Sample No. 11C	4/17	0.612 (320)	31.1 (68.5)
Sample No. 11D	4/17	0.635 (332)	32.3 (71.1)
Average	--	0.596 (311)	30.3 (66.7)
Sample No. 12A	4/18	0.577 (302)	29.8 (65.7)
Sample No. 12B	4/18	0.562 (294)	29.0 (63.9)
Sample No. 12C	4/18	0.723 (378)	37.3 (82.2)
Sample No. 12D	4/18	0.596 (312)	30.8 (67.9)
Average	--	0.614 (321)	31.7 (70.0)

TABLE C-40. SUMMARY OF EMISSION TEST RESULTS--PLANT G1

Industry: Fuller's earth
Process unit: Rotary dryer
Emission source: Scrubber outlet

Data	Run No. 1[a]	Run No. 2	Run No. 3	Average for test series
General				
Date	9/9/76	9/9/76	9/9/76	--
Sampling time, minutes	64	80	80	--
Isokinetic ratio, percent	106	97	106	--
Production rate, Mg/h (tons/h)	b	b	b	b
Capacity utilization, percent[c]	106	99	103	102
Gas stream data				
Temperature, °C	94	76	77	76.5
(°F)	(202)	(169)	(170)	(169.5)
Moisture, percent	36.2	34.1	38.7	36.4
Flow rate, m^3/s	13	12	12	12
(acfm)	(26,900)	(25,100)	(25,800)	(25,500)
Flow rate, dsm^3/s	6.4	6.5	6.2	6.4
(dscfm)	(13,600)	(13,800)	(13,200)	(13,500)
Particulate emissions				
g/dsm^3	0.134	0.050	0.069	0.059
(gr/dscf)	(0.059)	(0.022)	(0.030)	(0.026)
kg/h	3.1	1.2	1.6	1.4
(lb/h)	(6.8)	(2.5)	(3.4)	(3.0)
kg/Mg (lb/ton)	b	b	b	b

[a] Scrubber malfunction; data not included in average.
[b] Confidential data.
[c] Estimated using feed rate and material moisture content.

TABLE C-41. SUMMARY OF EMISSION TEST RESULTS--PLANT H1

Industry: Gypsum
Process unit: Kettle calciner No. 1
Emission source: Baghouse outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	11/19/75	11/19/75	11/19/75	--
Sampling time, minutes	66	65	65	--
Isokinetic ratio, percent	121	102	94	--
Production rate, Mg/h[a]	11.9	11.9	11.9	11.9
(tons/h)	(13.1)	(13.1)	(13.1)	(13.1)
Capacity utilization, percent	100	100	100	100
Gas stream data				
Temperature, °C	118	118	118	118
(°F)	(245)	(245)	(244)	(245)
Moisture, percent	65.6	64.6	60.8	63.7
Flow rate, m^3/s	0.89	0.89	0.89	0.89
(acfm)	(1,860)	(1,880)	(1,880)	(1,870)
Flow rate, dsm^3/s	0.22	0.23	0.26	0.24
(dscfm)	(472)	(492)	(544)	(503)
Particulate emissions				
g/dsm^3	0.014	0.007	0.076	0.032
(gr/dscf)	(0.006)	(0.003)	(0.033)	(0.014)
kg/h	0.009	0.005	0.09	0.035
(lb/h)	(0.02)	(0.01)	(0.20)	(0.077)
kg/Mg	0.001	0.0004	0.008	0.003
(lb/ton)	(0.002)	(0.0008)	(0.015)	(0.006)

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[a] Process weight rate.

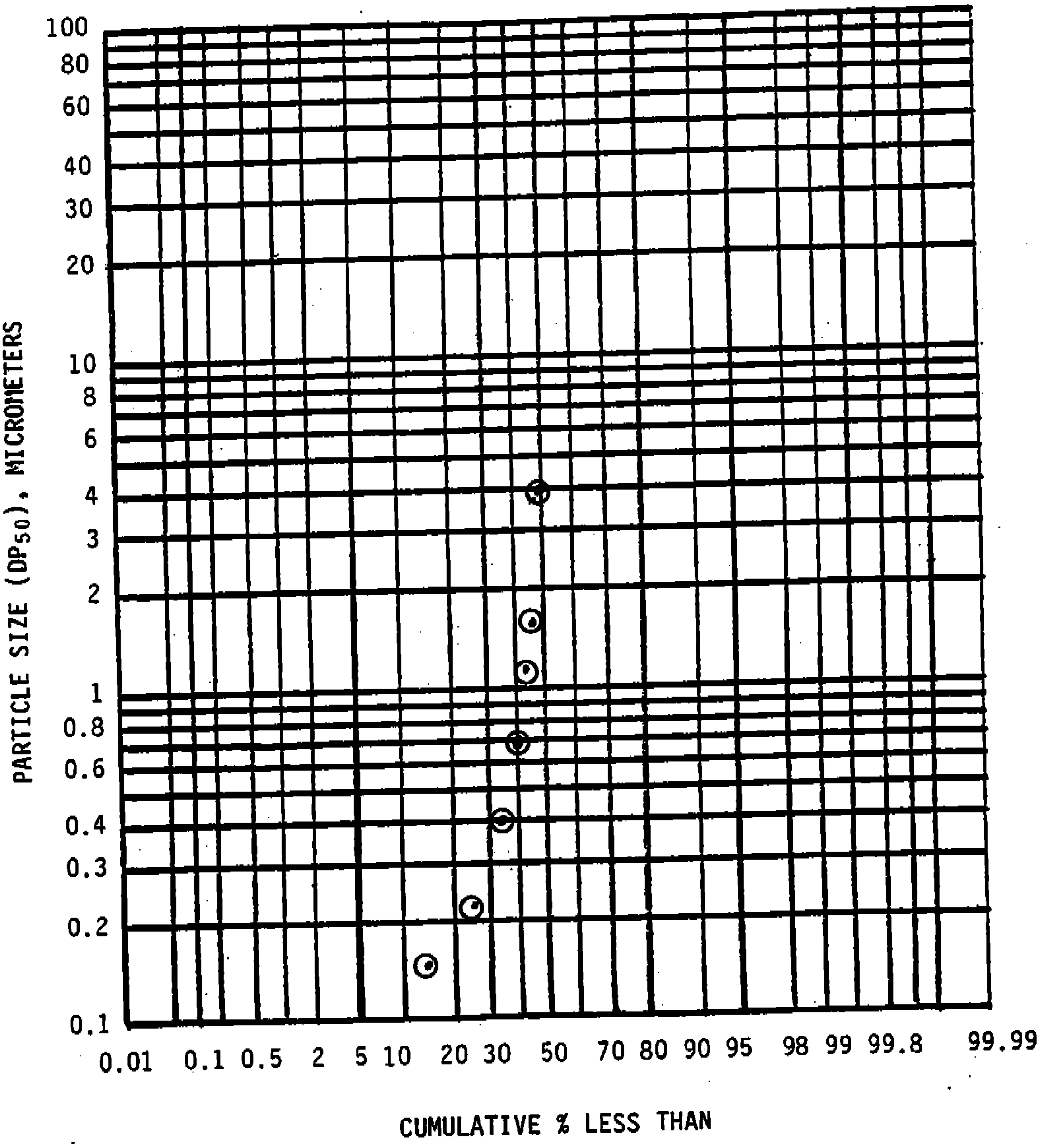


Figure C-40. Particle size distribution data: rotary dryer baghouse outlet--Plant H1.

TABLE C-42. SUMMARY OF EMISSION TEST RESULTS--PLANT H1

Industry: Gypsum
Process unit: Kettle calciner No. 4
Emission source: Baghouse inlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	6/3/80	6/3/80	6/4/80	--
Sampling time, minutes	98	86	81	--
Isokinetic ratio, percent	105	103	98	--
Production rate, Mg/h	10.4	10.4	10.4	10.4
(tons/h)	(11.5)	(11.5)	(11.5)	(11.5)
Capacity utilization, percent	100	100	100	100
Gas stream data				
Temperature, °C	129	129	126	128
(°F)	(264)	(264)	(259)	(262)
Moisture, percent	69.8	72.2	73.4	71.8
Flow rate, m^3/s	1.2	1.2	1.2	1.2
(acfm)	(2,590)	(2,600)	(2,610)	(2,600)
Flow rate, dsm^3/s	0.27	0.25	0.24	0.25
(dscfm)	(564)	(522)	(505)	(530)
Particulate emissions				
g/dsm^3	221	259	272	251
(gr/dscf)	(97)	(113)	(119)	(110)
kg/h	212	230	234	225
(lb/h)	(467)	(507)	(515)	(496)
kg/Mg	20	22	23	22
(lb/ton)	(41)	(44)	(45)	(43)

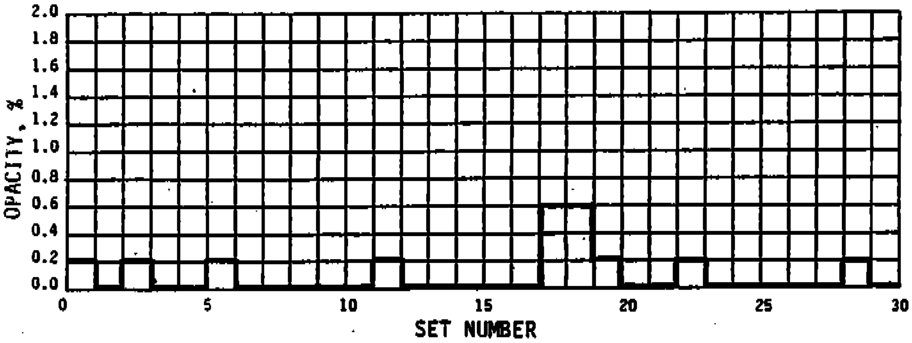
TABLE C-43. SUMMARY OF EMISSION TEST RESULTS--PLANT H1

Industry: Gypsum
Process unit: Kettle calciner No. 4
Emission source: Baghouse outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	6/3/80	6/3/80	6/4/80	--
Sampling time, minutes	78	130	113	--
Isokinetic ratio, percent	105	103	108	--
Production rate, Mg/h	10.4	10.4	10.4	10.4
(tons/h)	(11.5)	(11.5)	(11.5)	(11.5)
Capacity utilization, percent	100	100	100	100
Gas stream data				
Temperature, °C	118	120	114	117
(°F)	(245)	(248)	(238)	(244)
Moisture, percent	68.9	69.1	69.9	69.3
Flow rate, m³/s	1.1	1.1	1.1	1.1
(acfm)	(2,340)	(2,360)	(2,370)	(2,360)
Flow rate, dsm³/s	0.26	0.25	0.25	0.25
(dscfm)	(542)	(540)	(538)	(540)
Particulate emissions				
g/dsm³	0.046	0.014	0.023	0.028
(gr/dscf)	(0.020)	(0.006)	(0.010)	(0.012)
kg/h	0.04	0.013	0.023	0.026
(lb/h)	(0.09)	(0.03)	(0.05)	(0.04)
kg/Mg	0.004	0.001	0.002	0.002
(lb/ton)	(0.008)	(0.002)	(0.004)	(0.005)

TABLE C-44. SUMMARY OF VISIBLE EMISSIONS--PLANT H1

Date	6/3-4/80
Industry	Gypsum
Process unit	Kettle calciner
Location of discharge	Baghouse outlet
Height of observation point, ft	Ground
Height of point of discharge, ft	Level 2 plus 5 ft
Distance from observer to discharge point, ft	100
Direction of observer from discharge point	SW
Description of background	Blue sky
Description of sky	Partly cloudy
Wind direction	W
Wind velocity, mph	5
Color of plume	White
Duration of observation, min	348
Period of observation	
6/3/80	0925-1130
	1400-1542
6/4/80	0830-1030
Highest single reading, percent	5
Highest 6-minute average, percent	0.6



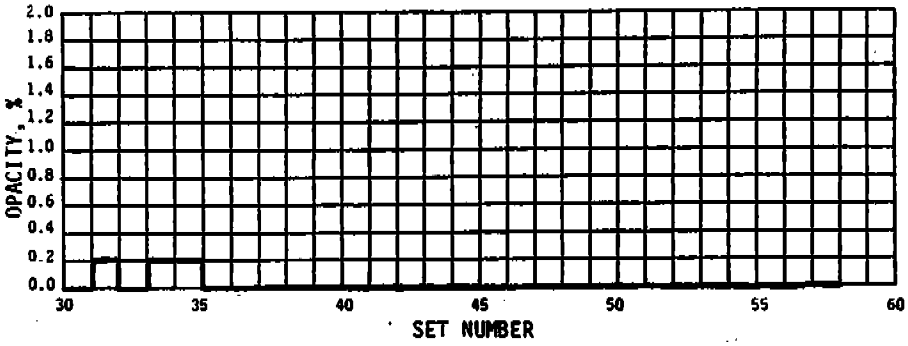


TABLE C-45. SUMMARY OF EMISSION TEST RESULTS--PLANT H1
Industry: Gypsum
Process unit: Rotary dryer
Emission source: Baghouse inlet

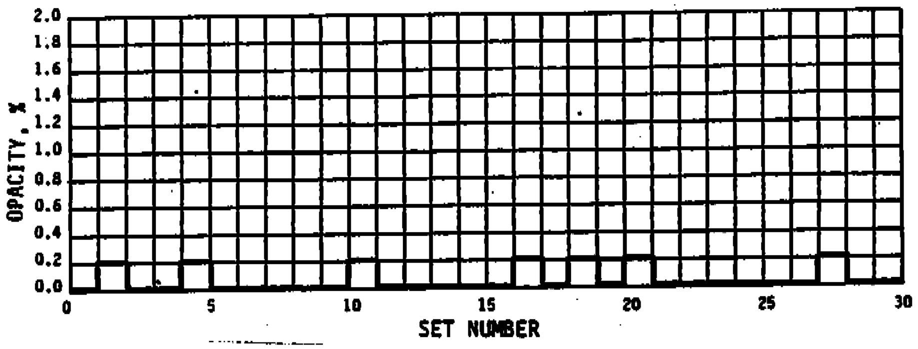
Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	6/5/80	6/6/80	6/6/80	--
Sampling time, minutes	84	82	81	--
Isokinetic ratio, percent	107	109	109	--
Production rate, Mg/h	63.5	63.5	63.5	63.5
(tons/h)	(70)	(70)	(70)	(70)
Capacity utilization, percent	92	92	92	92
Gas stream data				
Temperature, °C	79	78	81	79
(°F)	(174)	(173)	(178)	(175)
Moisture, percent	9.1	8.9	9.0	9.0
Flow rate, m^3/s	4.7	4.5	4.5	4.6
(acfm)	(9,950)	(9,550)	(9,600)	(9,700)
Flow rate, dsm^3/s	3.5	3.4	3.4	3.4
(dscfm)	(7,500)	(7,150)	(7,150)	(7,270)
Particulate emissions				
g/dsm^3	7.41	9.56	9.45	8.81
(gr/dscf)	(3.24)	(4.18)	(4.13)	(3.85)
kg/h	94	117	115	107
(lb/h)	(208)	(257)	(253)	(239)
kg/Mg	1.5	1.9	1.8	1.7
(lb/ton)	(3.0)	(3.7)	(3.6)	(3.4)

TABLE C-46. SUMMARY OF EMISSION TEST RESULTS--PLANT H1
Industry: Gypsum
Process unit: Rotary dryer
Emission source: Baghouse outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	6/5/80	6/6/80	6/6/80	--
Sampling time, minutes	85	157	81	--
Isokinetic ratio, percent	106	104	110	--
Production rate, Mg/h	63.5	63.5	63.5	63.5
(tons/h)	(70)	(70)	(70)	(70)
Capacity utilization, percent	92	92	92	92
Gas stream data				
Temperature, °C	78	76	79	78
(°F)	(172)	(169)	(174)	(172)
Moisture, percent	9.0	9.2	9.4	9.2
Flow rate, m^3/s	4.9	4.9	4.7	4.8
(acfm)	(10,300)	(10,300)	(9,950)	(10,200)
Flow rate, dsm^3/s	3.7	3.7	3.5	3.7
(dscfm)	(7,900)	(7,850)	(7,500)	(7,750)
Particulate emissions				
g/dsm^3	0.009	0.009	0.011	0.010
(gr/dscf)	(0.004)	(0.004)	(0.005)	(0.004)
kg/h	0.14	0.12	0.15	0.14
(lb/h)	(0.30)	(0.28)	(0.34)	(0.31)
kg/Mg	0.002	0.002	0.002	0.002
(lb/ton)	(0.004)	(0.004)	(0.005)	(0.004)

TABLE C-47. SUMMARY OF VISIBLE EMISSIONS--PLANT H1

Date	6/5-6/80
Industry	Gypsum
Process unit	Rotary dryer
Location of discharge	Baghouse outlet
Height of observation point, ft	10 ft below stack
Height of point of discharge, ft	Level 2 + 20 ft
Distance from observer to discharge point, ft	15
Direction of observer from discharge point	W
Description of background	Grey building
Description of sky	Partly cloudy
Wind direction	W
Wind velocity, mph	3-5
Color of plume	White
Duration of observation, min	264
Period of observation	
5/5/80	1810-1930
5/6/80	0930-1055
5/6/80	1150-1320
Highest single reading, percent	Not available
Highest 6-minute average, percent	0.4



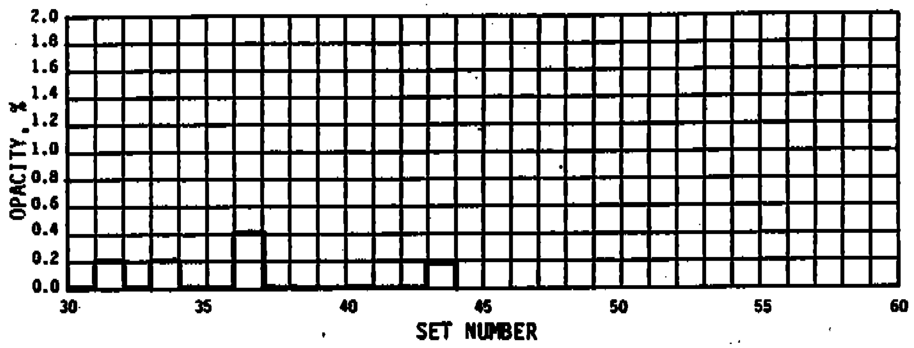


TABLE C-48. SUMMARY OF EMISSION TEST RESULTS--PLANT H2

Industry: Gypsum
Process unit: Flash calciner
Emission source: Baghouse inlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	5/19/80	5/20/80	5/20/80	--
Sampling time, minutes	94	73	76	--
Isokinetic ratio, percent	109	107	104	--
Production rate, Mg/h	6.4	6.4	6.4	6.4
(tons/h)	(7.0)	(7.0)	(7.0)	(7.0)
Capacity utilization, percent	95	95	95	95
Gas stream data				
Temperature, °C	188	189	187	188
(°F)	(370)	(373)	(369)	(371)
Moisture, percent	38.9	40.9	43.0	40.9
Flow rate, m^3/s	1.9	1.9	1.9	1.9
(acfm)	(3,920)	(4,110)	(4,100)	(4,040)
Flow rate, dsm^3/s	0.72	0.72	0.70	0.71
(dscfm)	(1,520)	(1,530)	(1,480)	(1,510)
Particulate emissions				
g/dsm^3	50.3	49.4	48.5	49.4
(gr/dscf)	(22.0)	(21.6)	(21.2)	(21.6)
kg/h	131	129	122	127
(lb/h)	(288)	(284)	(269)	(280)
kg/Mg	20	20	19	20
(lb/ton)	(41)	(41)	(38)	(40)

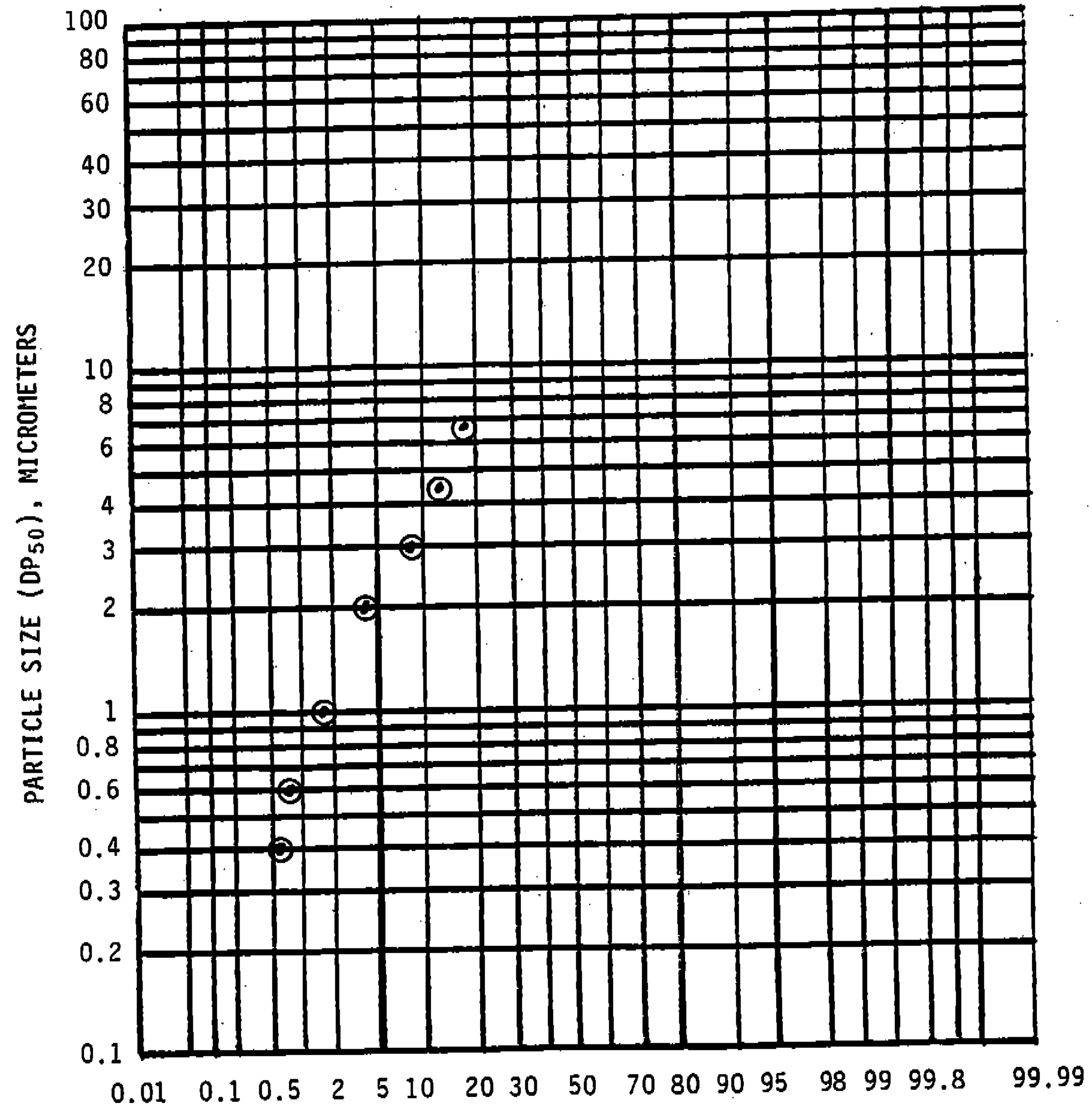


Figure C-41. Particle size distribution data: flash calciner baghouse inlet--Plant H2.

TABLE C-49. SUMMARY OF EMISSION TEST RESULTS--PLANT H2

Industry: Gypsum
Process unit: Flash calciner
Emission source: Baghouse outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	5/19/80	5/20/80	5/20/80	--
Sampling time, minutes	150	100	115	--
Isokinetic ratio, percent	109	101	103	--
Production rate, Mg/h	6.4	6.4	6.4	6.4
(tons/h)	(7.0)	(7.0)	(7.0)	(7.0)
Capacity utilization, percent	95	95	95	95
Gas stream data				
Temperature, °C	172	171	172	172
(°F)	(341)	(340)	(341)	(341)
Moisture, percent	31.8	41.5	42.5	38.6
Flow rate, m^3/s	1.9	1.9	1.9	1.9
(acfm)	(3,910)	(4,070)	(4,010)	(4,000)
Flow rate, dsm^3/s	0.8	0.7	0.7	0.7
(dscfm)	(1,610)	(1,580)	(1,530)	(1,570)
Particulate emissions				
g/dsm^3	0.048	0.055	0.060	0.054
(gr/dscf)	(0.021)	(0.024)	(0.026)	(0.024)
kg/h	0.13	0.15	0.15	0.14
(lb/h)	(0.28)	(0.33)	(0.34)	(0.31)
kg/Mg	0.020	0.023	0.023	0.022
(lb/ton)	(0.040)	(0.047)	(0.048)	(0.045)

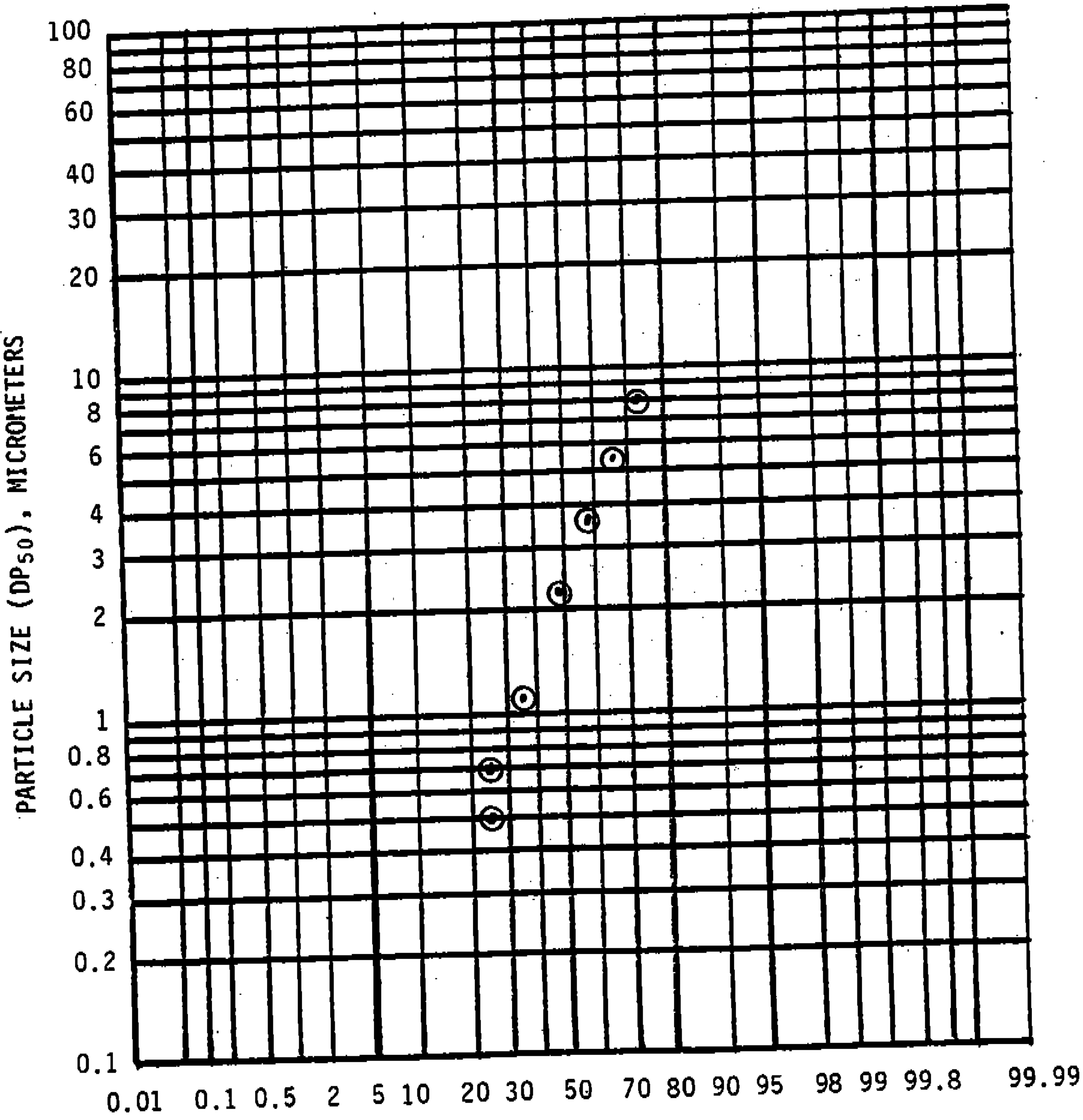


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Figure C-42. Particle size distribution data: flash calciner baghouse outlet (1 run)--Plant H2.

TABLE C-50. SUMMARY OF VISIBLE EMISSIONS--PLANT H2

Date	5/19/80
Industry	Gypsum
Process unit	Flash calciner
Location of discharge	Baghouse outlet
Height of observation point, ft	6
Height of point of discharge, ft	10 ft above roof
Distance from observer to discharge point, ft	25
Direction of observer from discharge point	S
Description of background	Sky
Description of sky	Partly cloudy
Wind direction	W
Wind velocity, mph	10-15
Color of plume	White
Duration of observation, min	120
Period of observation	1400-1600
Highest single reading, percent	Not available
Highest 6-minute average, percent	1.0

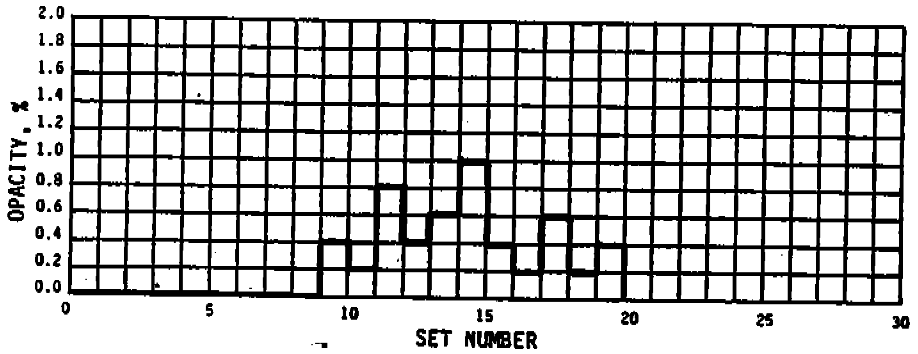
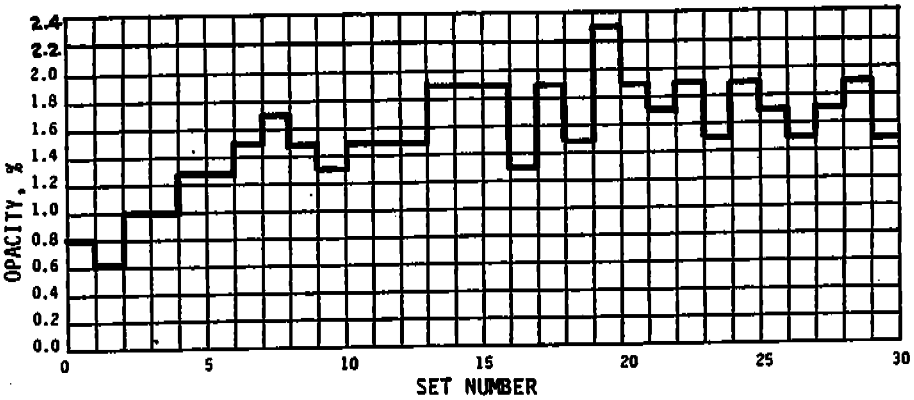


TABLE C-51 SUMMARY OF VISIBLE EMISSIONS--PLANT H2

Date	5/20/80
Industry	Gypsum
Process unit	Flash calciner
Location of discharge	Baghouse outlet
Height of observation point, ft	6
Height of point of discharge, ft	10 ft above roof
Distance from observer to discharge point, ft	25
Direction of observer from discharge point	S
Description of background	Sky
Description of sky	Partly cloudy
Wind direction	W
Wind velocity, mph	10-15
Color of plume	White
Duration of observation, min	204
Period of observation	0934-1113 1333-1513
Highest single reading, percent	Not available
Highest 6-minute average, percent	2.3



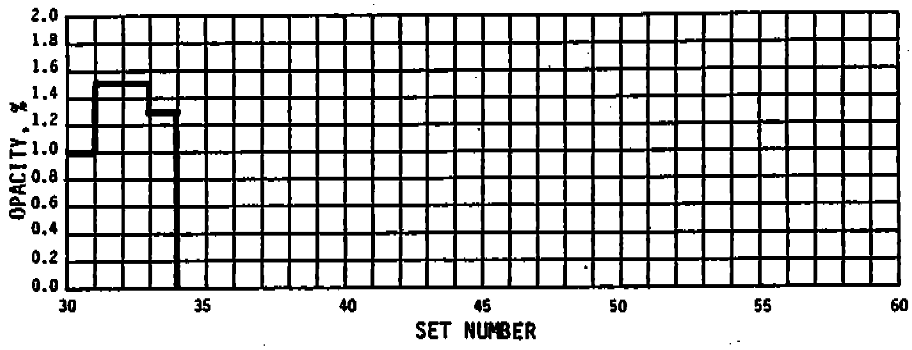


TABLE C-52. SUMMARY OF EMISSION TEST RESULTS--PLANT H3

Industry: Gypsum
Process unit: Kettle calciner--Batch operation
Emission source: Baghouse inlet

Data	Run No. 1	Run No. 2	Run No. 3[a]	Average for test series
General				
Date	10/28/80	10/28/80	10/29/80	--
Sampling time, minutes	40	18.5	19	--
Isokinetic ratio, percent	109	98	139	--
Production rate, Mg/h	4.4	4.4	4.4	4.4
(tons/h)	(4.9)	(4.9)	(4.9)	(4.9)
Capacity utilization, percent	100	100	100	100
Gas stream data				
Temperature, °C	74	72	80	73
(°F)	(166)	(161)	(176)	(164)
Moisture, percent	32.7	33.0	46.9	32.9
Flow rate, m^3/s	1.4	1.4	1.2	1.4
(acfm)	(2,930)	(3,000)	(2,560)	(2,960)
Flow rate, dsm^3/s	0.79	0.81	0.54	0.80
(dscfm)	(1,680)	(1,720)	(1,140)	(1,700)
Particulate emissions				
g/dsm^3	72.6	47.1	35.6	59.8
(gr/dscf)	(31.7)	(20.6)	(15.5)	(26.2)
kg/h	207	138	69	172
(lb/h)	(456)	(303)	(152)	(379)
kg/Mg	47	31	16	39
(lb/ton)	(93)	(62)	(31)	(78)

[a] Isokinetic ratio not within allowable limits; data not included in average.

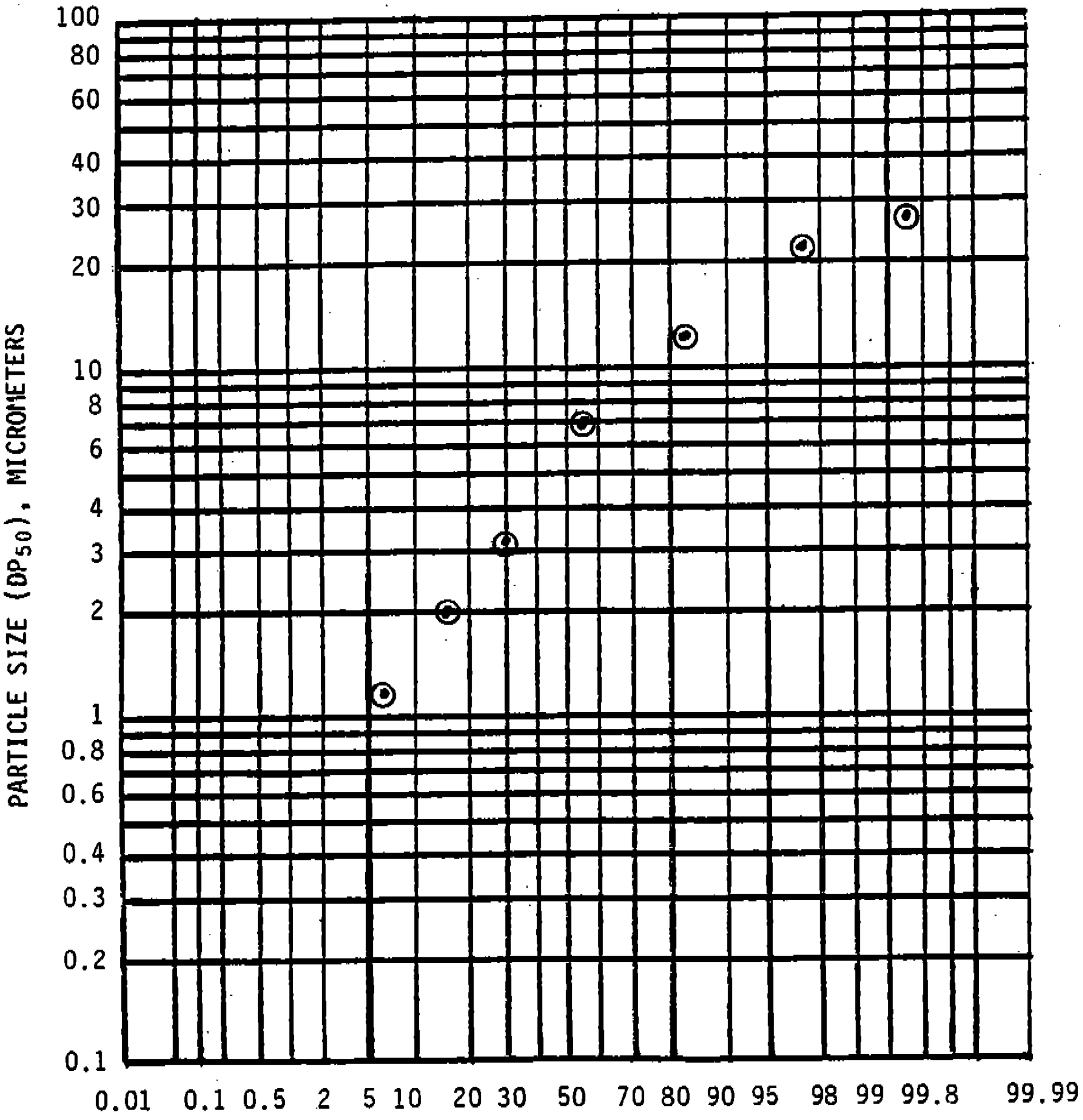


Figure C-43. Particle size distribution data: kettle calciner baghouse inlet (batch)--Plant H3.

TABLE C-53. SUMMARY OF EMISSION TEST RESULTS--PLANT H3

Industry: Gypsum
Process unit: Kettle calciner--Continuous operation
Emission source: Baghouse inlet

Data	Run No. 4	Run No. 5	Run No. 6	Average for test series
<u>General</u>				
Date	10/30/80	10/30/80	10/30/80	--
Sampling time, minutes	20	20	20	--
Isokinetic ratio, percent	97	96	103	--
Production rate, Mg/h	9.8	9.8	9.8	9.8
(tons/h)	(11.0)	(11.0)	(11.0)	(11.0)
Capacity utilization, percent	100	100	100	100
<u>Gas stream data</u>				
Temperature, °C	126	131	124	127
(°F)	(258)	(268)	(256)	(261)
Moisture, percent	59.1	58.8	61.4	59.8
Flow rate, m^3/s	1.5	1.5	1.4	1.4
(acfm)	(3,160)	(3,180)	(2,870)	(3,070)
Flow rate, dsm^3/s	0.45	0.46	0.39	0.43
(dscfm)	(963)	(967)	(825)	(918)
<u>Particulate emissions</u>				
g/dsm^3	113	133	127	125
(gr/dscf)	(49.5)	(58.1)	(55.7)	(54.4)
kg/h	185	219	179	194
(lb/h)	(409)	(482)	(394)	(428)
kg/Mg	19	22	18	20
(lb/ton)	(37)	(44)	(36)	(39)

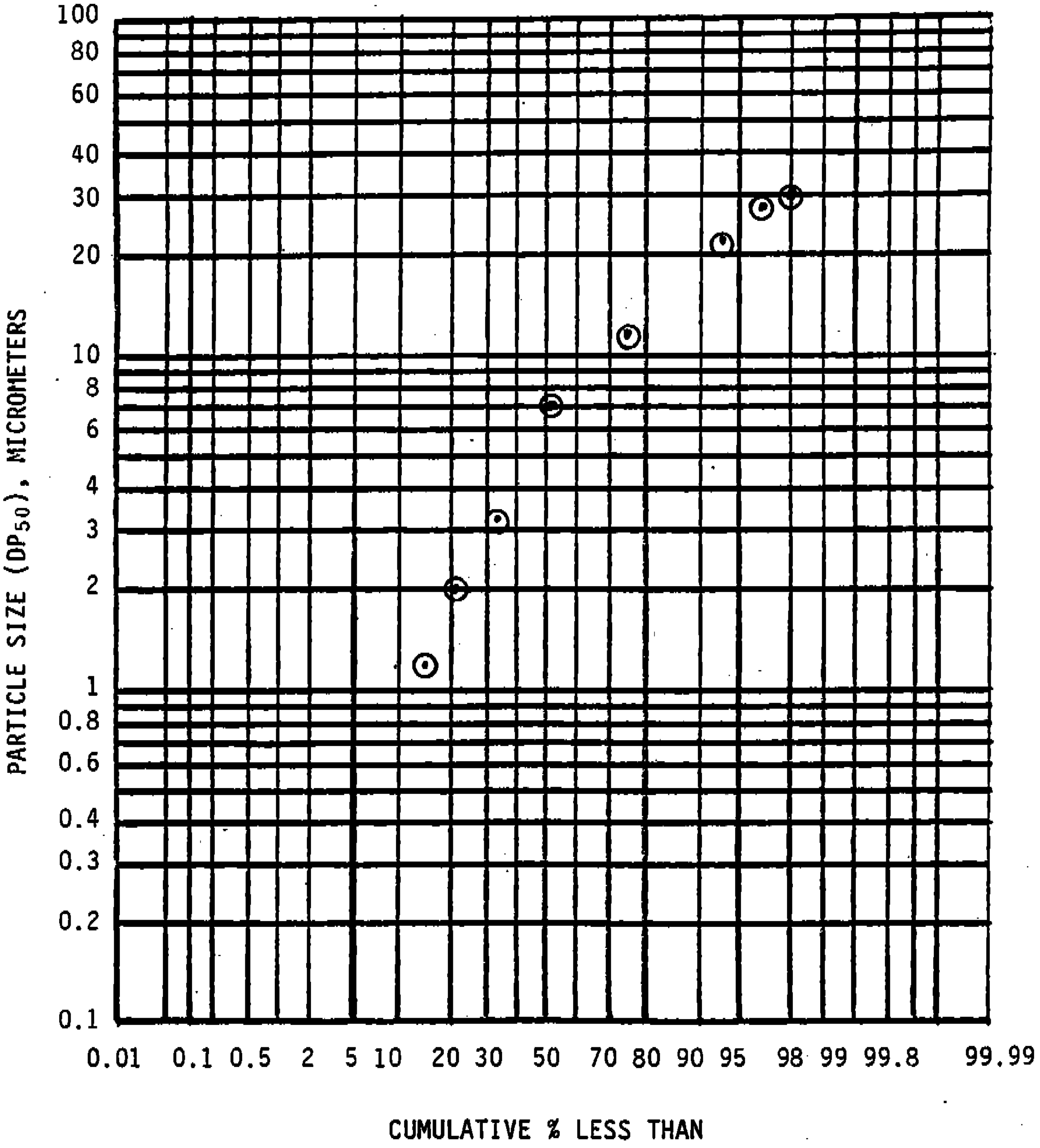


Figure C-44. Particle size distribution data: kettle calciner baghouse inlet (continuous)--Plant H3.

TABLE C-54. SUMMARY OF EMISSION TEST RESULTS--PLANT H4

Industry: Gypsum
Process unit: Flash calciner
Emission source: Baghouse inlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	7/15/80	7/16/80	7/16/80	--
Sampling time, minutes	187	101	84	--
Isokinetic ratio, percent	110	101	108	--
Production rate, Mg/h	6.4	6.4	6.4	6.0
(tons/h)	(7.0)	(7.0)	(7.0)	(7.0)
Capacity utilization, percent	95	95	95	95
Gas stream data				
Temperature, °C	149	148	152	150
(°F)	(300)	(298)	(306)	(301)
Moisture, percent	52.6	45.2	50.0	49.3
Flow rate, m^3/s	1.8	1.8	1.8	1.8
(acfm)	(3,700)	(3,720)	(3,730)	(3,720)
Flow rate, dsm^3/s	0.57	0.67	0.60	0.62
(dscfm)	(1,220)	(1,410)	(1,280)	(1,310)
Particulate emissions				
g/dsm^3	48.8	48.5	52.3	49.9
(gr/dscf)	(21.3)	(21.2)	(22.9)	(21.8)
kg/h	101	117	114	110
(lb/h)	(223)	(257)	(251)	(244)
kg/Mg	16	18	18	17
(lb/ton)	(32)	(37)	(36)	(35)

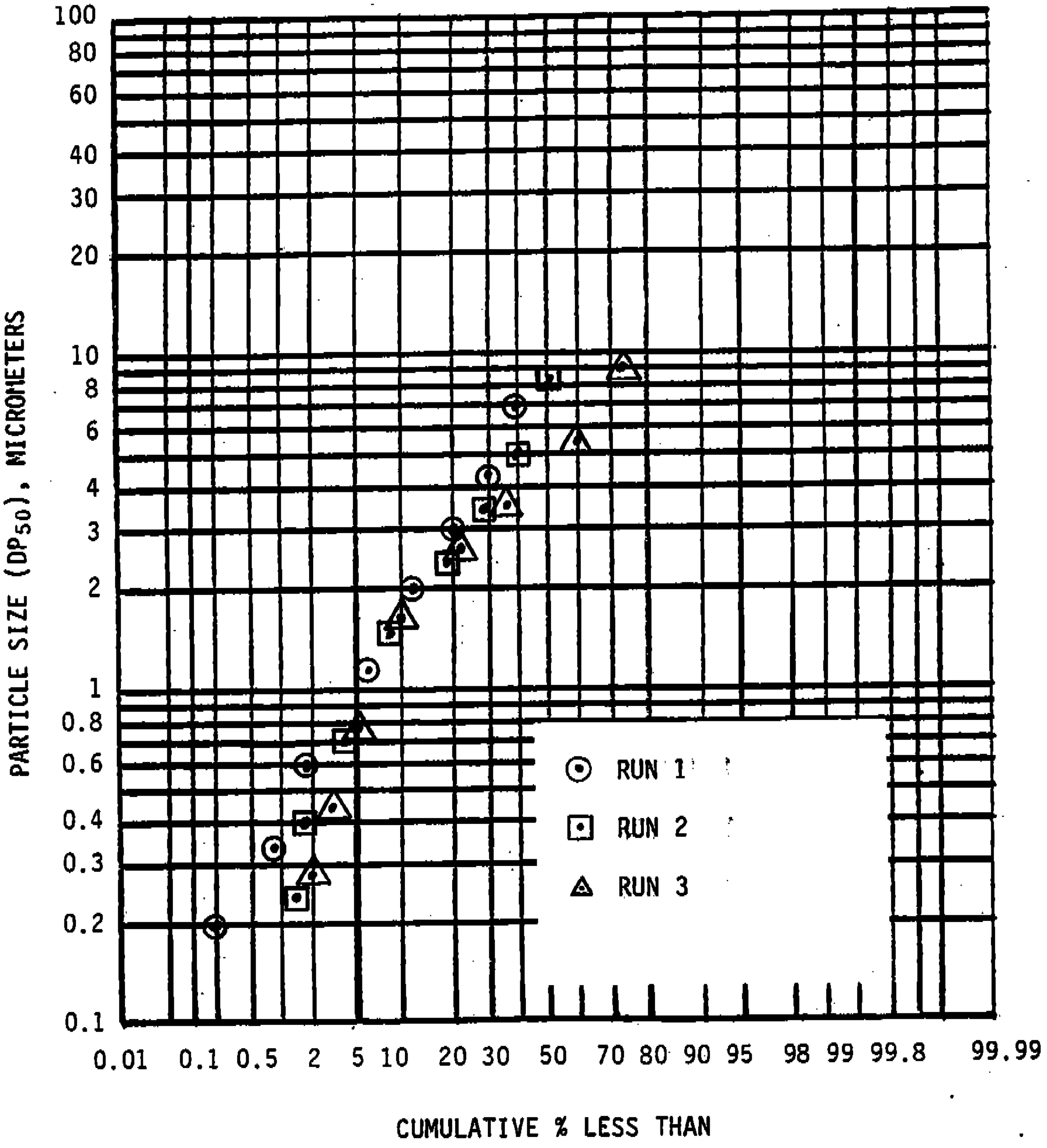


Figure C-45. Particle size distribution data: flash calciner baghouse inlet--Plant H4.

TABLE C-55. SUMMARY OF EMISSION TEST RESULTS--PLANT H4

Industry: Gypsum
Process unit: Flash calciner
Emission source: Baghouse outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	7/16/80	7/16/80	7/16/80	--
Sampling time, minutes	78	110	104	--
Isokinetic ratio, percent	109	109	103	--
Production rate, Mg/h	6.4	6.4	6.4	6.4
(tons/h)	(7.0)	(7.0)	(7.0)	(7.0)
Capacity utilization, percent	95	95	95	95
Gas stream data				
Temperature, °C	165	166	166	166
(°F)	(329)	(330)	(330)	(330)
Moisture, percent	46.2	47.6	49.3	47.7
Flow rate, m^3/s	20	1.9	1.9	1.9
(acfm)	(4,200)	(4,000)	(4,000)	(4,100)
Flow rate, dsm^3/s	0.72	0.67	0.65	0.68
(dscfm)	(1,520)	(1,420)	(1,370)	(1,440)
Particulate emissions				
g/dsm^3	0.021	0.012	0.010	0.014
(gr/dscf)	(0.009)	(0.005)	(0.005)	(0.006)
kg/h	0.05	0.03	0.02	0.04
(lb/h)	(0.12)	(0.06)	(0.05)	(0.08)
kg/Mg	0.008	0.005	0.003	0.005
(lb/ton)	(0.017)	(0.009)	(0.007)	(0.011)

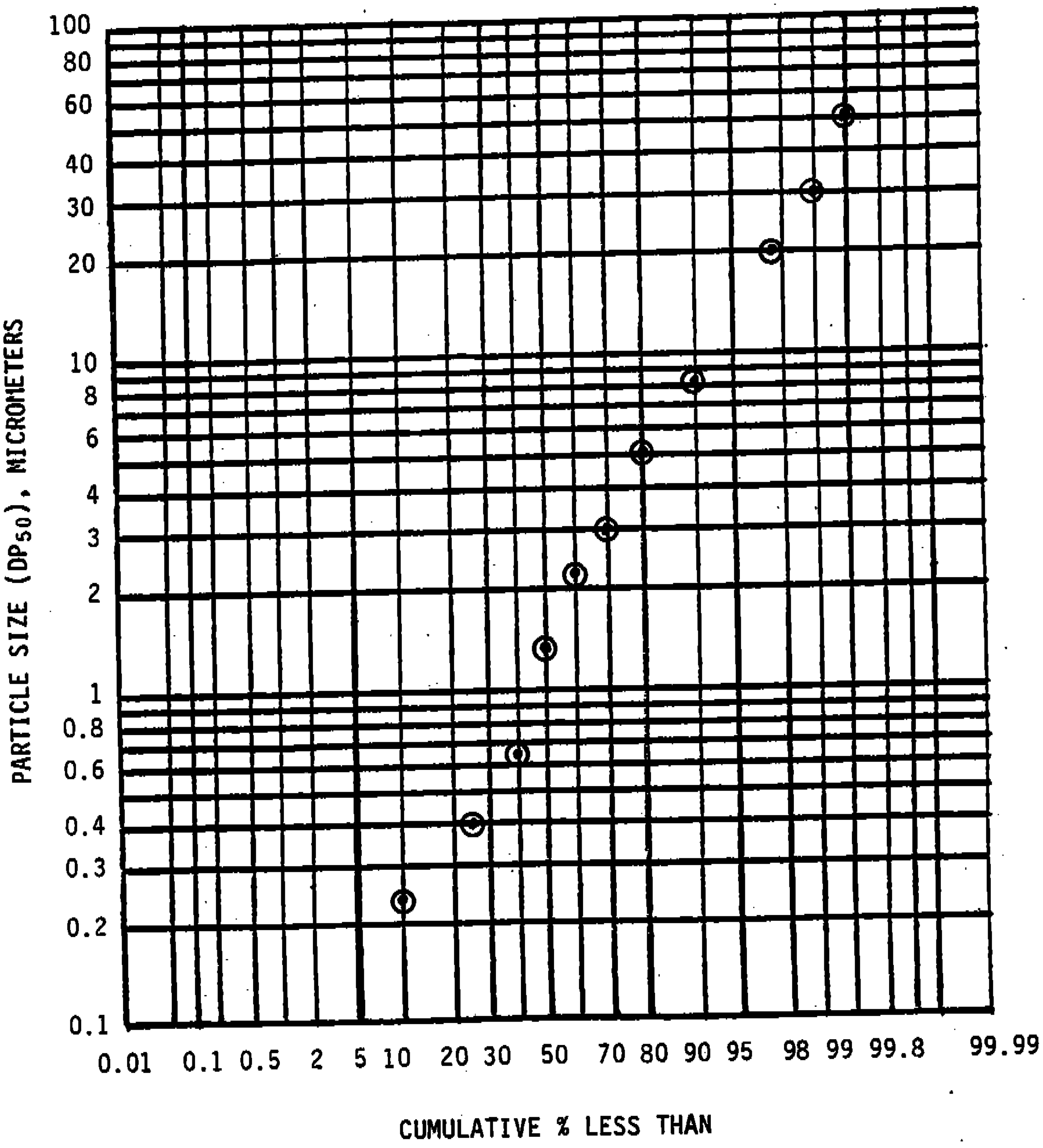


Figure C-46. Particle size distribution data: flash calciner baghouse outlet--Plant H4.

TABLE C-56. SUMMARY OF EMISSION TEST RESULTS--PLANT H5

Industry: Gypsum
Process unit: Flash calciner
Emission source: Baghouse outlet

Data	Run No. 2[a]	Run No. 3	Run No. 4	Average for test series
General				
Date	3/21/78	3/21/78	3/21/78	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	106	97	103	--
Production rate, Mg/h	6.4	6.4	6.4	6.4
(tons/h)	(7)	(7)	(7)	(7)
Capacity utilization, percent	100	100	100	100
Gas stream data				
Temperature, °C	179	179	179	179
(°F)	(355)	(354)	(354)	(354)
Moisture, percent	39	33	39	37
Flow rate, m^3/s	1.5	1.5	1.5	1.5
(acfm)	(3,160)	(3,100)	(3,090)	(3,120)
Flow rate, dsm^3/s	0.59	0.64	0.58	0.60
(dscfm)	(1,250)	(1,360)	(1,230)	(1,280)
Particulate emissions				
g/dsm^3	0.078	0.089	0.088	0.085
(gr/dscf)	(0.034)	(0.039)	(0.038)	(0.037)
kg/h	0.17	0.21	0.18	0.18
(lb/h)	(0.37)	(0.45)	(0.41)	(0.41)
kg/Mg	0.026	0.032	0.029	0.029
(lb/ton)	(0.052)	(0.065)	(0.058)	(0.058)

[a] Isokinetic ratio not within allowable limits; data not included in average.

TABLE C-57. SUMMARY OF VISIBLE EMISSIONS--PLANT H5

Date	3/21/78
Industry	Gypsum
Process unit	Flash calciner
Location of discharge	Baghouse outlet
Height of observation point, ft	--
Height of point of discharge, ft	20
Distance from observer to discharge point, ft	50
Direction of observer from discharge point	NNE
Description of background	--
Description of sky	--
Wind direction	SE
Wind velocity, mph	3-5
Color of plume	--
Duration of observation, min	48
Period of observation	[a] 1429-1445 1627-1643[b]
Highest single reading, percent	5
Highest 6-minute average, percent	0.6

[a] Due to illegibility of the test report, actual time of the first periods of observations cannot be determined.

[b] A 4-minute period of observation was made during this time.

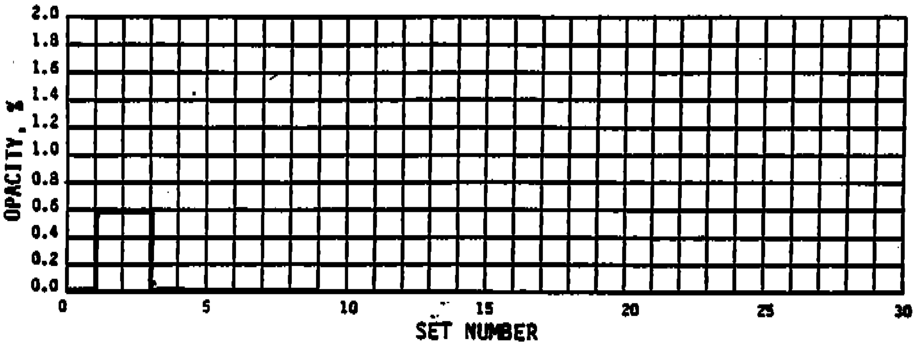


TABLE C-58. SUMMARY OF EMISSION TEST RESULTS--PLANT I1

Industry: Industrial sand
Process unit: Fluid bed dryer
Emission source: Hood exhaust duct

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	9/13/83	9/13/83	9/14/83	--
Sampling time, minutes	120	120	120	--
Isokinetic ratio, percent	99	98	101	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent	99	99	94	97
Gas stream data				
Temperature, °C	41	41	40	41
(°F)	(105)	(105)	(103)	(104)
Moisture, percent	2.6	2.3	2.3	2.4
Flow rate, m^3/s	0.38	0.39	0.37	0.38
(acfm)	(797)	(821)	(774)	(797)
Flow rate, dsm^3/s	0.34	0.35	0.33	0.34
(dscfm)	(713)	(736)	(698)	(716)
Particulate emissions				
g/dsm^3	2.61	2.82	3.40	2.94
(gr/dscf)	(1.14)	(1.23)	(1.49)	(1.29)
kg/h	3.2	3.5	4.0	3.6
(lb/h)	(7.0)	(7.8)	(8.9)	(7.9)
kg/Mg (lb/ton)	a	a	a	a

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[a] Confidential data.

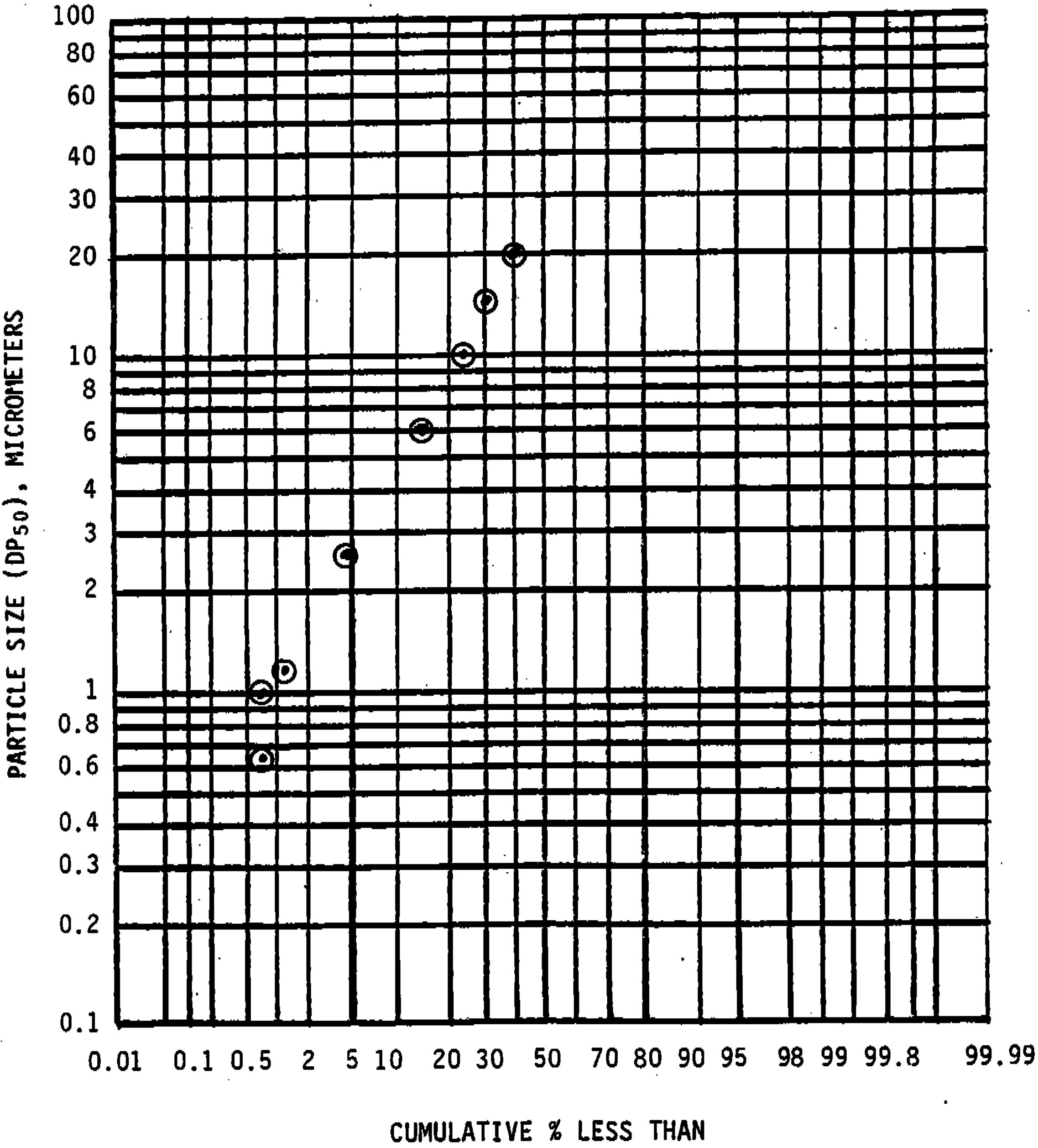

Figure C-47. Particle size distribution data: fluid bed dryer hood exhaust outlet--Plant I1.

TABLE C-59. SUMMARY OF EMISSION TEST RESULTS--PLANT I1

Industry: Industrial sand
Process unit: Fluid bed dryer
Emission source: Scrubber inlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	9/13/83	9/13/83	9/14/83	--
Sampling time, minutes	126	126	126	--
Isokinetic ratio, percent	96	93	96	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent	99	99	94	97
Gas stream data				
Temperature, °C	74	73	75	74
(°F)	(165)	(164)	(167)	(165)
Moisture, percent	22.3	21.6	24.7	22.9
Flow rate, m^3/s	28	32	33	31
(acfm)	(60,300)	(67,000)	(69,800)	(65,700)
Flow rate, dsm^3/s	18	21	21	20
(dscfm)	(38,800)	(43,600)	(43,500)	(42,000)
Particulate emissions				
g/dsm^3	24.4	21.2	20.7	22.1
(gr/dscf)	(10.7)	(9.24)	(9.05)	(9.65)
kg/h	1,610	1,570	1,530	1,570
(lb/h)	(3,550)	(3,450)	(3,380)	(3,460)
kg/Mg (lb/ton)	a	a	a	a

[a] Confidential data.

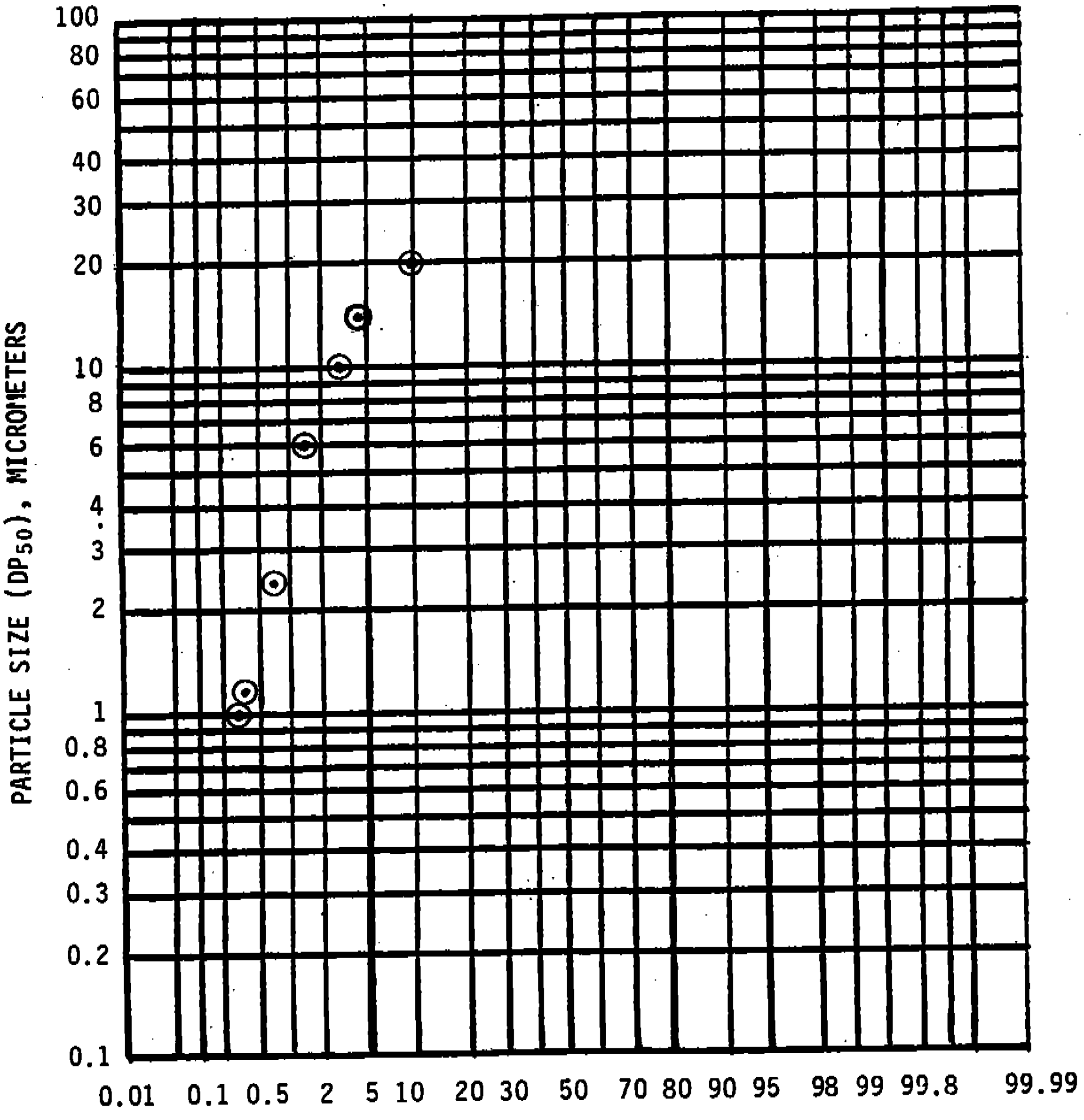

Figure C-48. Particle size distribution data: fluid bed dryer scrubber inlet--Plant I1.

TABLE C-60. SUMMARY OF EMISSION TEST RESULTS--PLANT I1

Industry: Industrial sand
Process unit: Fluid bed dryer
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	9/13/83	9/13/83	9/14/83	--
Sampling time, minutes	144	144	144	--
Isokinetic ratio, percent	106	103	109	--
Production rate, Mg/h	a	a	a	a
(tons/h)				
Capacity utilization, percent	99	99	94	97
Gas stream data				
Temperature, °C	58	57	59	58
(°F)	(136)	(134)	(138)	(136)
Moisture, percent	17.7	18.1	18.2	18.0
Flow rate, m^3/s	23	23	24	23
(acfm)	(4,800)	(49,200)	(49,800)	(49,000)
Flow rate, dsm^3/s	16	17	17	16
(dscfm)	(34,300)	(35,200)	(35,400)	(35,000)
Particulate emissions				
g/dsm^3	0.039	0.044	0.063	0.049
(gr/dscf)	(0.017)	(0.019)	(0.028)	(0.021)
kg/h	2.29	2.62	3.79	2.90
(lb/h)	(5.05)	(5.78)	(8.36)	(6.40)
kg/Mg	a	a	a	a
(lb/ton)				

[a] Confidential data.

TABLE C-61. SUMMARY OF VISIBLE EMISSIONS--PLANT I1

Date	9/14/83
Industry	Industrial sand
Process unit	Fluid bed dryer
Location of discharge	Scrubber outlet
Height of observation point, ft	Ground
Height of point of discharge, ft	80
Distance from observer to discharge point, ft	300
Direction of observer from discharge point	E
Description of background	Blue sky, white clouds
Description of sky	Scattered
Wind direction	NE
Wind velocity, mph	3-4
Color of plume	Light beige
Duration of observation, min	144
Period of observation	0900-0912 0912-1030[a] 1035-1129[a]
Highest single reading, percent	5
Highest 6-minute average, percent	0.8

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[a] Opacity readings were not recorded for every 15-second time interval of these periods due to interference by a plume from an adjacent stack.

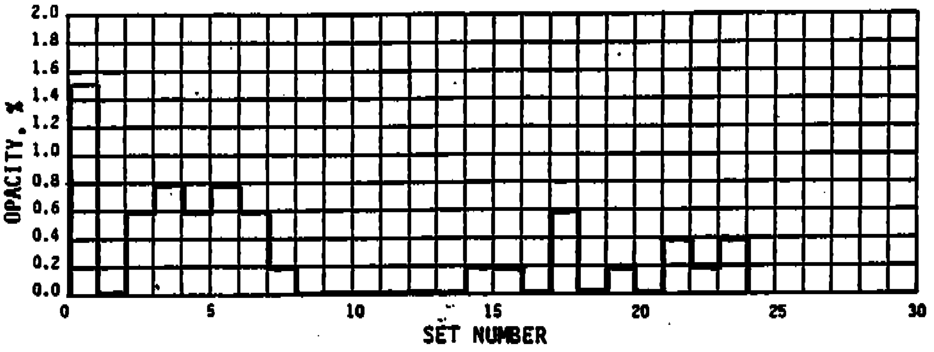


TABLE C-62. SUMMARY OF EMISSION TEST RESULTS--PLANT I1
Industry: Industrial sand
Process unit: Rotary dryer
Emission source: Scrubber inlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	9/15/83	9/15/83	9/16/83	--
Sampling time, minutes	144	144	144	--
Isokinetic ratio, percent	106	108	110	--
Production rate, Mg/h (tons/h)	a	b	a	a
Capacity utilization, percent[c]	100	b	100	100
Gas stream data				
Temperature, °C	53	59	49	54
(°F)	(127)	(139)	(120)	(129)
Moisture, percent	14.0	12.6	12.6	13.1
Flow rate, m^3/s	5.4	5.4	5.2	5.3
(acfm)	(11,500)	(11,400)	(11,000)	(11,300)
Flow rate, dsm^3/s	4.2	4.1	4.1	4.1
(dscfm)	(8,850)	(8,760)	(8,670)	(8,760)
Particulate emissions				
g/dsm^3	0.175	0.052	0.105	0.111
(gr/dscf)	(0.076)	(0.023)	(0.046)	(0.048)
kg/h	2.63	0.77	1.55	1.65
(lb/h)	(5.79)	(1.69)	(3.42)	(3.63)
kg/Mg (lb/ton)	a	a	a	a

[a] Confidential data.
[b] Silo gain (i.e., production rate) could not be measured during Run No. 2.
[c] The dryer was operating at maximum capacity at all times to achieve desired product [illegible]

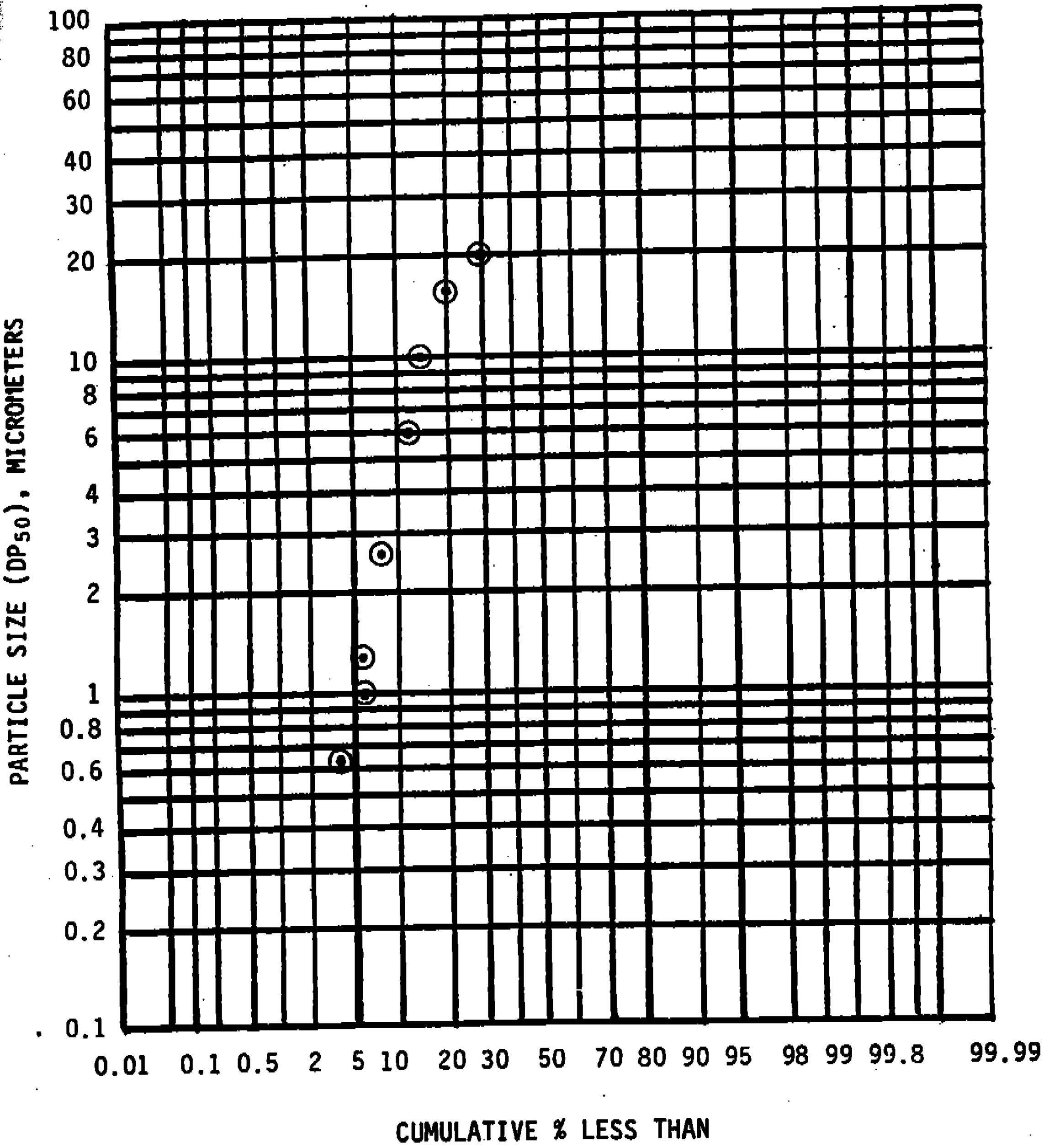


Figure C-49. Particle size distribution data:
rotary dryer scrubber inlet--Plant I1.

TABLE C-63. SUMMARY OF EMISSION TEST RESULTS--PLANT I1

Industry: Industrial sand
Process unit: Rotary dryer
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	9/15/83	9/15/83	9/16/83	--
Sampling time, minutes	181	181	181	--
Isokinetic ratio, percent	106	106	106	--
Production rate, Mg/h	a	b	a	a
(tons/h)				
Capacity utilization, percent[c]	100	b	100	100
Gas stream data				
Temperature, °C	44	47	46	46
(°F)	(112)	(117)	(115)	(115)
Moisture, percent	10.4	10.9	10.5	10.6
Flow rate, m^3/s[d]	7.4	6.7	6.9	7.0
(acfm)	(15,700)	(14,200)	(14,700)	(14,900)
Flow rate, dsm^3/s[d]	6.1	5.4	5.6	5.7
(dscfm)	(12,900)	(11,400)	(11,900)	(12,100)
Particulate emissions[d]				
g/dsm^3	0.026	0.007	0.008	0.014
(gr/dscf)	(0.011)	(0.003)	(0.003)	(0.006)
kg/h	0.59	0.099	0.20	0.30
(lb/h)	(1.3)	(0.22)	(0.44)	(0.66)
kg/Mg	a	b	a	a
(lb/ton)				

[a] Confidential data.
[b] Silo gain (i.e., production rate) could not be measured during Run No. 2.
[c] The dryer was operating at maximum capacity at all times to achieve desired product quality.
[d] Flow rate and emission data corrected for cyclonic flow.

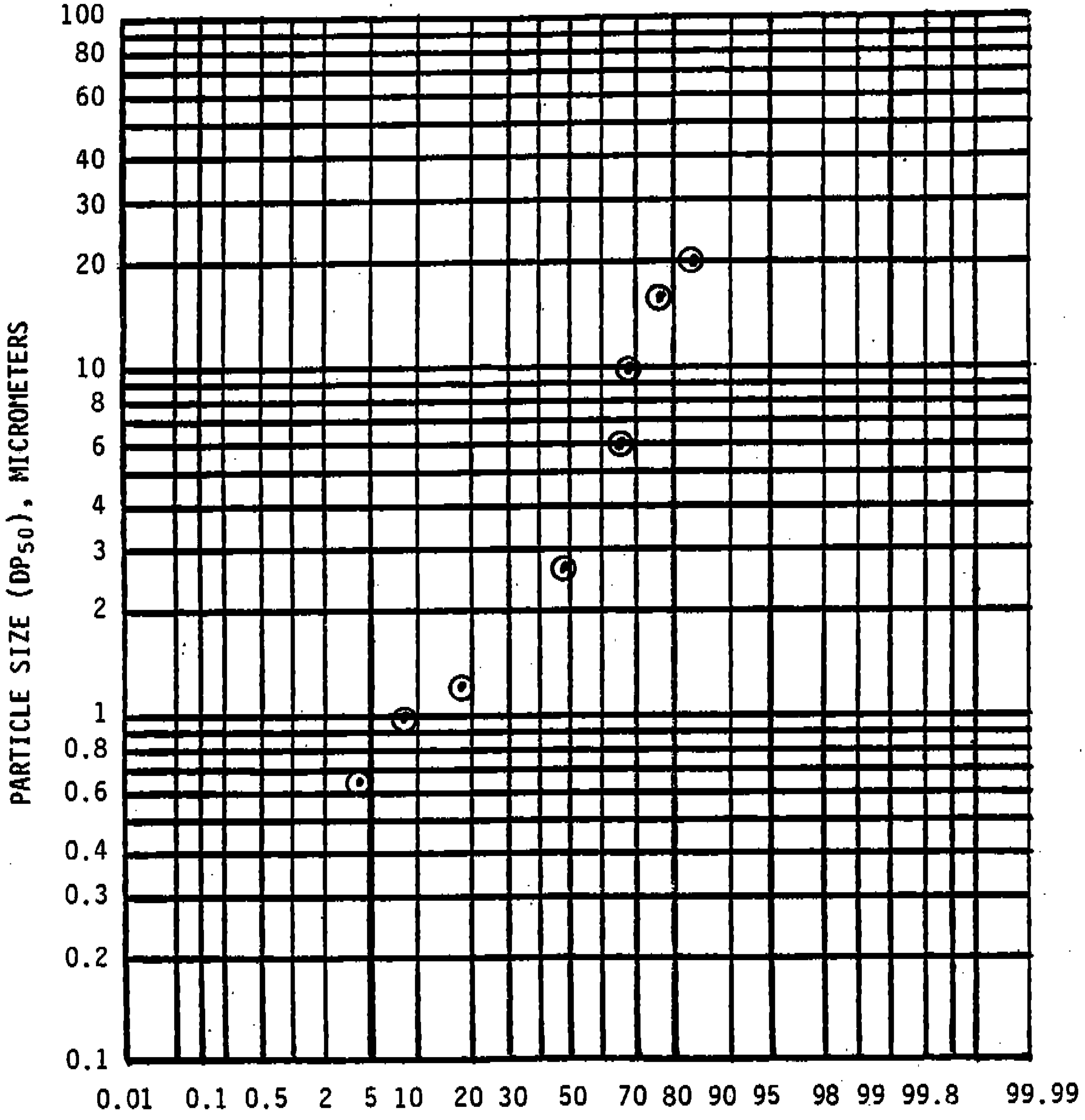
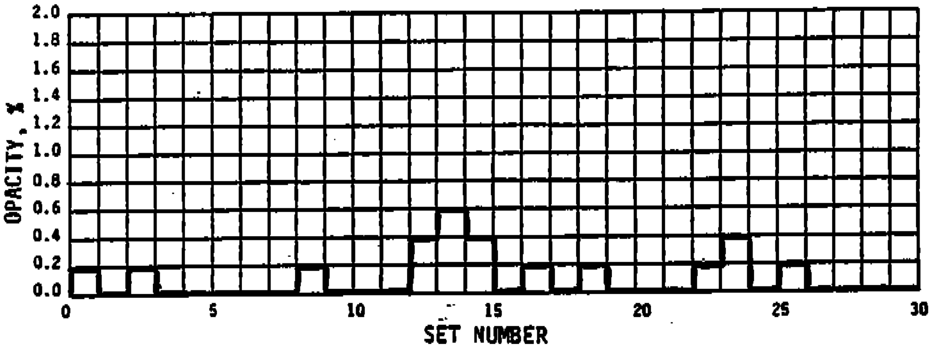


Figure C-50. Particle size distribution data: rotary dryer scrubber outlet--Plant I1.

TABLE C-64. SUMMARY OF VISIBLE EMISSIONS--PLANT I1

Date	9/15/83
Industry	Industrial sand
Process unit	Rotary dryer
Location of discharge	Scrubber outlet
Height of observation point, ft	100; 70
Height of point of discharge, ft	60
Distance from observer to discharge point, ft	120; 600
Direction of observer from discharge point	SE; SW
Description of background	Blue sky, green foliage
Description of sky	Clear
Wind direction	NE; ESE
Wind velocity, mph	7-8; 3-5
Color of plume	White
Duration of observation, min:s	210
Period of observation	1200-1330 1345-1459:45 1520-1550:45 1551-1610:15
Highest single reading, percent	5
Highest 6-minute average, percent	1.5



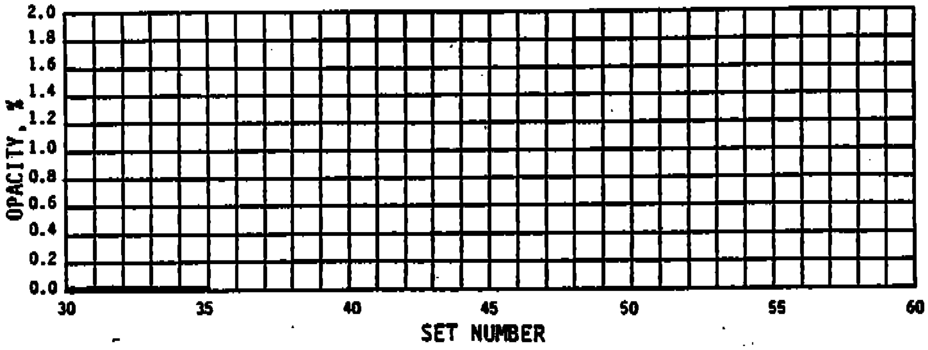


TABLE C-65. SUMMARY OF PROCESS FUGITIVE EMISSIONS--PLANT I1

Date	9/15/83
Industry	Industrial sand
Process unit	Rotary dryer
Period of observation	12:00-16:11, 17:00-20:20
Location of discharge point	Conveyor discharge to dryer
Highest single reading, percent	5
Highest 6-minute average, percent[a]	4.2

[a] All other 6-minute averages were 0 percent opacity.

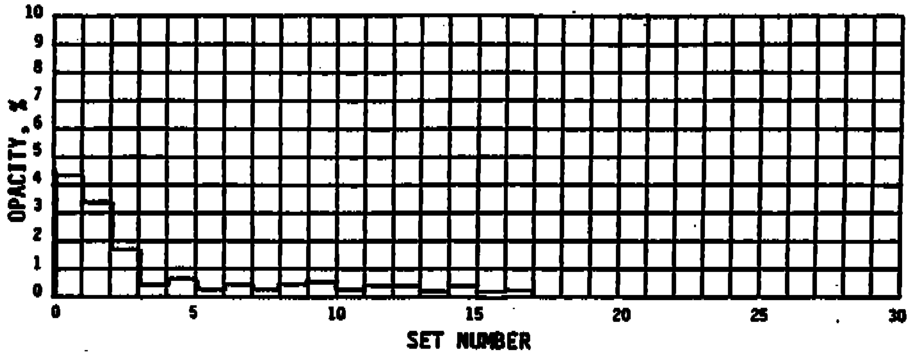


TABLE C-66. SUMMARY OF EMISSION TEST RESULTS--PLANT I2

Industry: Industrial sand
Process unit: Fluid bed dryer
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	5/25/76	5/26/76	5/26/76	--
Sampling time, minutes	120	114	120	--
Isokinetic ratio, percent	110	108	104	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent	94	92	88	91
Gas stream data				
Temperature, °C	53	53	49	52
(°F)	(128)	(128)	(121)	(126)
Moisture, percent	12.8	13.1	11.7	12.5
Flow rate, m^3/s	16	18	18	17
(acfm)	(34,100)	(37,900)	(38,200)	(36,700)
Flow rate, dsm^3/s	13	14	14	13
(dscfm)	(26,800)	(29,000)	(30,000)	(28,600)
Particulate emissions				
g/dsm^3	0.018	0.023	0.014	0.018
(gr/dscf)	(0.008)	(0.01)	(0.006)	(0.008)
kg/h	0.82	1.09	0.73	0.88
(lb/h)	(1.8)	(2.4)	(1.6)	(1.93)
kg/Mg (lb/ton)	a	a	a	a

[a] Confidential data.

TABLE C-67. SUMMARY OF EMISSION TEST RESULTS--PLANT I3

Industry: Industrial sand
Process unit: Fluid bed dryer
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	4/13/82	4/13/82	4/13/82	--
Sampling time, minutes	77	74	75	--
Isokinetic ratio, percent	106	104	106	--
Production rate, Mg/h	45.4	45.4	45.4	45.4
(tons/h)	(50)	(50)	(50)	(50)
Capacity utilization, percent	100	100	100	100
Gas stream data				
Temperature, °C	58	59	53	57
(°F)	(136)	(138)	(127)	(134)
Moisture, percent	7.6	8.3	8.2	8.0
Flow rate, m^3/s	10	9.1	9.5	9.5
(acfm)	(21,100)	(19,200)	(20,100)	(20,100)
Flow rate, dsm^3/s	8.2	7.4	7.9	7.8
(dscfm)	(17,400)	(15,700)	(16,700)	(16,600)
Particulate emissions				
g/dsm^3	0.014	0.014	0.011	0.013
(gr/dscf)	(0.006)	(0.006)	(0.005)	(0.006)
kg/h	0.40	0.44	0.29	0.38
(lb/h)	(0.88)	(0.97)	(0.65)	(0.83)
kg/Mg	0.0088	0.0097	0.0064	0.0084
(lb/ton)	(0.018)	(0.019)	(0.013)	(0.017)

TABLE C-68. SUMMARY OF EMISSION TEST RESULTS--PLANT I4

Industry: Industrial sand

Process unit: Fluid bed dryer

Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	2/2/82	2/2/82	2/2/82	--
Sampling time, minutes	66	65	63	--
Isokinetic ratio, percent	106	106	106	--
Production rate, Mg/h	70.3	70.3	70.3	70.3
(tons/h)	(77.5)	(77.5)	(77.5)	(77.5)
Capacity utilization, percent	103	103	103	103
Gas stream data				
Temperature, °C	39	39	38	39
(°F)	(103)	(103)	(101)	(102)
Moisture, percent	6.3	6.5	6.4	6.4
Flow rate, m^3/s	22	21	21	21
(acfm)	(47,600)	(44,600)	(44,200)	(45,500)
Flow rate, dsm^3/s	20	19	19	19
(dscfm)	(42,200)	(39,500)	(39,300)	(40,300)
Particulate emissions				
g/dsm^3	0.057	0.034	0.034	0.042
(gr/dscf)	(0.025)	(0.015)	(0.015)	(0.018)
kg/h	4.1	2.2	2.3	2.9
(lb/h)	(9.1)	(4.9)	(5.0)	(6.3)
kg/Mg	0.058	0.032	0.032	0.042
(lb/ton)	(0.12)	(0.064)	(0.065)	(0.083)

TABLE C-69. SUMMARY OF EMISSION TEST RESULTS--PLANT J1

Industry: Kaolin
Process unit: Multiple hearth furnace
Emission source: Scrubber inlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	9/26/83	9/27/83	9/27/83	--
Sampling time, minutes	72	72	72	--
Isokinetic ratio, percent	112	103	101	--
Production rate, Mg/h[a]	b	b	b	b
(tons/h)				
Capacity utilization, percent	106	129	109	115
Gas stream data				
Temperature, °C	301	294	290	295
(°F)	(573)	(560)	(554)	(562)
Moisture, percent	17.1	17.2	15.5	17
Flow rate, m³/s	5.0	5.2	5.3	5.1
(acfm)	(10,600)	(11,000)	(11,100)	(10,900)
Flow rate, dsm³/s	2.1	2.2	2.3	2.2
(dscfm)	(4,410)	(4,650)	(4,830)	(4,630)
Particulate emissions				
g/dsm³	8.44	8.15	9.14	8.58
(gr/dscf)	(3.69)	(3.56)	(4.00)	(3.75)
kg/h	63	64	75	68
(lb/h)	(140)	(140)	(160)	(150)
kg/Mg[c]	b	b	b	b
(lb/ton)				

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[a] Estimated using feed rate and material moisture content.
[b] Confidential data.
[c] Calculated from estimate of production rate.

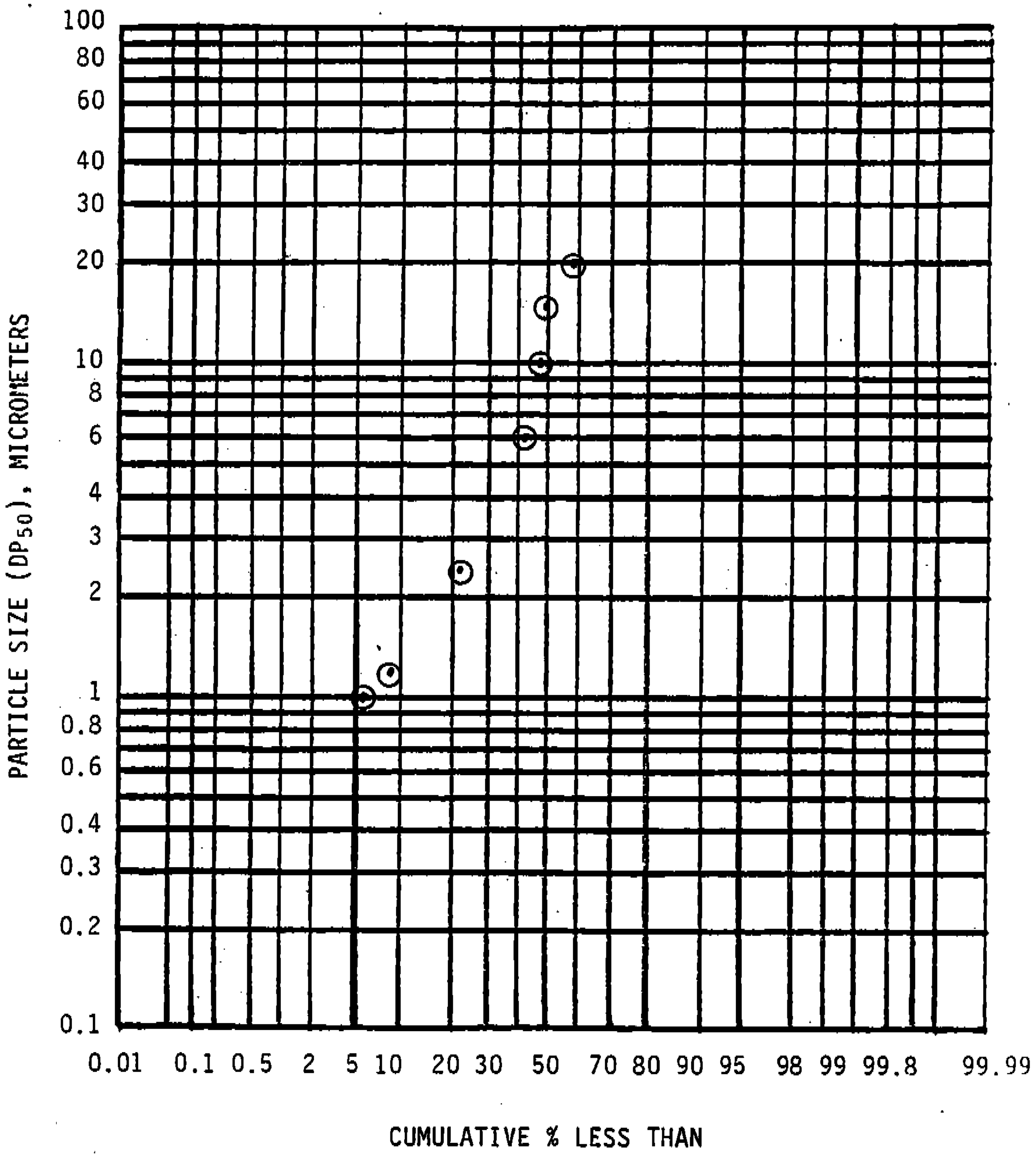

Figure C-51. Particle size distribution data: multiple hearth furnace scrubber inlet--Plant J1.

TABLE C-70. SUMMARY OF EMISSION TEST RESULTS--PLANT J1

Industry: Kaolin
Process unit: Multiple hearth furnace
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	9/26/83	9/27/83	9/27/83	
Sampling time, minutes	64	64	72	--
Isokinetic ratio, percent	101	107	105	--
Production rate, Mg/h[a]				--
(tons/h)	b	b	b	b
Capacity utilization, percent	106	129	109	115
Gas stream data				
Temperature, °C	56	55	56	56
(°F)	(133)	(132)	(132)	(132)
Moisture, percent	18.9	17.6	15.7	17.4
Flow rate, m³/s	3.6	3.9	3.7	3.7
(acfm)	(7,640)	(8,160)	(7,790)	(7,860)
Flow rate, dsm³/s	2.6	2.8	2.7	2.7
(dscfm)	(5,460)	(5,940)	(5,790)	(5,730)
Particulate emissions				
g/dsm³	0.056	0.039	0.047	0.047
(gr/dscf)	(0.025)	(0.017)	(0.021)	(0.021)
kg/h	0.52	0.39	0.46	0.46
(lb/h)	(1.1)	(0.86)	(1.0)	(1.0)
kg/Mg[c]	b	b	b	b
(lb/ton)				

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[a] Estimated using feed rate and material moisture content.
[b] Confidential data.
[c] Calculated from estimates of production rates.

TABLE C-71. SUMMARY OF EMISSION TEST RESULTS--PLANT J1

Industry: Kaolin
Process unit: Flash calciner
Emission source: Baghouse inlet

Data	Run No. 1[a]	Run No. 2	Run No. 3	Average for test series
General				
Date	9/28/83	9/29/83	9/29/83	--
Sampling time, minutes	72	36	36	--
Isokinetic ratio, percent	102	102	100	--
Production rate, Mg/h (tons/h)	b	b	b	b
Capacity utilization, percent[c]	72	90	82	86
Gas stream data				
Temperature, °C	130	123	128	126
(°F)	(265)	(254)	(263)	(258)
Moisture, percent	7.1	8.9	5.5	7.2
Flow rate, m^3/s	14	14	13	14
(acfm)	(29,700)	(29,800)	(28,400)	(29,100)
Flow rate, dsm^3/s	9.3	9.3	9.0	9.2
(dscfm)	(19,600)	(19,600)	(19,100)	(19,400)
Particulate emissions				
g/dsm^3	49.5	49.1	48.9	49.0
(gr/dscf)	(21.6)	(21.5)	(21.4)	(21.5)
kg/h	1,600	1,600	1,600	1,600
(lb/h)	(3,400)	(3,600)	(3,500)	(3,500)
kg/Mg[c] (lb/ton)	b	b	b	b

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[a] Data from Run 1 not included in average for test series because of low capacity utilization.
[b] Confidential data
[c] Estimated using feed rate and material moisture content.

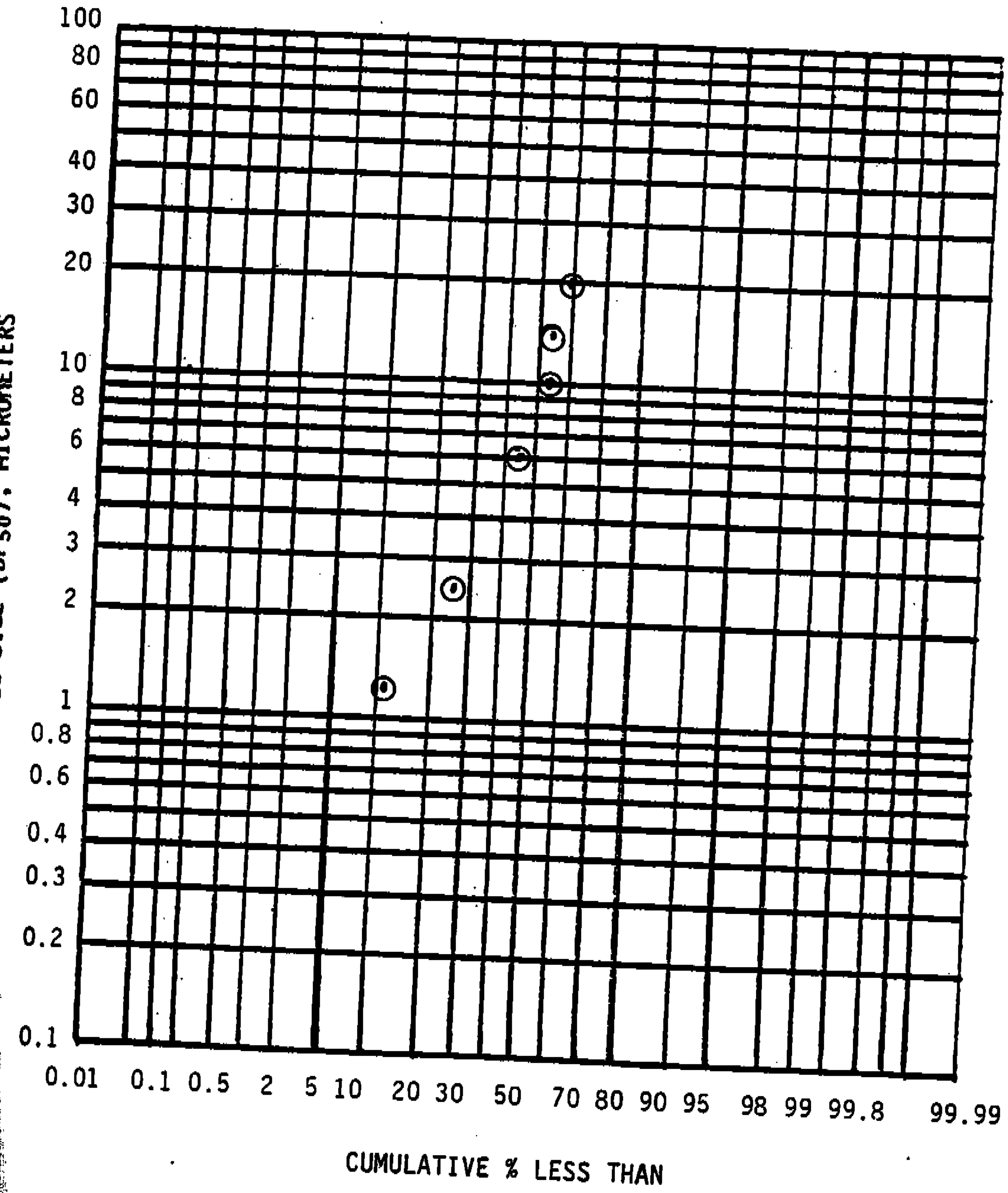

Figure C-52. Particle size distribution data: flash calciner baghouse inlet--Plant J1.

TABLE C-72. SUMMARY OF EMISSION TEST RESULTS--PLANT J1

Industry: Kaolin
Process unit: Flash calciner
Emission source: Baghouse outlet

Data	Run No. 1[a]	Run No. 2	Run No. 3	Average for test series
General				
Date	9/28/83	9/29/83	9/29/83	--
Sampling time, minutes	128	176	176	--
Isokinetic ratio, percent	102	103	101	--
Production rate, Mg/h (tons/h)	b	b	b	b
Capacity utilization, percent[c]	72	90	82	86
Gas stream data				
Temperature, °C	91	77	83	80
(°F)	(195)	(171)	*181)	(176)
Moisture, percent	5.9	5.7	5.1	5.4
Flow rate, m^3/s	12	12	13	12
(acfm)	(26,300)	(26,400)	(27,100)	(26,800)
Flow rate, dsm^3/s	9.2	9.7	9.9	9.8
(dscfm)	(19,500)	(20,600)	(20,900)	(20,800)
Particulate emissions				
g/dsm^3	0.036	0.003	0.002	0.002
(gr/dscf)	(0.016)	(0.001)	(0.001)	(0.001)
kg/h	1.2	0.094	0.076	0.085
(lb/h)	(2.6)	(0.21)	(0.17)	(0.19)
kg/Mg[c] (lb/ton)	b	b	b	b

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[a] Data for Run No. 1 not included in average for test series because a bag had slipped off its mounting.

[b] [illegible]

[c] [illegible]

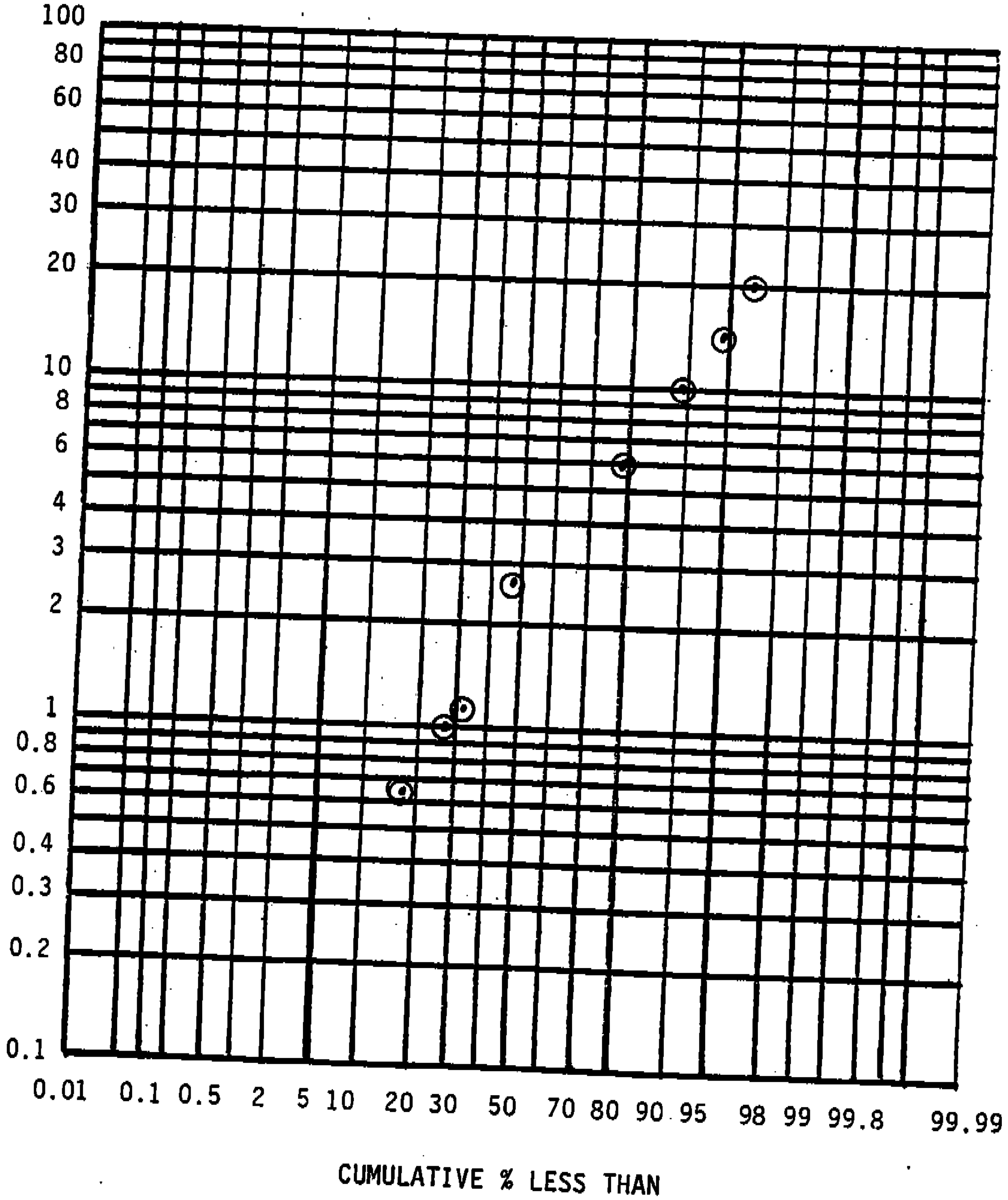

Figure C-53. Particle size distribution data: flash calciner baghouse outlet--Plant J1.

TABLE C-73. SUMMARY OF VISIBLE EMISSIONS--PLANT J[illegible]

Date	
Industry	[illegible]
Process unit	[illegible]
Location of discharge	Flash [illegible] Baghouse [illegible]
Height of observation point, ft	
Height of point of discharge, ft	
Distance from observer to discharge point, ft	
Direction of observer from discharge point	[illegible]
Description of background	Building; [illegible]
Description of sky	[illegible]
Wind direction	[illegible]
Wind velocity, mph	5-10
Color of plume	Light [illegible]
Duration of observation, min	[illegible]
Period of observation	1646 [illegible] 1710 [illegible]
Highest single reading, percent	
Highest 6-minute average, percent	

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[a] Opacity was not recorded for every 15-second time interval for this period due to interference by a steam plume from an adjacent stack.

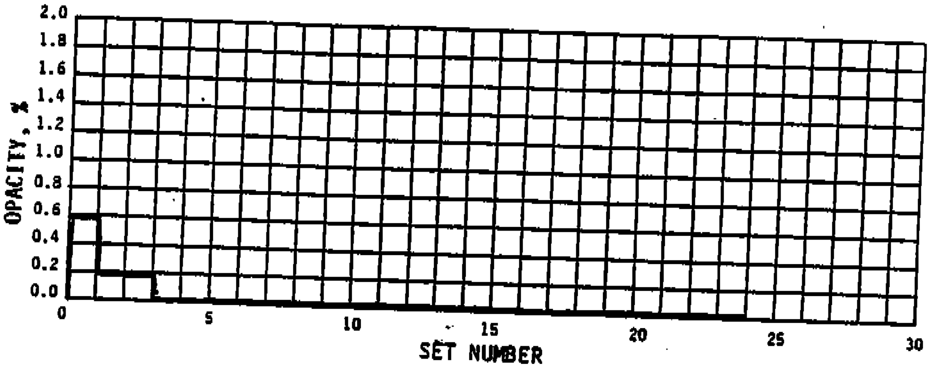

TABLE C-74. SUMMARY OF PROCESS FUGITIVE EMISSIONS--PLANT J1

te	9/28/83, 9/29/83
dustry	Kaolin
ocess unit	Flash calciner
riod of observation	(9/28) 16:35-19:15; (9/29) 10:19-13:18, 14:33-17:30
cation of discharge point	I. D. fan on calciner inlet
ghest single reading, percent	100
ghest 6-minute average, percent[a]	8.9

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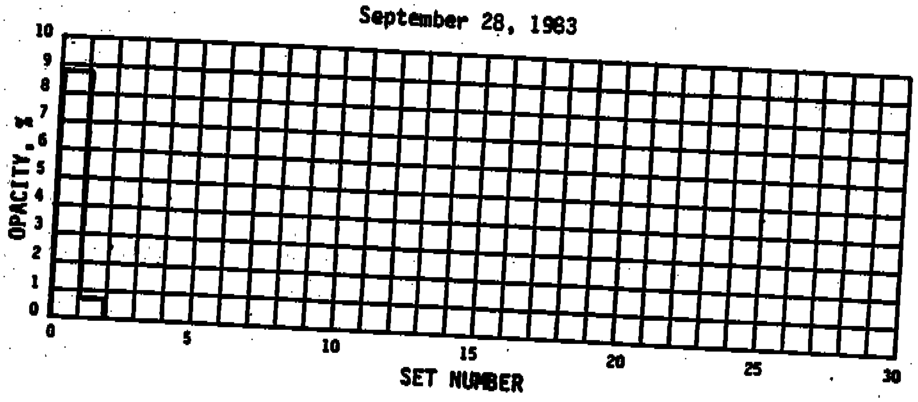
ix-minute averages taken during testing were all 0 percent opacity unless oted below.


September 28, 1983

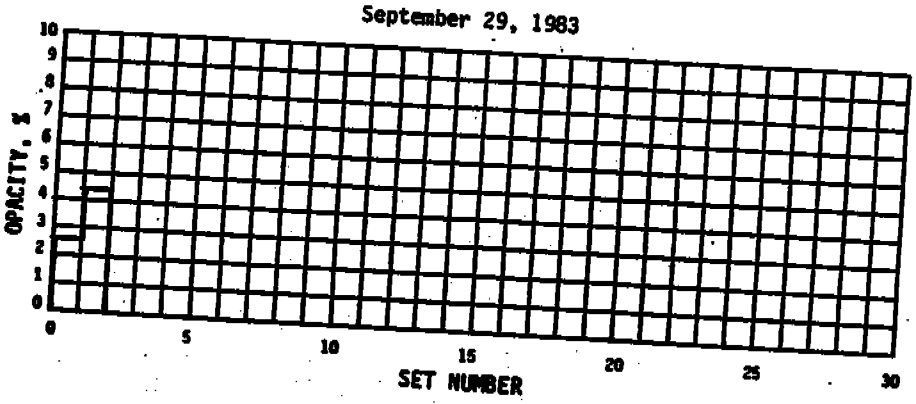

September 29, 1983

TABLE C-75. SUMMARY OF EMISSION TEST RESULTS--PLANT J2

Industry: Kaolin
Process unit: Multiple hearth furnace
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	9/22/81	9/22/81	9/22/81	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	93	91	92	--
Production rate, Mg/h	a	a	a	a
(tons/h)				
Capacity utilization, percent[b]	110	110	110	110
Gas stream data				
Temperature, °C	63	68	71	67
(°F)	(146)	(154)	(159)	(153)
Moisture, percent	24.2	22.4	24.0	23.5
Flow rate, m^3/s	3.3	3.3	3.3	3.3
(acfm)	(6,900)	(6,900)	(6,900)	(6,900)
Flow rate, dsm^3/s	2.5	2.2	2.1	2.1
(dscfm)	(4,500)	(4,600)	(4,500)	(4,500)
Particulate emissions				
g/dsm^3	0.058	0.076	0.057	0.097
(gr/dscf)	(0.025)	(0.033)	(0.025)	(0.028)
kg/h	0.44	0.58	0.44	0.49
(lb/h)	(0.98)	(1.3)	(0.96)	(1.1)
kg/Mg	a	a	a	a
(lb/ton)				

---

[a] Confidential data.

[b] Estimated using feed rate and material moisture content.

TABLE C-76. SUMMARY OF EMISSION TEST RESULTS--PLANT J2

Industry: Kaolin
Process unit: Spray dryer
Emission source: Baghouse outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	7/29/82	7/29/82	7/29/82	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	108	108	109	--
Production rate, Mg/h	a	a	a	a
(tons/h)				
Capacity utilization, percent[b]	81	81	81	81
Gas stream data				
Temperature, °C	82	79	78	80
(°F)	(179)	(175)	(172)	(175)
Moisture, percent	26.1	27.0	26.6	26.6
Flow rate, m³/s	35	35	35	35
(acfm)	(75,200)	(73,600)	(73,900)	(74,200)
Flow rate, dsm³/s	21	21	21	21
(dscfm)	(45,400)	(44,300)	(44,800)	(44,800)
Particulate emissions				
g/dsm³	0.007	0.008	0.008	0.007
(gr/dscf)	(0.003)	(0.004)	(0.003)	(0.003)
kg/h	0.51	0.60	0.58	0.56
(lb/h)	(1.1)	(1.3)	(1.3)	(1.2)
kg/Mg	a	a	a	a
(lb/ton)				

[a] Confidential data.
[b] Estimated using feed rate and material moisture content.

TABLE C-77. SUMMARY OF EMISSION TEST RESULTS--PLANT J3

Industry: Kaolin
Process unit: Spray dryer
Emission source: Baghouse outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	9/27/74	9/28/74	9/30/74	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent[a]	100 ±10	100 ±10	100 ±10	--
Production rate, Mg/h[b]	10.7	12.2	11.1	11.3
(tons/h)	(11.8)	(13.5)	(12.2)	(12.5)
Capacity utilization, percent	79	90	81	83
Gas stream data				
Temperature, °C	94	91	93	93
(°F)	(201)	(195)	(199)	(198)
Moisture, percent	30.7	31.7	29.7	30.7
Flow rate, m^3/s	28	28	26	28
(acfm)	(59,700)	(59,900)	(55,400)	(58,300)
Flow rate, dsm^3/s	16	16	15	15
(dscfm)	(33,100)	(33,000)	(31,200)	(32,400)
Particulate emissions				
g/dsm^3	0.071	0.078	0.030	0.060
(gr/dscf)	(0.031)	(0.034)	(0.013)	(0.026)
kg/h	4.0	4.4	1.6	3.3
(lb/h)	(8.8)	(9.7)	(3.5)	(7.3)
kg/Mg[c]	0.38	0.36	0.14	0.29
(lb/ton)	(0.75)	(0.71)	(0.29)	(0.58)

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[a] Individual isokinetic ratios were not reported.
[b] Estimated using feed rate and material moisture content.
[c] Calculated from estimates of production rate.

TABLE C-78. SUMMARY OF EMISSION TEST RESULTS--PLANT J4
Industry: Kaolin
Process unit: Spray dryer
Emission source: Baghouse outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	4/29/81	4/29/81	4/29/81	--
Sampling time, minutes	72	72	72	--
Isokinetic ratio, percent	101	98	100	--
Production rate, Mg/h[a]	27.7	27.3	29.9	28.3
(tons/h)	(30.5)	(30.1)	(33.0)	(31.2)
Capacity utilization, percent	101	100	110	104
Gas stream data				
Temperature, °C	113	113	118	115
(°F)	(235)	(236)	(245)	(239)
Moisture, percent	22.4	21.6	22.9	22.3
Flow rate, m^3/s	40	40	42	41
(acfm)	(85,300)	(84,900)	(88,500)	(86,200)
Flow rate, dsm^3/s	24	23	24	24
(dscfm)	(49,600)	(49,700)	(50,400)	(49,900)
Particulate emissions				
g/dsm^3	0.008	0.006	0.005	0.006
(gr/dscf)	(0.003)	(0.003)	(0.002)	(0.003)
kg/h	0.65	0.50	0.39	0.52
(lb/h)	(1.4)	(1.1)	(0.86)	(1.1)
kg/Mg[b]	0.024	0.018	0.013	0.018
(lb/ton)	(0.047)	(0.037)	(0.026)	(0.037)

[a] Process weight rate.
[b] Calculated from process weight rate.

TABLE C-79. SUMMARY OF EMISSION TEST RESULTS--PLANT K1

Industry: Lightweight aggregate
Process unit: Rotary calciner
Emission source: Scrubber inlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	7/14/81	7/15/81	7/15/81	--
Sampling time, minutes	120	120	120	--
Isokinetic ratio, percent	106	105	106	--
Production rate, Mg/h	26	26	26	26
(tons/h)	(29)	(29)	(29)	(29)
Capacity utilization, percent	83	83	83	83
Gas stream data				
Temperature, °C	415	413	422	417
(°F)	(779)	(775)	(792)	(782)
Moisture, percent	7.2	8.4	8.5	8.0
Flow rate, m^3/s	48	51	52	50
(acfm)	(101,000)	(107,000)	(109,000)	(106,000)
Flow rate, dsm^3/s	19	19	20	19
(dscfm)	(39,400)	(41,300)	(41,500)	(40,800)
Particulate emissions				
g/dsm^3	54.4	62.9	62.9	59.7
(gr/dscf)	(23.8)	(27.5)	(27.1)	(26.1)
kg/h	3,600	4,400	4,700	4,200
(lb/h)	(8,000)	(9,700)	(9,600)	(9,100)
kg/Mg	140	170	180	160
(lb/ton)	(280)	(340)	(330)	(320)

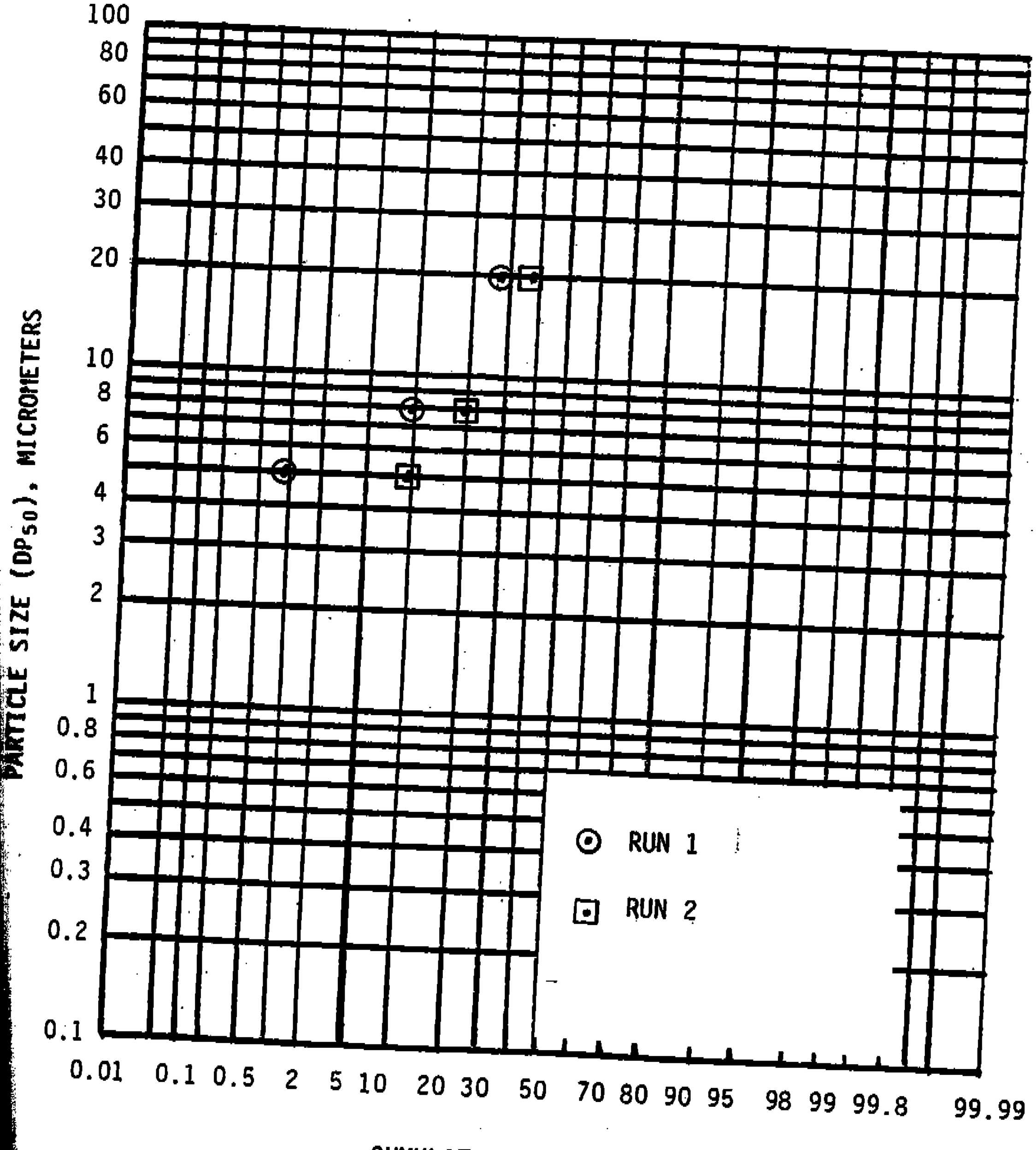


Figure C-54. Particle size distribution data: rotary calciner scrubber inlet--Plant K1.

TABLE C-80. SUMMARY OF EMISSION TEST RESULTS--PLANT K1

Industry: Lightweight aggregate
Process unit: Rotary calciner
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	7/14/81	7/15/81	7/15/81	--
Sampling time, minutes	128	128	128	--
Isokinetic ratio, percent	104	103	105	--
Production rate, Mg/h	26	26	26	26
(tons/h)	(29)	(29)	(29)	(29)
Capacity utilization, percent	83	83	83	83
Gas stream data				
Temperature, °C	65	63	65	64
(°F)	(149)	(145)	(148)	(147)
Moisture, percent	21.2	21.4	22.1	21.6
Flow rate, m^3/s	29	29	30	29
(acfm)	(61,100)	(62,400)	(63,200)	(62,300)
Flow rate, dsm^3/s	19	20	20	20
(dscfm)	(41,200)	(42,100)	(42,000)	(41,800)
Particulate emissions				
g/dsm^3	0.095	0.101	0.100	0.099
(gr/dscf)	(0.041)	(0.044)	(0.044)	(0.043)
kg/h	6.6	7.2	7.2	7.0
(lb/h)	(15)	(16)	(16)	(15)
kg/Mg	0.25	0.28	0.28	0.27
(lb/ton)	(0.50)	(0.55)	(0.54)	(0.53)

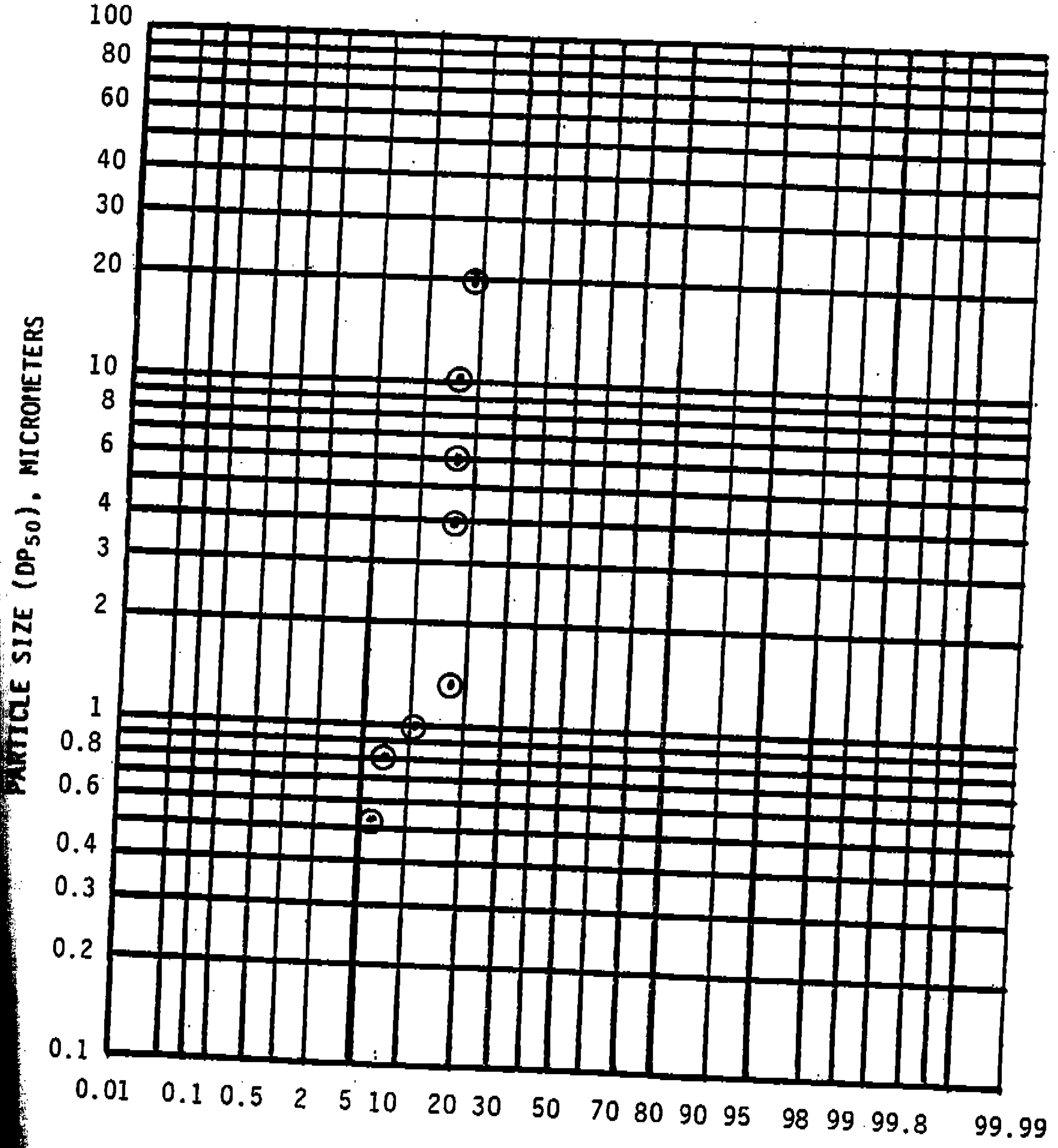


Figure C-55. Particle size distribution data: rotary calciner scrubber outlet (Run 4)--Plant K1.

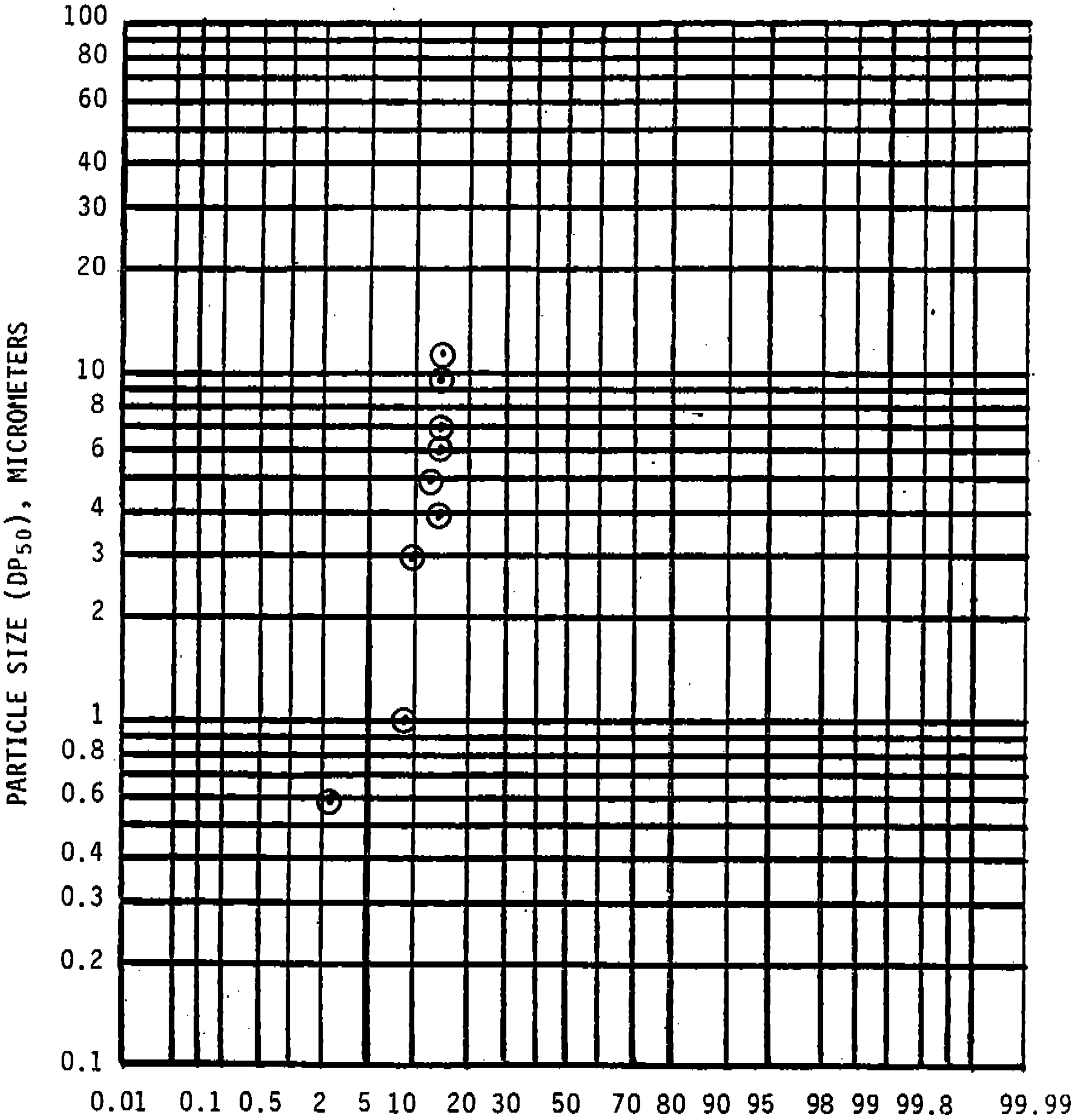


Figure C-56. Particle size distribution data: rotary calciner scrubber outlet (Run 5)--Plant K1.

TABLE C-81. SUMMARY OF VISIBLE EMISSIONS--PLANT K1

Date	7/14/81
Industry	Lightweight aggregate
Process unit	Rotary calciner
Location of discharge	Scrubber outlet
Height of observation point, ft	8
Height of point of discharge, ft	150
Distance from observer to discharge point, ft	400
Direction of observer from discharge point	E
Description of background	Sky
Description of sky	Scattered
Wind direction	NW
Wind velocity, mph	0-5
Color of plume	White
Duration of observation, min	90
Period of observation	1035-1129 1135-1153 1159-1229 1240-1310 1316-1334
Highest single reading, percent	5
Highest 6-minute average, percent	1.5

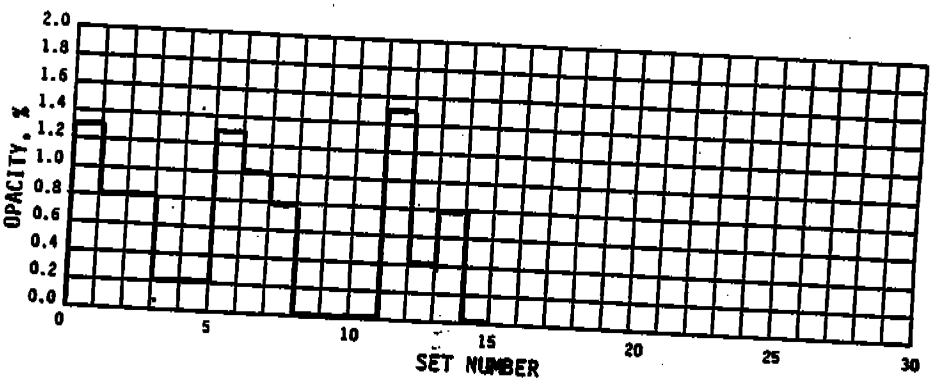


TABLE C-82. SUMMARY OF VISIBLE EMISSIONS--PLANT K1

Date	7/15/81
Industry	Lightweight aggregate
Process unit	Rotary calciner
Location of discharge	Scrubber outlet
Height of observation point, ft	8
Height of point of discharge, ft	150
Distance from observer to discharge point, ft	400
Direction of observer from discharge point	E
Description of background	Sky
Description of sky	Clear
Wind direction	NE
Wind velocity, mph	0-3
Color of plume	White
Duration of observation, min	84
Period of observation	0900-0954 1000-1054 1100-1142
Highest single reading, percent	5
Highest 6-minute average, percent	3.8

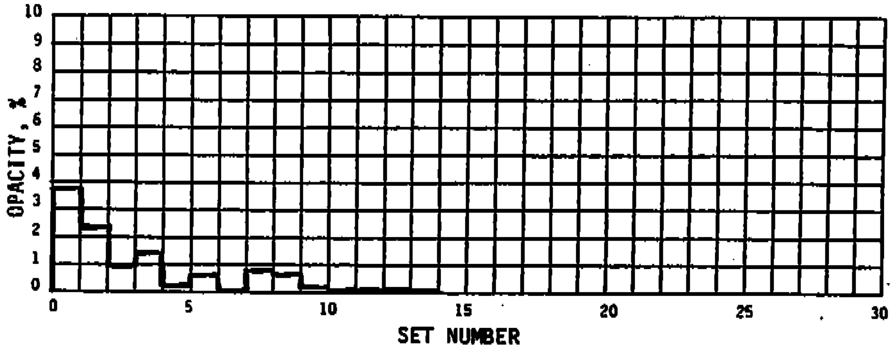


TABLE C-83. SUMMARY OF VISIBLE EMISSIONS--PLANT K1

Date	7/15/81
Industry	Lightweight aggregate
Process unit	Rotary calciner
Location of discharge	Scrubber outlet
Height of observation point, ft	10
Height of point of discharge, ft	150
Distance from observer to discharge point, ft	200
Direction of observer from discharge point	SE
Description of background	Sky
Description of sky	Scattered
Wind direction	S
Wind velocity, mph	0-5
Color of plume	White
Duration of observation, min	72
Period of observation	1355-1613[a]
Highest single reading, percent	5
Highest 6-minute average, percent	1.5

[a] 12 sets of 6-minute observations were made during this period.

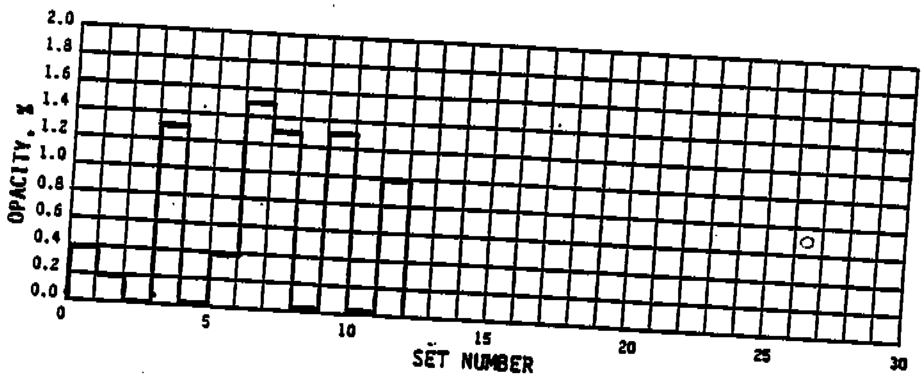


TABLE C-84. SUMMARY OF SULFUR DIOXIDE EMISSIONS DATA--PLANT K1

Industry: Lightweight aggregate
Process unit: Rotary calciner
Location of discharge: Scrubber inlet and outlet

Test location	Date, 1981	Concentration, g/dsm³ (ppm)	Mass emission rate, kg/h (lb/h)	Temp., °C (°F)
Scrubber inlet[a]				
Run No. 1	7/17	1.04 (390)	70.9 (156)	417 (782)
Run No. 2	7/17	1.76 (660)	120 (265)	417 (782)
Average	--	1.40 (525)	95.6 (211)	417 (982)
Run No. 3	7/17	1.67 (628)	114 (252)	417 (782)
Run No. 4	7/17	1.69 (635)	116 (255)	417 (782)
Average	--	1.68 (632)	115 (254)	417 (782)
Run No. 5	7/17	1.61 (603)	110 (242)	417 (782)
Run No. 6	7/17	1.69 (635)	116 (255)	417 (782)
Average	--	1.65 (619)	113 (248)	417 (782)
Scrubber outlet[b]				
Run No. 1	7/17	0.349 (131)	24.5 (54)	64 (147)
Run No. 2	7/17	0.508 (191)	35.7 (78.6)	64 (147)
Average	--	0.429 (161)	30.1 (66.3)	64 (147)
Run No. 3	7/17	0.421 (158)	29.6 (65.2)	64 (147)
Run No. 4	7/17	0.469 (176)	32.9 (72.6)	64 (147)
Average	--	0.445 (167)	31.3 (68.9)	64 (147)
Run No. 5	7/17	0.317 (119)	22.2 (48.9)	64 (147)
Run No. 6	7/17	0.218 (82)	15.2 (33.6)	64 (147)
Average	--	0.268 (101)	18.7 (41.3)	64 (147)

[a] Mass emission rates are based on the average stack gas flow rate determined during the inlet particulate tests (19.234 dsm³/s [40,755 dscfm].

[b] Mass emission rates are based on the average stack gas flow rate determined during the outlet particulate tests (19.721 dsm³/s [41,788 dscfm]).

TABLE C-85. SUMMARY OF NITROGEN OXIDE EMISSIONS DATA--PLANT K1

Industry: Lightweight aggregate
Process unit: Rotary calciner
Location of discharge: Scrubber outlet

Test location	Date, 1981	Concentration, g/dsm³ (ppm)	Mass emission rate, kg/h (lb/h)
Scrubber outlet[a]			
Sample No. 1A	7/17	0.358 (187)	25.4 (56.1)
Sample No. 1B	7/17	0.331 (173)	23.5 (51.8)
Sample No. 1C	7/17	0.365 (191)	26.0 (57.3)
Sample No. 1D	7/17	0.375 (196)	26.6 (58.7)
Average		0.357 (187)	25.4 (56.0)
Sample No. 2A	7/17	0.346 (181)	24.6 (54.2)
Sample No. 2B	7/17	0.365 (191)	25.9 (57.2)
Sample No. 2C	7/17	0.335 (175)	23.9 (52.6)
Sample No. 2D	7/17	0.377 (197)	26.8 (59.0)
Average	--	0.356 (186)	25.3 (55.8)
Sample No. 3A	7/17	0.337 (176)	23.9 (52.8)
Sample No. 3B	7/17	0.362 (189)	25.7 (56.6)
Sample No. 3C	7/17	0.365 (191)	25.9 (57.2)
Sample No. 3D	7/17	0.350 (183)	24.8 (54.7)
Average	--	0.354 (185)	25.1 (55.3)

[a] Mass emission rates are based on the average stack gas flow rate determined during the scrubber outlet particulate tests (19.721 dsm³/s [41,788 dscfm].

TABLE C-86. SUMMARY OF HYDROCARBON EMISSIONS--PLANT K1

Industry: Lightweight aggregate
Process unit: Rotary calciner
Emission source: Scrubber outlet

Test No.	Date, 1981	Sampling time, 24-h		NMO[a] concentration	Gas stream flow rate		Hydrocarbon emission rate expressed as methane[b]	
		Start	Finish	ppm as CH_4	dscmh	dscfh	kg/h	lb/h
SO-25-1	7/16	1500	1600	134	70,999	2,507,307	6.3	13.9
SO-25-2	7/16	1500	1600	231	70,999	2,507,307	10.9	24.0
SO-25-3	7/17	0905	1035	378	70,999	2,507,307	17.9	39.5
SO-25-4	7/17	1045	1200	128	70,999	2,507,307	6.0	13.2
Average				218	70,999	2,507,307	10.3	22.7

[a] NMO = nonmethane organics measured and expressed as methane (CH_4).

[b] Based on the molecular weight of methane, 16 g/g-mole (16 lb/lb-mole).

TABLE C-87. SUMMARY OF EMISSION TEST RESULTS--PLANT K2

Industry: Lightweight aggregate
Process unit: Rotary calciner
Emission source: Scrubber inlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	2/24/82	2/25/82	2/25/82	--
Sampling time, minutes	120	120	120	--
Isokinetic ratio, percent	106	106	105	--
Production rate, Mg/h	16.5	16.1	16.5	16.4
(tons/h)	(18.2)	(17.7)	(18.2)	(18.0)
Capacity utilization, percent	83	83	83	83
Gas stream data				
Temperature, °C	473	473	478	475
(°F)	(883)	(884)	(893)	(887)
Moisture, percent	5.9	6.7	6.7	6.4
Flow rate, m³/s	31	33	33	32
(acfm)	(65,000)	(70,400)	(69,600)	(68,300)
Flow rate, dsm³/s	11	12	12	12
(dscfm)	(23,600)	(25,400)	(25,000)	(25,000)
Particulate emissions				
g/dsm³	31.5	42.6	45.5	39.8
(gr/dscf)	(13.8)	(18.6)	(19.9)	(17.4)
kg/h	1,300	1,800	1,900	1,700
(lb/h)	(2,800)	(4,000)	(4,300)	(3,700)
kg/Mg	76	110	120	100
(lb/ton)	(150)	(230)	(230)	(200)

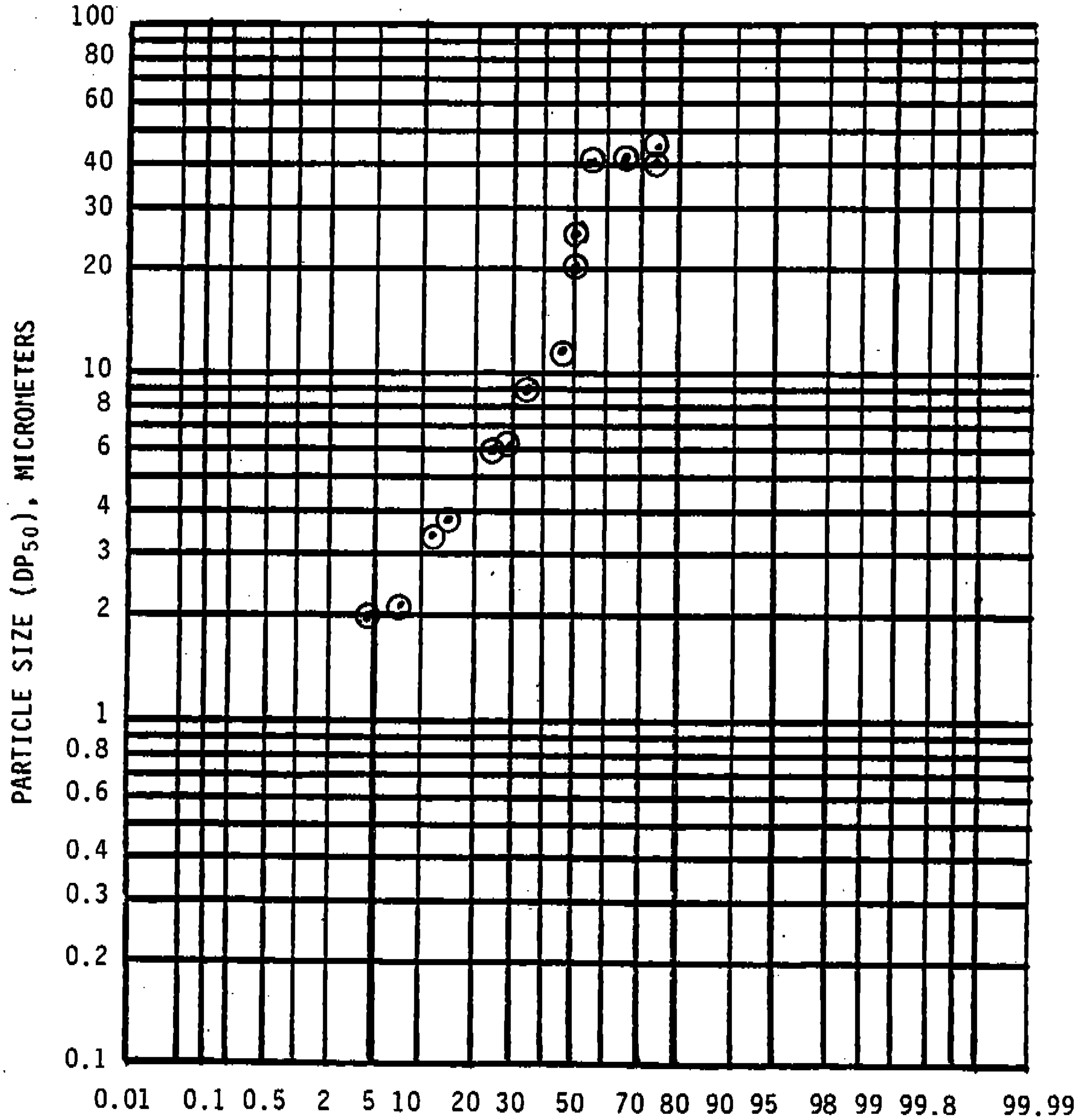
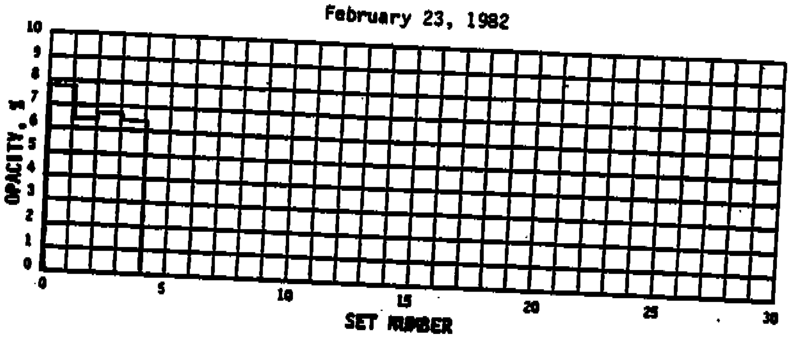


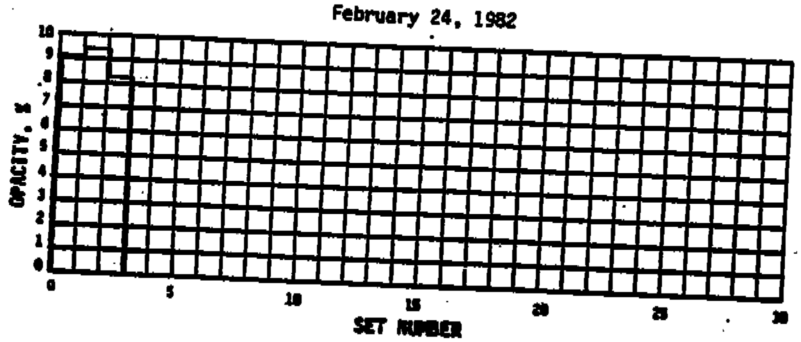
Figure C-57. Particle size distribution data: rotary calciner scrubber inlet--Plant K2.

TABLE C-88. SUMMARY OF PROCESS FUGITIVE EMISSIONS--PLANT K2

Date	2/23-25/82
Industry	Lightweight aggregate
Process unit	Rotary calciner
Period of observation	(2/23) 12:34-15:41; (2/24) 14:10-15:46; (2/25) 10:53-11:05; 12:49-13:00
Location of discharge point	Calciner inlet
Highest single reading, percent	10
Highest 6-minute average, percent[a]	10

[a] Six-minute averages taken during testing were all 0 percent opacity unless noted below.





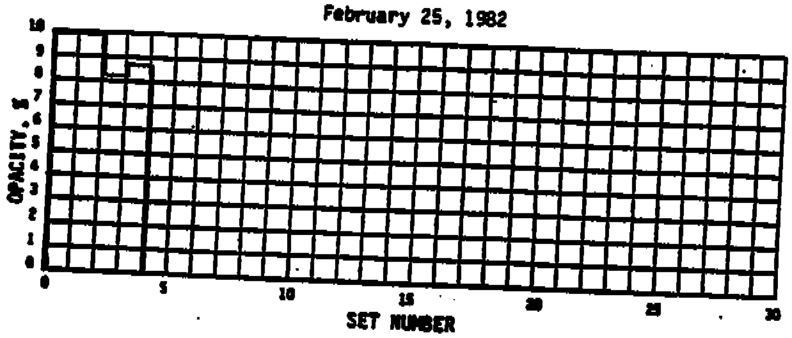


TABLE C-89. SUMMARY OF SULFUR DIOXIDE EMISSIONS DATA--PLANT K2

Industry: Lightweight aggregate
Process unit: Rotary calciner
Location of discharge: Scrubber inlet

Test location	Date, 1982	Concentration, g/dsm³ (ppm)	Mass emission rate, kg/h (lb/h)	Temp., °C (°F)
Scrubber inlet[a]				
Run No. 1	2/26	4.91 (1,862)	205 (452)	519 (968)
Run No. 2	2/26	6.09 (2,314)	255 (562)	530 (988)
Average	--	5.50 (2,088)	230 (507)	525 (978)
Run No. 3	2/26	6.17 (2,342)	258 (569)	524 (977)
Run No. 4	2/27	5.63 (2,135)	235 (519)	511 (954)
Average	--	5.90 (2,239)	247 (544)	518 (966)
Run No. 5	2/27	5.52 (2,095)	231 (509)	525 (979)
Run No. 6	2/27	5.40 (2,052)	226 (499)	527 (981)
Average	--	5.46 (2,074)	228 (504)	526 (980)

---

[a] Mass emission rates are based on the average stack gas flow rate determined during the inlet particulate tests (11.638 dsm³/s [24,659 dscfm].

TABLE C-90. SUMMARY OF NITROGEN OXIDE EMISSIONS DATA--PLANT K2

Industry: Lightweight aggregate
Process unit: Rotary calciner
Location of discharge: Scrubber outlet

Test location	Date, 1982	Concentration, g/dsm³ (ppm)	Mass emission rate, kg/h (lb/h)
Scrubber outlet[a]			
Sample No. 1A	2/27	0.363 (189)	30.4 (67.1)
Sample No. 1B	2/27	0.468 (244)	39.3 (86.6)
Sample No. 1C	2/27	0.399 (208)	33.5 (73.8)
Sample No. 1D	2/27	0.439 (229)	36.8 (81.2)
Average	--	0.417 (218)	35.0 (77.2)
Sample No. 2A	2/27	0.396 (207)	33.2 (73.3)
Sample No. 2B	2/27	0.394 (206)	33.0 (72.8)
Sample No. 2C	2/27	0.575 (300)	48.2 (106)
Sample No. 2D	2/27	0.386 (201)	32.3 (71.3)
Average	--	0.392 (205)	36.7 (72.5)
Sample No. 3A[b]	2/27	0.295 (154)	24.7 (54.5)
Sample No. 3B	2/27	0.411 (215)	34.5 (76.1)
Sample No. 3C	2/27	0.380 (198)	31.9 (70.3)
Sample No. 3D	2/27	0.367 (192)	30.8 (67.8)
Average	--	0.386 (202)	32.4 (71.4)

---

[a] Mass emission rates are based on the average stack gas flow rate determined during the scrubber outlet particulate tests (23.321 dsm³/s [49,414 dscfm].

[b] Outlier not used in average.

TABLE C-91. SUMMARY OF HYDROCARBON EMISSIONS--PLANT K2

Industry: Lightweight aggregate
Process unit: Rotary calciner
Emission source: Scrubber outlet

Test No.	Date, 1982	Sampling time, 24-h		NMO[a] concentration ppm as CH_4	Hydrocarbon emission rate expressed as methane[b]	
		Start	Finish		kg/h	lb/h
SO-VC-1[c]	2/26	--	--	--	--	--
SO-VC-2	2/26	1032	1120	60	3.6	7.4
SO-VC-3	2/26	1127	1215	141	8.5	17.4
SO-VC-4	2/27	0900	1010	68	4.1	8.4
Average				90	5.4	11.1

[a] NMO = nonmethane organics measured and expressed as methane (CH_4).

[b] Based on the molecular weight of methane, 16 g/g-mole (16 lb/lb-mole). Mass emission rates are calculated using the average gas flow rate measured during the particulate tests (2,964,856 dscfh).

[c] SO-VC-1 voided due to plug in sampling probe.

TABLE C-92. SUMMARY OF EMISSION TEST RESULTS--PLANT K3

Industry: Lightweight aggregate
Process unit: Rotary calciner No. 1
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	11/12/81	11/12/81	11/12/81	--
Sampling time, minutes	96	96	96	--
Isokinetic ratio, percent	97	98	99	--
Production rate, Mg/h	29.8	29.8	29.8	29.8
(tons/h)	(32.8)	(32.8)	(32.8)	(32.8)
Capacity utilization, percent	109	109	109	109
Gas stream data				
Temperature, °C	59	59	59	59
(°F)	(138)	(138)	(138)	(138)
Moisture, percent	17.5	17.7	17.6	17.5
Flow rate, m³/s	17	27	28	27
(acfm)	(58,000)	(57,400)	(58,400)	(57,900)
Flow rate, dsm³/s	20	20	20	20
(dscfm)	(42,400)	(41,700)	(42,500)	(42,200)
Particulate emissions				
g/dsm³	0.101	0.116	0.111	0.109
(gr/dscf)	(0.044)	(0.051)	(0.049)	(0.048)
kg/h	7.3	8.2	8.1	7.9
(lb/h)	(16)	(18)	(18)	(17)
kg/Mg	0.24	0.28	0.27	0.26
(lb/ton)	(0.49)	(0.55)	(0.54)	(0.53)

TABLE C-93. SUMMARY OF EMISSION TEST RESULTS--PLANT K3[a]

Industry: Lightweight aggregate
Process unit: Rotary calciner No. 2
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	11/11/81	11/11/81	11/11/81	--
Sampling time, minutes	96	96	96	--
Isokinetic ratio, percent	97	96	97	--
Production rate, Mg/h	36.3	36.3	36.3	36.3
(tons/h)	(40)	(40)	(40)	(40)
Capacity utilization, percent	100	100	100	100
Gas stream data				
Temperature, °C	58	59	59	59
(°F)	(136)	(138)	(139)	(138)
Moisture, percent	17.2	17.8	18.4	17.8
Flow rate, m^3/s	32	33	34	33
(acfm)	(67,800)	(69,100)	(71,100)	(69,300)
Flow rate, dsm^3/s	24	24	24	24
(dscfm)	(49,800)	(50,300)	(51,200)	(50,400)
Particulate emissions				
g/dsm^3	0.178	0.158	0.179	0.172
(gr/dscf)	(0.078)	(0.069)	(0.078)	(0.075)
kg/h	15	13	16	15
(lb/h)	(33)	(30)	(34)	(32)
kg/Mg	0.42	0.37	0.44	0.41
(lb/ton)	(0.83)	(0.74)	(0.86)	(0.81)

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[a] The multiclone that precedes the wet scrubber was bypassed during the particulate test series. Therefore, the test results do not represent typical operating conditions.

TABLE C-94. SUMMARY OF SULFUR DIOXIDE EMISSIONS DATA--PLANT K3

Industry: Lightweight aggregate
Process unit: Rotary calciner
Location of discharge: Multiple cyclone collector inlet

Test location	Date, 1979	Concentration, g/dsm^3 (ppm)	Mass emission rate, kg/h (lb/h)	Temp., °C (°F)
Multiple cyclone inlet				
Run No. 1	6/5	2.60 (N/A)[a]	281 (619)	146 (295)
Run No. 2	6/5	2.71 (N/A)	171 (377)	164 (328)
Run No. 3	6/6	3.14 (N/A)	195 (429)	166 (330)
Average	--	2.82 (N/A)	216 (475)	159 (318)

[a] N/A = Information not available.

TABLE C-95. SUMMARY OF EMISSION TEST RESULTS--PLANT K4

Industry: Lightweight aggregate
Process unit: Rotary calciner
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	10/29/82	10/29/82	10/29/82	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	101	99	100	--
Production rate, Mg/h	6.4	6.4	6.4	6.4
(tons/h)	(7)	(7)	(7)	(7)
Capacity utilization, percent	92	92	92	92
Gas stream data				
Temperature, °C	61	58	125	81
(°F)	(142)	(137)	(143)	(141)
Moisture, percent	15	16.3	17.8	16.4
Flow rate, m^3/s	8.4	8.3	8.6	8.4
(acfm)	(17,800)	(17,500)	(18,100)	(17,800)
Flow rate, dsm^3/s	6.3	6.2	6.2	6.2
(dscfm)	(13,400)	(13,100)	(13,200)	(13,200)
Particulate emissions				
g/dsm^3	0.063	0.076	0.071	0.070
(gr/dscf)	(0.027)	(0.033)	(0.031)	(0.031)
kg/h	1.4	1.7	1.6	1.8
(lb/h)	(3.2)	(3.8)	(3.5)	(3.5)
kg/Mg	0.22	0.27	0.25	0.25
(lb/ton)	(0.45)	(0.54)	(0.50)	(0.50)

TABLE C-96. SUMMARY OF EMISSION TEST RESULTS--PLANT K5

Industry: Lightweight aggregate
Process unit: Rotary calciner
Emission source: Baghouse inlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	4/29/80	4/29/80	4/29/80	--
Sampling time, minutes	63	71	62	--
Isokinetic ratio, percent	95	100	99	--
Production rate, Mg/h	21	21	21	21
(tons/h)	(23)	(23)	(23)	(23)
Capacity utilization, percent	100	100	100	100
Gas stream data				
Temperature, °C	173	169	161	168
(°F)	(344)	(336)	(321)	(334)
Moisture, percent	5.5	6.6	7.1	6.4
Flow rate, m^3/s	8.2	8.3	8.5	8.3
(acfm)	(17,300)	(17,600)	(17,900)	(17,600)
Flow rate, dsm^3/s	4.9	4.9	5.1	5.0
(dscfm)	(10,400)	(10,500)	(10,900)	(10,600)
Particulate emissions				
g/dsm^3	20.3	17.2	17.6	18.4
(gr/dscf)	(8.87)	(7.50)	(7.67)	(8.01)
kg/h	360	310	320	330
(lb/h)	(790)	(670)	(710)	(720)
kg/Mg	17	15	15	16
(lb/ton)	(34)	(29)	(31)	(32)

TABLE C-97. SUMMARY OF EMISSION TEST RESULTS--PLANT K5

Industry: Lightweight aggregate
Process unit: Rotary calciner
Emission source: Baghouse outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	4/29/80	4/29/80	4/29/80	--
Sampling time, minutes	67	72	67	--
Isokinetic ratio, percent	105	97	105	--
Production rate, Mg/h	21	21	21	21
(tons/h)	(23)	(23)	(23)	(23)
Capacity utilization, percent	100	100	100	100
Gas stream data				
Temperature, °C	83	78	76	79
(°F)	(181)	(173)	(169)	(174)
Moisture, percent	2.6	2.4	3.2	2.7
Flow rate, m^3/s	19	19	19	19
(acfm)	(39,800)	(39,500)	(40,300)	(39,900)
Flow rate, dsm^3/s	15	15	15	15
(dscfm)	(30,900)	(31,200)	(31,700)	(31,300)
Particulate emissions				
g/dsm^3	0.048	0.083	0.091	0.074
(gr/dscf)	(0.021)	(0.036)	(0.040)	(0.032)
kg/h	2.5	4.4	4.9	3.9
(lb/h)	(5.6)	(9.7)	(11)	(8.7)
kg/Mg	0.12	0.21	0.23	0.19
(lb/ton)	(0.24)	(0.42)	(0.47)	(0.38)

TABLE C-98. SUMMARY OF EMISSION TEST RESULTS--PLANT K6

Industry: Lightweight aggregate
Process unit: Rotary calciner
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	2/23/81	2/23/81	2/24/81	--
Sampling time, minutes	136	134	124	--
Isokinetic ratio, percent	99	99	101	--
Production rate, Mg/h[a]	12.0	12.0	12.0	12.0
(tons/h)	(13.3)	(13.3)	(13.3)	(13.3)
Capacity utilization, percent	100	100	100	100
Gas stream data				
Temperature, °C	78	78	81	79
(°F)	(172)	(173)	(178)	(174)
Moisture, percent	17.5	15.2	19.3	17.3
Flow rate, m^3/s	14	15	15	14
(acfm)	(30,300)	(30,700)	(30,800)	(30,600)
Flow rate, dsm^3/s	10	10	10	10
(dscfm)	(21,100)	(22,000)	(20,700)	(21,300)
Particulate emissions				
g/dsm^3	0.090	0.090	0.108	0.096
(gr/dscf)	(0.040)	(0.040)	(0.047)	(0.042)
kg/h	3.2	3.4	3.8	3.5
(lb/h)	(7.1)	(7.4)	(8.4)	(7.6)
kg/Mg[a]	0.27	0.28	0.32	0.29
(lb/ton)	(0.54)	(0.57)	(0.64)	(0.58)

[a] Based on "average operating rate" of the rotary calciner at Plant K6. Actual production rate data were not monitored during tests.

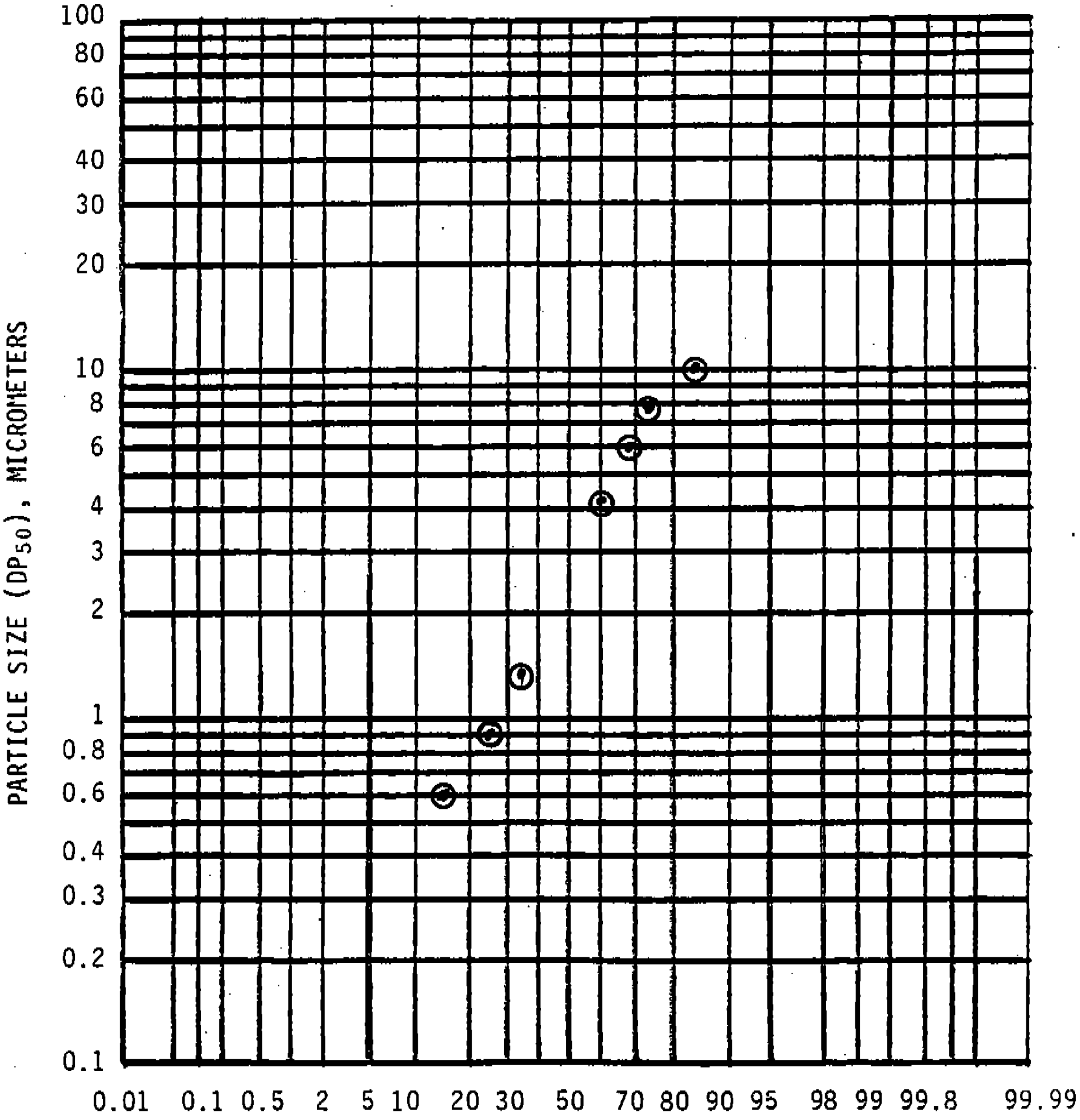

Figure C-58. Particle size distribution data: rotary calciner scrubber outlet--Plant K6.

TABLE C-99. SUMMARY OF VISIBLE EMISSIONS--PLANT K6

Date	2/23/81
Industry	Lightweight aggregate
Process unit	Rotary calciner
Location of discharge	Scrubber outlet
Height of observation point, ft	Ground
Height of point of discharge, ft	100
Distance from observer to discharge point, ft	200, 100
Direction of observer from discharge point	E, SW
Description of background	Clear sky
Description of sky	Clear
Wind direction	SW
Wind velocity, mph	10-15
Color of plume	White
Duration of observation, min	84
Period of observation	1030-1709[a]
Highest single reading, percent	15
Highest 6-minute average, percent	10.0

[a] 14 sets of 6-minute observations were made during this period.

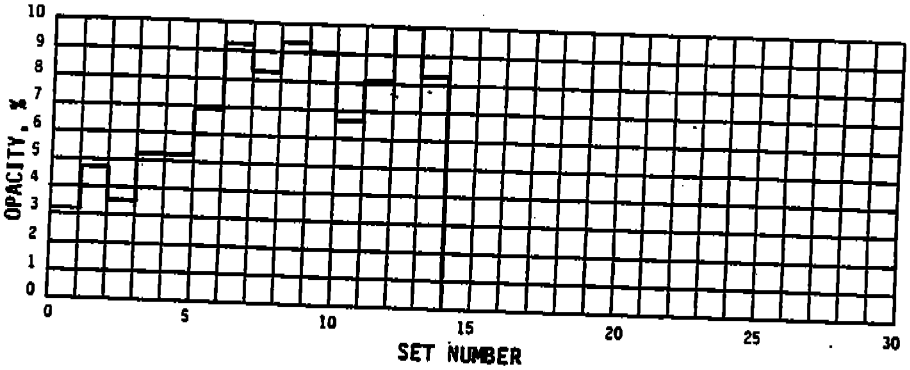

TABLE C-100. SUMMARY OF VISIBLE EMISSIONS--PLANT K6

Date	2/24/81
Industry	Lightweight aggregate
Process unit	Rotary calciner
Location of discharge	Scrubber outlet
Height of observation point, ft	Ground
Height of point of discharge, ft	100
Distance from observer to discharge point, ft	200, 100
Direction of observer from discharge point	E, SW
Description of background	Clear sky
Description of sky	Scattered, broken
Wind direction	SW, S
Wind velocity, mph	5
Color of plume	White
Duration of observation, min	78[a]
Period of observation	0912-1526[a]
Highest single reading, percent	15
Highest 6-minute average, percent	9.8

[a] 13 sets of 6-minute observations were made during this period.

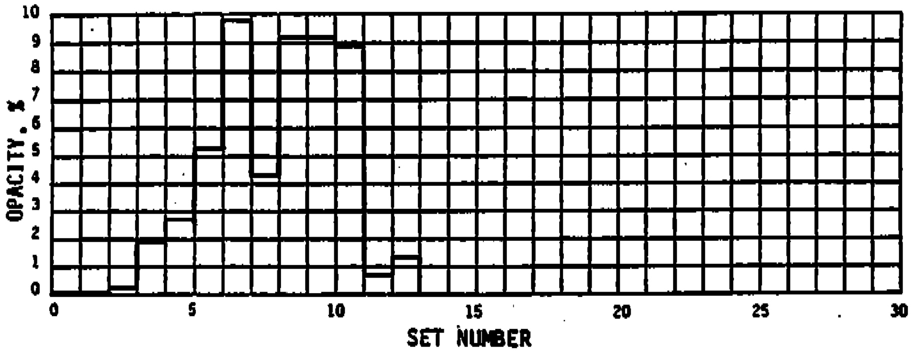

TABLE C-101. SUMMARY OF SULFUR DIOXIDE EMISSIONS DATA--PLANT K6

Industry: Lightweight aggregate
Process unit: Rotary calciner
Location of discharge: Scrubber inlet and outlet

Test location	Date, 1981	Concentration, g/dsm³ (ppm)	Mass emission rate, kg/h (lb/h)	Temp., °C (°F)
Scrubber inlet				
Run No. 1	2/26	0.718 (273)	19.9 (43.9)	338 (640)
Run No. 2	2/26	0.753 (286)	19.8 (43.7)	338 (640)
Average	--	0.736 (280)	19.9 (43.8)	338 (640)
Run No. 3	2/26	0.785 (299)	24.3 (53.6)	338 (640)
Run No. 4	2/26	0.702 (267)	21.7 (48.0)	338 (640)
Average	--	0.744 (283)	23.0 (50.8)	338 (640)
Run No. 5	2/26	0.660 (251)	19.2 (42.2)	338 (640)
Run No. 6	2/26	0.231[a] (88)[a]	6.7[a] (14.7)[a]	338 (640)
Average	--	0.660 (251)	19.2 (42.2)	338 (640)
Scrubber outlet				
Run No. 1	2/26	0.481 (183)	17.4 (38.3)	77 (170)
Run No. 2	2/26	0.509 (194)	18.4 (40.5)	77 (170)
Average	--	0.495 (189)	17.9 (39.4)	77 (170)
Run No. 3	2/26	0.562 (214)	20.3 (44.8)	77 (170)
Run No. 4	2/26	0.485 (185)	17.5 (38.7)	77 (170)
Average	--	0.524 (200)	18.9 (41.8)	77 (170)
Run No. 5	2/26	0.489 (186)	17.7 (38.9)	77 (170)
Run No. 6	2/26	0.537 (204)	19.4 (42.8)	77 (170)
Average	--	0.513 (195)	18.6 (40.9)	77 (170)

[a] Outlier--not included in averages.

TABLE C-102. SUMMARY OF NITROGEN OXIDE EMISSIONS DATA--PLANT K6

Industry: Lightweight aggregate
Process unit: Rotary calciner
Location of discharge: Scrubber outlet

Test location	Date, 1981	Concentration, g/dsm³ (ppm)	Mass emission rate,[a] kg/h (lb/h)
<u>Scrubber outlet</u>			
Sample No. 1A	2/26	0.282 (147)	10.2 (22.4)
Sample No. 1B	2/26	0.330 (172)	11.9 (26.3)
Sample No. 1C	2/26	0.325 (170)	11.8 (25.9)
Sample No. 1D	2/26	0.266 (139)	9.6 (21.2)
Average	--	0.301 (157)	10.9 (24.0)
Sample No. 2A	2/26	0.268 (140)	9.7 (21.4)
Sample No. 2B	2/26	0.270 (141)	9.7 (21.5)
Sample No. 2C	2/26	0.289 (151)	10.4 (23.0)
Sample No. 2D	2/26	0.300 (157)	10.8 (23.9)
Average	--	0.282 (147)	10.2 (22.5)
Sample No. 3A	2/26	0.302 (158)	10.9 (24.1)
Sample No. 3B	2/26	0.231 (121)	8.3 (18.4)
Sample No. 3C	2/26	0.294 (153)	10.6 (23.4)
Sample No. 3D	2/26	0.287 (150)	10.4 (22.9)
Average	--	0.279 (146)	10.1 (22.2)

[a] Mass emission rate in kilograms per hour (kg/h) and pounds per hour (lb/h) calculated using average measured flow obtained from the particulate tests.

TABLE C-103. SUMMARY OF TRACE METAL ANALYSIS--PLANT K6[a]

(Composite samples per category, ppm of impinger solution [unless noted])

Industry: Lightweight aggregate
Process unit: Rotary calciner
Sample source: Method 5 particulate catch

Element	Coal	Clay	Final product	Scrubber effluent
Calcium	3.1%	0.65%	0.82%	320
Magnesium	0.384%	0.71%	0.79%	33
Potassium	0.568%	0.53%	0.58%	10
Sodium	0.480%	0.40%	0.46%	62
Silicon	9.6%	28%	34%	12
Barium	630	370	360	0.080
Manganese	470	700	430	2.2
Aluminum	4.2%	6.6%	7.4%	<0.05
Chrominum	46	62	70	<0.001
Copper	100	19	24	<0.001
Zinc	540	77	94	0.058
Titanium	0.244%	0.38%	0.490%	<0.005
Strontium	250	66	80	1.1
Vanadium	73	92	110	0.008
Lithium	7.5	40	52	0.18
Yttrium	19	23	25	<0.002
Iron	4.0%	3.2%	3.9%	0.040

[a] Elements not detected in samples: Phosphorus, Tungsten, Platinum, Boron, Mercury, Thallium, Molybdenum, Antimony, Gold, Tellurium, Nickel, Bismuth, Beryllium, Arsenic, Indium, Selenium, Silver, Lead, Cadmium, Cobalt, Tin, and Uranium.

TABLE C-104. SUMMARY OF EMISSION TEST RESULTS--PLANT L1

Industry: Magnesium compounds
Process unit: Multiple hearth furnace
Emission source: Baghouse outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
<u>General</u>				
Date	6/14/83	6/15/83	6/15/83	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	98	98	98	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent[b]	85	85	85	85
<u>Gas stream data</u>				
Temperature, °C	163	165	164	164
(°F)	(325)	(329)	(328)	(327)
Moisture, percent	a	a	a	a
Flow rate, m^3/s (acfm)	a	a	a	a
Flow rate, dsm^3/s (dscfm)	a	a	a	a
<u>Particulate emissions</u>				
g/dsm^3	0.005	0.025	0.037	0.022
(gr/dscf)	(0.002)	(0.011)	(0.016)	(0.010)
kg/h (lb/h)	a	a	a	a
kg/Mg (lb/ton)	a	a	a	a

---

[a] Confidential data.

[b] Estimated from process feed rate.

TABLE C-105. SUMMARY OF EMISSION TEST RESULTS--PLANT L2
Industry: Magnesium compounds
Process unit: Rotary calciner
Emission source: ESP outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	5/5/81	5/5/81	5/5/81	--
Sampling time, minutes	63	61	62	--
Isokinetic ratio, percent	105	98	99	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent	92	92	92	92
Gas stream data				
Temperature, °C	213	213	214	213
(°F)	(416)	(415)	(417)	(416)
Moisture, percent	28.1	28.1	29.0	28.4
Flow rate, m³/s	24	24	24	24
(acfm)	(50,800)	(49,900)	(50,100)	(50,200)
Flow rate, dsm³/s	10	10	10	10
(dscfm)	(21,700)	(21,400)	(21,200)	(21,400)
Particulate emissions				
g/dsm³	0.044	0.037	0.032	0.037
(gr/dscf)	(0.019)	(0.016)	(0.014)	(0.016)
kg/h	1.6	1.3	1.2	1.4
(lb/h)	(3.6)	(2.9)	(2.6)	(3.0)
kg/Mg (lb/ton)	a	a	a	a

---

[a] Confidential data.

TABLE C-106. SUMMARY OF EMISSION TEST RESULTS--PLANT L3

Industry: Magnesium compounds
Process unit: Rotary calciner
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	6/5/80	6/5/80	6/6/80	--
Sampling time, minutes	59	62	65	--
Isokinetic ratio, percent	98	98	104	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent	95	95	95	95
Gas stream data				
Temperature, °C (°F)	a	a	a	a
Moisture, percent	a	a	a	a
Flow rate, m^3/s (acfm)	a	a	a	a
Flow rate, dsm^3/s (dscfm)	a	a	a	a
Particulate emissions				
g/dsm^3	0.053	0.044	0.053	0.050
(gr/dscf)	(0.023)	(0.019)	(0.030)	(0.024)
kg/h (lb/h)	a	a	a	a
kg/Mg (lb/ton)	a	a	a	a

---

[a] Confidential data.

TABLE C-107. SUMMARY OF EMISSION TEST RESULTS--PLANT L4
Industry: Magnesium compounds
Process unit: Rotary calciner
Emission source: ESP outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	11/10/81	11/10/81	11/10/81	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	110	101	106	--
Production rate, Mg/h	a	a	a	a
(tons/h)				
Capacity utilization, percent[b]	98	102	102	101
Gas stream data				
Temperature, °C	221	212	209	214
(°F)	(429)	(414)	(409)	(417)
Moisture, percent	34.6	32.6	34.1	33.8
Flow rate, m^3/s	16	18	18	17
(acfm)	(34,900)	(38,100)	(37,900)	(37,000
Flow rate, dsm^3/s	10	11	11	11
(dscfm)	(21,100)	(23,400)	(23,400)	(22,600)
Particulate emissions				
g/dsm^3	0.021	0.050	0.055	0.042
(gr/dscf)	(0.009)	(0.022)	(0.024)	(0.018)
kg/h	0.49	1.3	1.5	1.1
(lb/h)	(1.1)	(2.9)	(3.2)	(2.4)
kg/Mg	a	a	a	a
(lb/ton)				

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[a] Confidential data.
[b] Estimated from process feed rate.

TABLE C-108. SUMMARY OF EMISSION TEST RESULTS--PLANT M1

Industry: Perlite
Process unit: Expansion furnace
Emission source: Baghouse outlet--West

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	2/1/84	2/1/84	2/1/84	--
Sampling time, minutes	120	120	120	--
Isokinetic ratio, percent	99	101	101	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent	95	92	91	93
Gas stream data				
Temperature, °C	188	195	192	192
(°F)	(370)	(383)	(378)	(377)
Moisture, percent	4.7	5.5	5.8	5.3
Flow rate, m^3/s	2.1	2.1	2.2	2.1
(acfm)	(4,530)	(4,460)	(4,570)	(4,520)
Flow rate, dsm^3/s	1.3	1.2	1.3	1.3
(dscfm)	(2,700)	(2,600)	(2,670)	(2,660)
Particulate emissions				
g/dsm^3	0.025	0.031	0.024	0.027
(gr/dscf)	(0.011)	(0.013)	(0.011)	(0.012)
kg/h	0.12	0.14	0.12	0.12
(lb/h)	(0.26)	(0.30)	(0.24)	(0.26)
kg/Mg (lb/ton)	a	a	a	a

[a] Confidential data.

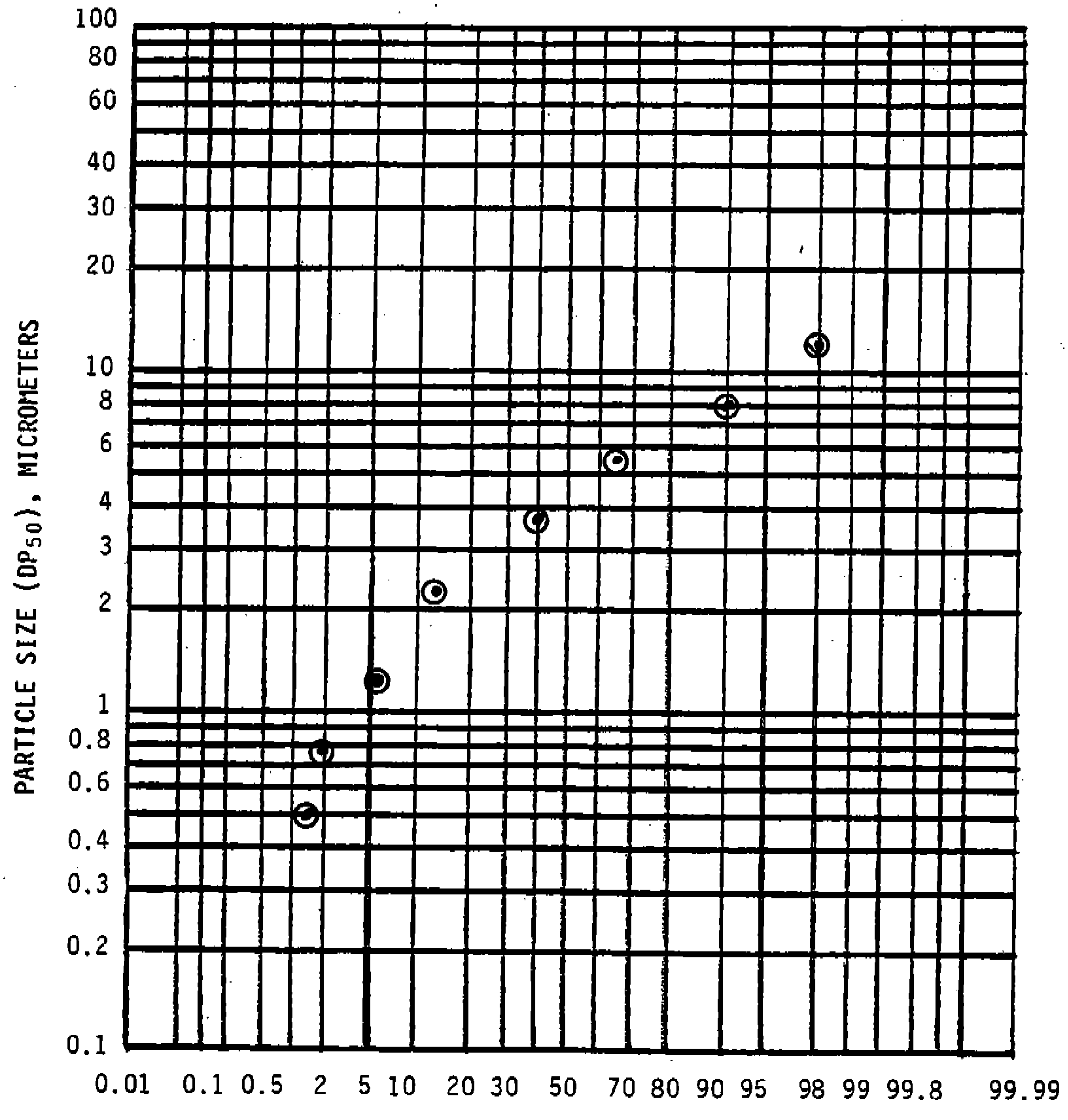

Figure C-59. Particle size distribution data: expansion furnace baghouse outlet (West)--Plant M1.

TABLE C-109. SUMMARY OF VISIBLE EMISSIONS--PLANT M1

Date	2/1/84
Industry	Perlite
Process unit	Expansion furnace
Location of discharge	Baghouse stack--West
Height of observation point, ft	30
Height of point of discharge, ft	50
Distance from observer to discharge point, ft	50
Direction of observer from discharge point	W
Description of background	Shaded
Description of sky	Clear
Wind direction	W
Wind velocity, mph	5-10
Color of plume	White
Duration of observation, min	126
Period of observation	1150-1350
Highest single reading, percent	10
Highest 6-minute average, percent	0.8

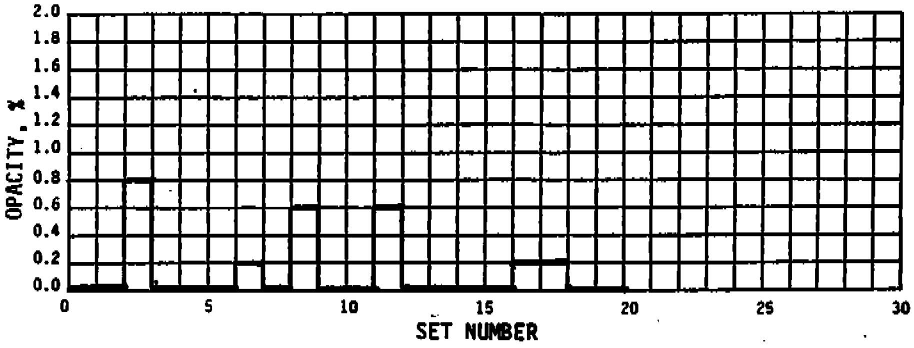

TABLE C-110. SUMMARY OF VISIBLE EMISSIONS--PLANT M1

Date	2/1/84
Industry	Perlite
Process unit	Expansion furnace
Location of discharge	Baghouse stack--West
Height of observation point, ft	25
Height of point of discharge, ft	50
Distance from observer to discharge point, ft	60
Direction of observer from discharge point	W
Description of background	Blue sky
Description of sky	Clear
Wind direction	W
Wind velocity, mph	0-5
Color of plume	White
Duration of observation, min	54
Period of observation	1635-1729
Highest single reading, percent	10
Highest 6-minute average, percent	0.4

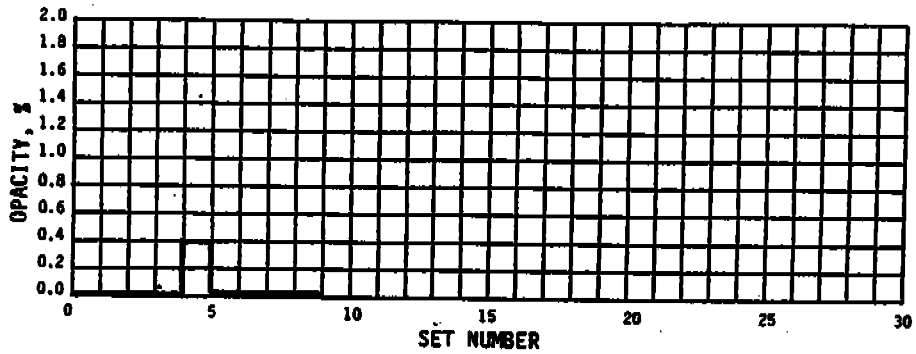

TABLE C-111. SUMMARY OF EMISSION TEST RESULTS--PLANT M1
Industry: Perlite
Process unit: Expansion furnace
Emission source: Baghouse outlet--East

Data	Run No. 4	Run No. 5	Run No. 6	Average for test series
General				
Date	2/1/84	2/1/84	2/1/84	--
Sampling time, minutes	120	120	120	--
Isokinetic ratio, percent	105	106	105	--
Production rate, Mg/h	a	a	a	a
(tons/h)				
Capacity utilization, percent	95	92	91	93
Gas stream data				
Temperature, °C	188	191	189	189
(°F)	(371)	(376)	(372)	(373)
Moisture, percent	5.1	5.5	5.7	
Flow rate, m^3/s	1.6	1.6	1.6	1.6
(acfm)	(3,350)	(3,380)	(3,390)	(3,370)
Flow rate, dsm^3/s	0.94	0.94	0.94	0.94
(dscfm)	(1,990)	(1,990)	(2,000)	(2,000)
Particulate emissions				
g/dsm^3	0.043	0.045	0.045	0.045
(gr/dscf)	(0.019)	(0.020)	(0.020)	(0.020)
kg/h	0.15	0.15	0.15	0.15
(lb/h)	(0.32)	(0.34)	(0.34)	(0.33)
kg/Mg	a	a	a	a
(lb/ton)				

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[a] Confidential data.

TABLE C-112. SUMMARY OF VISIBLE EMISSIONS--PLANT M1

Date	2/1/84
Industry	Perlite
Process unit	Expansion furnace
Location of discharge	Baghouse stack--East
Height of observation point, ft	Ground
Height of point of discharge, ft	55
Distance from observer to discharge point, ft	100
Direction of observer from discharge point	S
Description of background	--
Description of sky	Clear
Wind direction	W
Wind velocity, mph	5-10
Color of plume	White
Duration of observation, min	120
Period of observation	1145-1345
Highest single reading, percent	15
Highest 6-minute average, percent	0.6

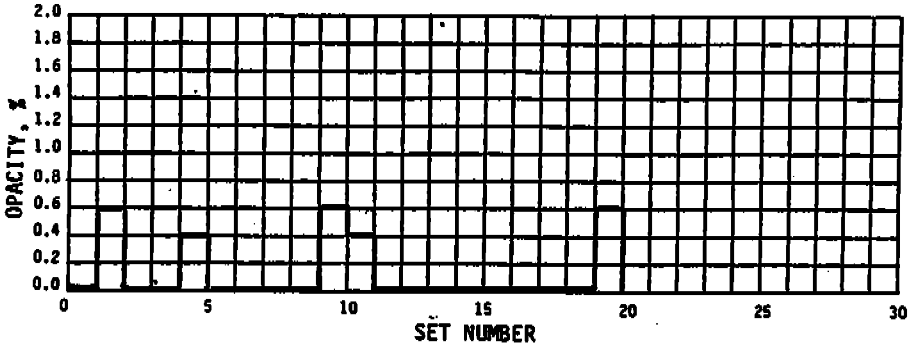

TABLE C-113 SUMMARY OF VISIBLE EMISSIONS--PLANT M1

Date	2/1/84
Industry	Perlite
Process unit	Expansion furnace
Location of discharge	Baghouse stack--East
Height of observation point, ft	Ground
Height of point of discharge, ft	55
Distance from observer to discharge point, ft	100
Direction of observer from discharge point	S
Description of background	--
Description of sky	Clear
Wind direction	W
Wind velocity, mph	5-10
Color of plume	White
Duration of observation, min	60
Period of observation	1631-1731
Highest single reading, percent	20
Highest 6-minute average, percent	0.8

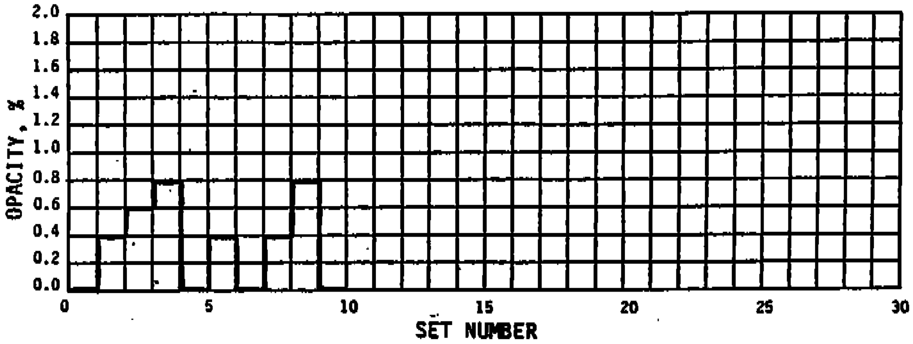

TABLE C-114. SUMMARY OF PROCESS FUGITIVE EMISSIONS--PLANT M1[a]

Date	2/1/84
Industry	Perlite
Process unit	Expansion furnace
Period of observation	11:52-14:00, 16:32-17:32
Location of discharge point	Feed conveyor to furnace

---

[a] Method 22 was used to record visible emissions. All other 6-minute averages were 0 percent opacity.

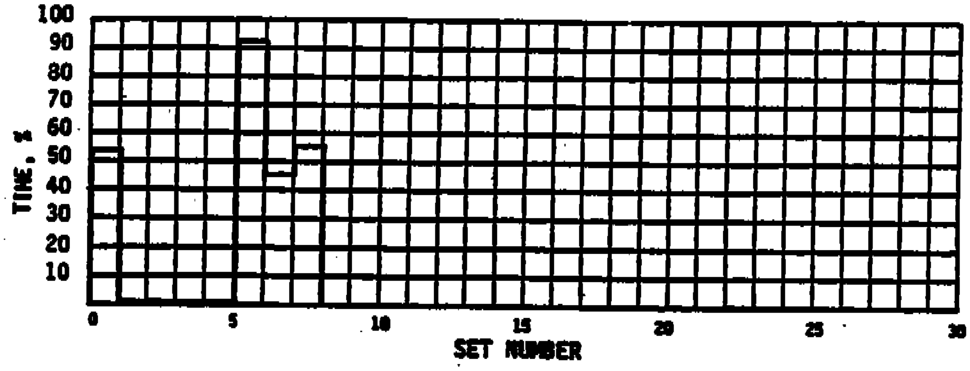

TABLE C-115. TRACE METALS CONCENTRATIONS AND ANALYTICAL RESULTS--PLANT MI

Industry: Perlite
Process unit: Expansion furnace
Sample source: Method 5 particulate catch

Element	Run No. 5: Baghouse West outlet[a]	Run No. 5: Baghouse East outlet[a]
Aluminum	4,210 (1.49)	5,340 (1.58)
Beryllium	BDL[b]	BDL[b]
Calcium	17,780 (4.23)	13,890 (2,760)
Chromium	26.7 (0.00490)	29.5 (0.00452)
Fluorine	1,000 (0.502)	2,800 (1.17)
Iron	985 (0.168)	5,920 (0.844)
Lead	16.1 (0.000741)	8.25 (0.000317)
Magnesium	444 (0.174)	724 (0.237)
Manganese	29.4 (0.00510)	54.6 (0.00792)
Mercury	1.27 (0.00006)	1.86 (0.000074)
Nickel	45.2 (0.00736)	239 (0.0324)
Titanium	57.0 (0.0114)	71.8 (0.0119)
Uranium	c	c
Vanadium	BDL[d]	BDL[d]
Zinc	188 (0.0274)	54.1 (0.00659)

[a] mg (ppm) of impinger solution.
[b] Below detection limit of 0.001 mg.
[c] Not reported.
[d] Below detection limit of 0.01 mg.

TABLE C-116. SUMMARY OF EMISSION TEST RESULTS--PLANT M2

Industry: Perlite
Process unit: Rotary dryer
Emission source: Baghouse outlet

Data	Run No. 2[a]	Run No. 3	Run No. 4	Average for test series
General				
Date	2/17/81	2/18/81	2/19/81	--
Sampling time, minutes	72	72	72	--
Isokinetic ratio, percent	96	97	97	--
Production rate, Mg/h	b	b	b	b
(tons/h)				
Capacity utilization, percent[c]	142	142	133	139
Gas stream data				
Temperature, °C	82	82	82	82
(°F)	(180)	(180)	(180)	(180)
Moisture, percent	15.6	15.2	16.1	15.6
Flow rate, m^3/s	26	26	24	25
(acfm)	(56,100)	(55,600)	(50,200)	(54,000)
Flow rate, dsm^3/s	13	13	12	13
(dscfm)	(28,000)	(28,200)	(26,300)	(27,500)
Particulate emissions				
g/dsm^3	0.043	0.044	0.030	0.037
(gr/dscf)	(0.019)	(0.018)	(0.013)	(0.016)
kg/h	2.1	2.0	1.3	1.8
(lb/h)	(4.6)	(4.2)	(2.9)	(3.9)
kg/Mg	b	b	b	b
(lb/ton)				

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[a] Run No. 1 was a preliminary check of the assumed value of the orifice temperature.
[b] Confidential data.
[c] Combined production of two rotary dryers.

TABLE C-117. SUMMARY OF VISIBLE EMISSIONS--PLANT M2

Date	2/17/81
Industry	Perlite
Process unit	Rotary dryer
Location of discharge	Baghouse outlet
Height of observation point, ft	55
Height of point of discharge, ft	30
Distance from observer to discharge point, ft	75
Direction of observer from discharge point	E
Description of background	Rust red
Description of sky	Clear
Wind direction	SE
Wind velocity, mph	0-10
Color of plume	White
Duration of observation, min	16
Period of observation	1222-1228 1240-1246 1246-1250
Highest single reading, percent	10
Highest 6-minute average, percent	4.7[a]

[a] Reading represents a 4-minute average.

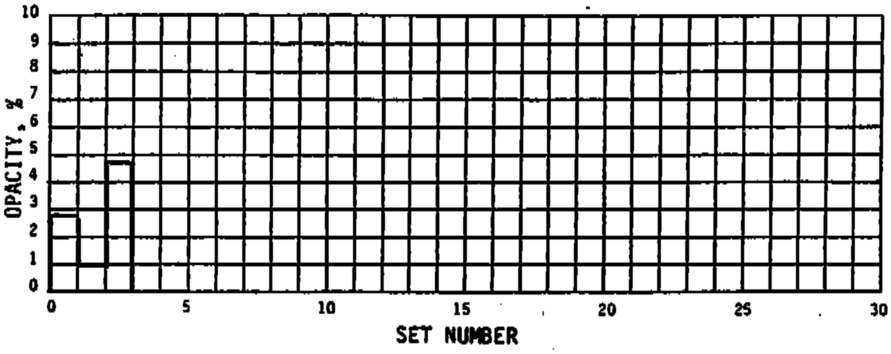

TABLE C-118. SUMMARY OF VISIBLE EMISSIONS--PLANT M2

Date	2/17/81
Industry	Perlite
Process unit	Rotary dryer
Location of discharge	Baghouse outlet
Height of observation point, ft	Ground
Height of point of discharge, ft	30
Distance from observer to discharge point, ft	150
Direction of observer from discharge point	SSW
Description of background	Dark green
Description of sky	Broken
Wind direction	E
Wind velocity, mph	0-5
Color of plume	White
Duration of observation, min	10
Period of observation	1618-1624 1624-1628
Highest single reading, percent	15
Highest 6-minute average, percent	1.9

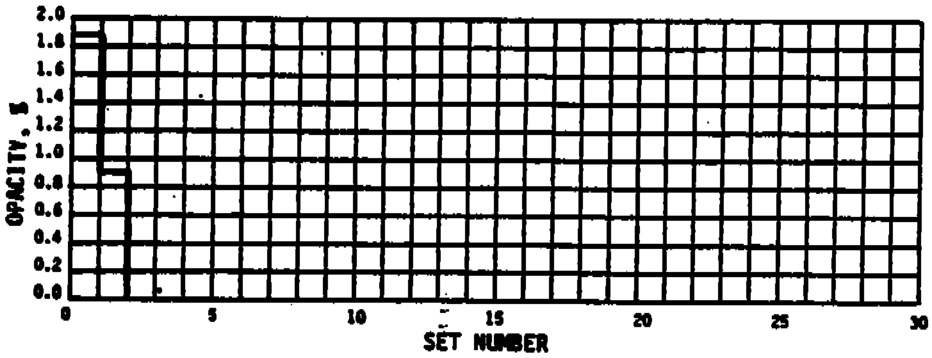

TABLE C-119. SUMMARY OF VISIBLE EMISSIONS--PLANT M2

Date	2/18/81
Industry	Perlite
Process unit	Rotary dryer
Location of discharge	Baghouse outlet
Height of observation point, ft	55
Height of point of discharge, ft	30
Distance from observer to discharge point, ft	75
Direction of observer from discharge point	E
Description of background	Rust and tan
Description of sky	Clear
Wind direction	SE
Wind velocity, mph	0-10
Color of plume	White
Duration of observation, min	20
Period of observation	1129-1215[a]
Highest single reading, percent	15
Highest 6-minute average, percent	4.0

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[a] Two 6-minute and two 4-minute observations were made during this period.

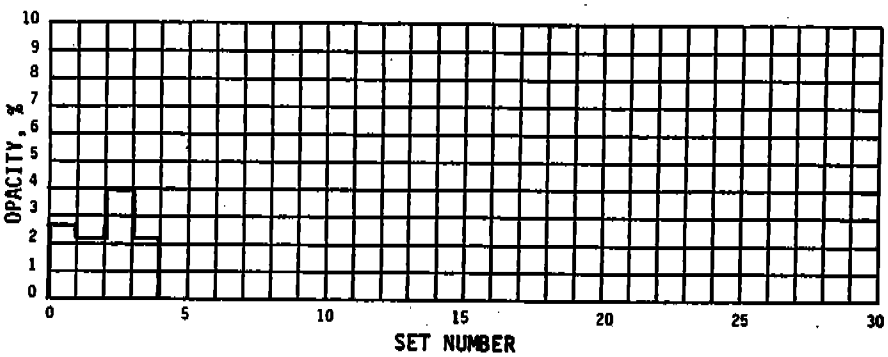

TABLE C-120. SUMMARY OF EMISSION TEST RESULTS--PLANT M3

Industry: Perlite
Process unit: Expansion furnace
Emission source: Baghouse outlet

Data	Run No. P[a]	Run No. 1	Run No. 2	Average for test series
General				
Date	10/25/72	10/26/72	10/26/72	--
Sampling time, minutes	64	64	64	--
Isokinetic ratio, percent	96	96	97	--
Production rate, Mg/h	1.2	1.2	1.2	1.2
(tons/h)	(1.3)	(1.3)	(1.3)	(1.3)
Capacity utilization, percent	100	100	100	100
Gas stream data				
Temperature, °C	76	83	85	81
(°F)	(169)	(181)	(185)	(178)
Moisture, percent	1.9	1.9	2.1	
Flow rate, m^3/s	2.5	2.6	2.4	2.5
(acfm)	(5,230)	(5,420)	(5,180)	(5,280)
Flow rate, dsm^3/s	3.6	3.7	3.5	3.6
(dscfm)	(7,690)	(7,790)	(7,380)	(7,600)
Particulate emissions				
g/dsm^3	0.009	0.015	0.013	0.012
(gr/dscf)	(0.004)	(0.007)	(0.006)	(0.005)
kg/h	0.12	0.20	0.16	0.16
(lb/h)	(0.26)	(0.44)	(0.36)	(0.35)
kg/Mg	0.10	0.17	0.14	0.13
(lb/ton)	(0.20)	(0.34)	(0.28)	(0.27)

[a] P = Preliminary run.

TABLE C-121. SUMMARY OF EMISSION TEST RESULTS--PLANT N1

Industry: Roofing granules
Process unit: Rotary dryer
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	8/6/81	8/11/81	8/18/81	--
Sampling time, minutes	96	96	96	--
Isokinetic ratio, percent	96	103	102	--
Production rate, Mg/h	a	a	a	a
(tons/h)				
Capacity utilization, percent	100	100	100	100
Gas stream data				
Temperature, °C	37	41	46	41
(°F)	(99)	(105)	(115)	(106)
Moisture, percent	1.9	2.9	2.7	2.5
Flow rate, m^3/s	14	15	14	14
(acfm)	(30,100)	(31,500)	(29,600)	(30,400)
Flow rate, dsm^3/s	13	14	13	13
(dscfm)	(28,200)	(29,000)	(26,900)	(28,100)
Particulate emissions				
g/dsm^3	0.021	0.007	0.004	0.012
(gr/dscf)	(0.009)	(0.003)	(0.002)	(0.005)
kg/h	1.04	0.34	0.17	0.52
(lb/h)	(2.23)	(0.75)	(0.38)	(1.14)
kg/Mg	a	a	a	a
(lb/ton)				

[a] Confidential data.

TABLE C-122. SUMMARY OF EMISSION TEST RESULTS--PLANT P1

Industry: Titanium dioxide
Process unit: Rotary calciner No. 1
Emission source: ESP outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	5/19/83	5/19/83	5/19/83	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	92	93	93	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent	85	85	85	85
Gas stream data				
Temperature, °C	50	51	49	50
(°F)	(122)	(123)	(120)	(122)
Moisture, percent	3.8	5.2	4.5	4.5
Flow rate, m^3/s	30	30	30	30
(acfm)	(63,600)	(63,400)	(63,400)	(63,500)
Flow rate, dsm^3/s	27	27	27	27
(dscfm)	(57,600)	(57,300)	(57,600)	(57,500)
Particulate emissions				
g/dsm^3	0.069	0.039	0.078	0.062
(gr/dscf)	(0.030)	(0.017)	(0.034)	(0.027)
kg/h	23	13	27	21
(lb/h)	(10)	(5.7)	(12)	(9.3)
kg/Mg (lb/ton)	a	a	a	a

[a] Confidential data.

TABLE C-123. SUMMARY OF EMISSION TEST RESULTS--PLANT P1

Industry: Titanium dioxide
Process unit: Spray dryer No. 1--Chloride process
Emission source: Baghouse inlet

Data	Run No. 1[a]	Run No. 2	Run No. 3	Run No. 28	Average for test series
General					
Date	2/9/84	2/11/84	2/11/84	2/16/84	--
Sampling time, minutes	24	24	24	24	--
Isokinetic ratio, percent	96	107	103	104	--
Production rate, Mg/h (tons/h)	b	b	b	b	b
Capacity utilization, percent[c]	71	79	79	81	80
Gas stream data					
Temperature, °C	148	148	148	150	149
(°F)	(298)	(299)	(299)	(302)	(299.5)
Moisture, percent	20.0	22.0	22.7	22.9	21.9
Flow rate, m^3/s	6.8	7.5	7.5	7.3	7.3
(acfm)	(14,300)	(15,900)	(15,800)	(15,400)	(15,400)
Flow rate, dsm^3/s	3.8	4.1	4.0	3.9	3.9
(dscfm)	(8,000)	(8,600)	(8,500)	(8,205)	(8,300)
Particulate emissions					
g/dsm^3	47.3	56.4	64.2	65.9	58.5
(gr/dscf)	(20.7)	(24.7)	(28.1)	(28.8)	(25.6)
kg/h	640	820	930	920	830
(lb/h)	(1,400)	(1,800)	(2,000)	(2,000)	(1,800)
kg/Mg (lb/ton)	b	b	b	b	b

[a] Spray dryer malfunction; data not included in average for test series.
[b] Confidential data.
[c] Estimated based on daily packaging rates.

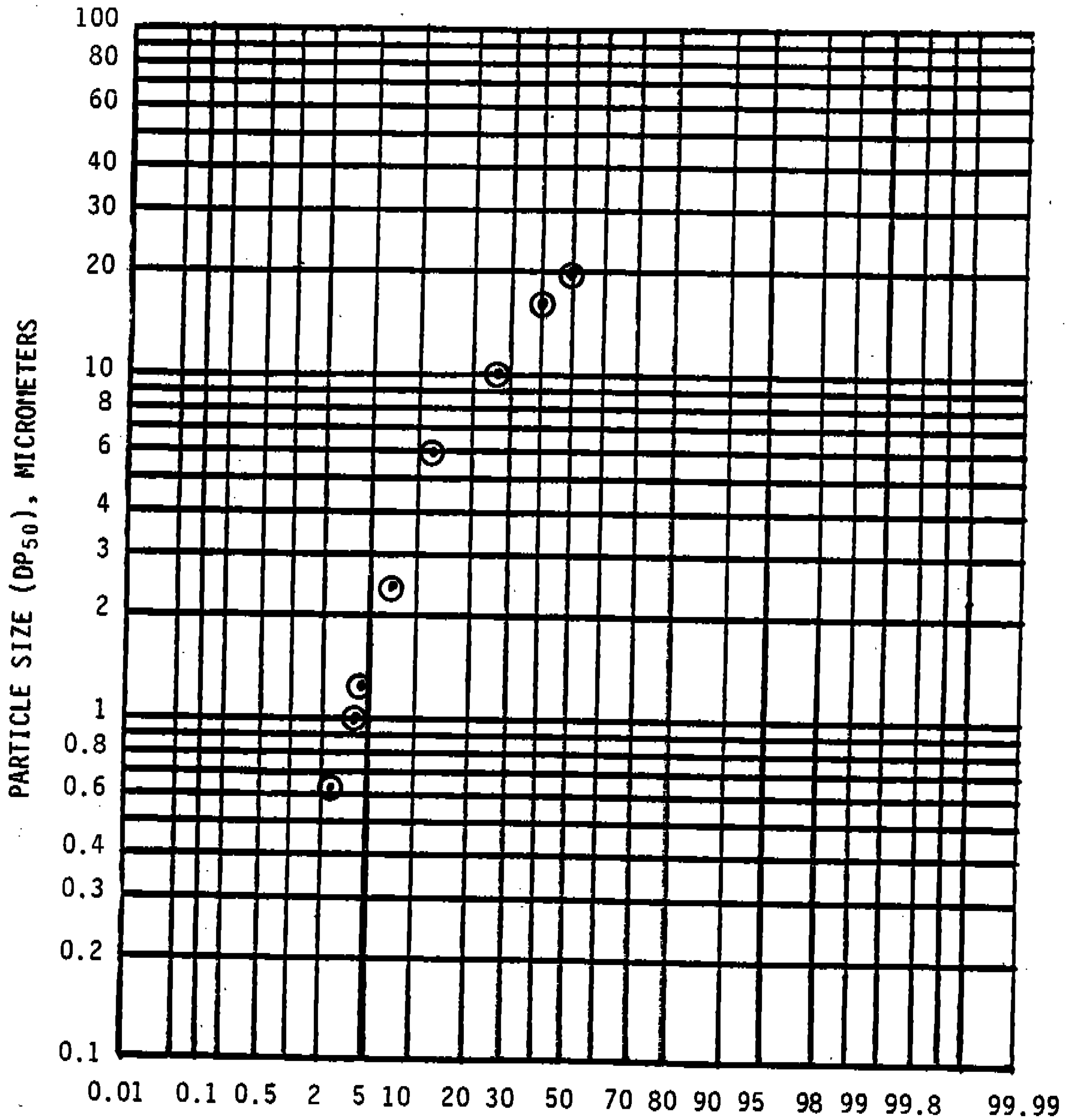

Figure C-60. Particle size distribution data: No. 1 spray dryer baghouse inlet--Plant P1.

TABLE C-124. SUMMARY OF EMISSION TEST RESULTS--PLANT P1
Industry: Titanium dioxide
Process unit: Spray dryer No. 1--Chloride process
Emission source: Baghouse outlet

Data	Run No. 4[a]	Run No. 5	Run No. 6	Run No. 29	Average for test series
General					
Date	2/9/84	2/11/84	2/11/84	2/16/84	--
Sampling time, minutes	120	120	120	120	--
Isokinetic ratio, percent	107	109	110	97	--
Production rate, Mg/h (tons/h)	b	b	b	b	b
Capacity utilization, percent[c]	71	79	79	81	80
Gas stream data					
Temperature, °C	127	131	133	132	131
(°F)	(260)	(269)	(271)	(270)	(268)
Moisture, percent	18.7	19.1	19.4	16.8	18.5
Flow rate, m^3/s	8.5	10	10	9.0	10
(acfm)	(18,000)	(20,300)	(20,300)	(19,100)	(19,400)
Flow rate, dsm^3/s	5.1	5.7	5.6	5.4	5.4
(dscfm)	(10,700)	(12,000)	(12,000)	(11,500)	(11,500)
Particulate emissions					
g/dsm^3	0.006	0.003	0.018	0.021	0.012
(gr/dscf)	(0.002)	(0.001)	(0.008)	(0.009)	(0.005)
kg/h	0.10	0.052	0.36	0.40	0.23
(lb/h)	(0.22)	(0.11)	(0.79)	(0.89)	(0.50)
kg/Mg (lb/ton)	b	b	b	b	b

[a] Spray dryer malfunction; data not included in average for test series.
[b] Confidential data.
[c] Estimated based on daily packaging rates.

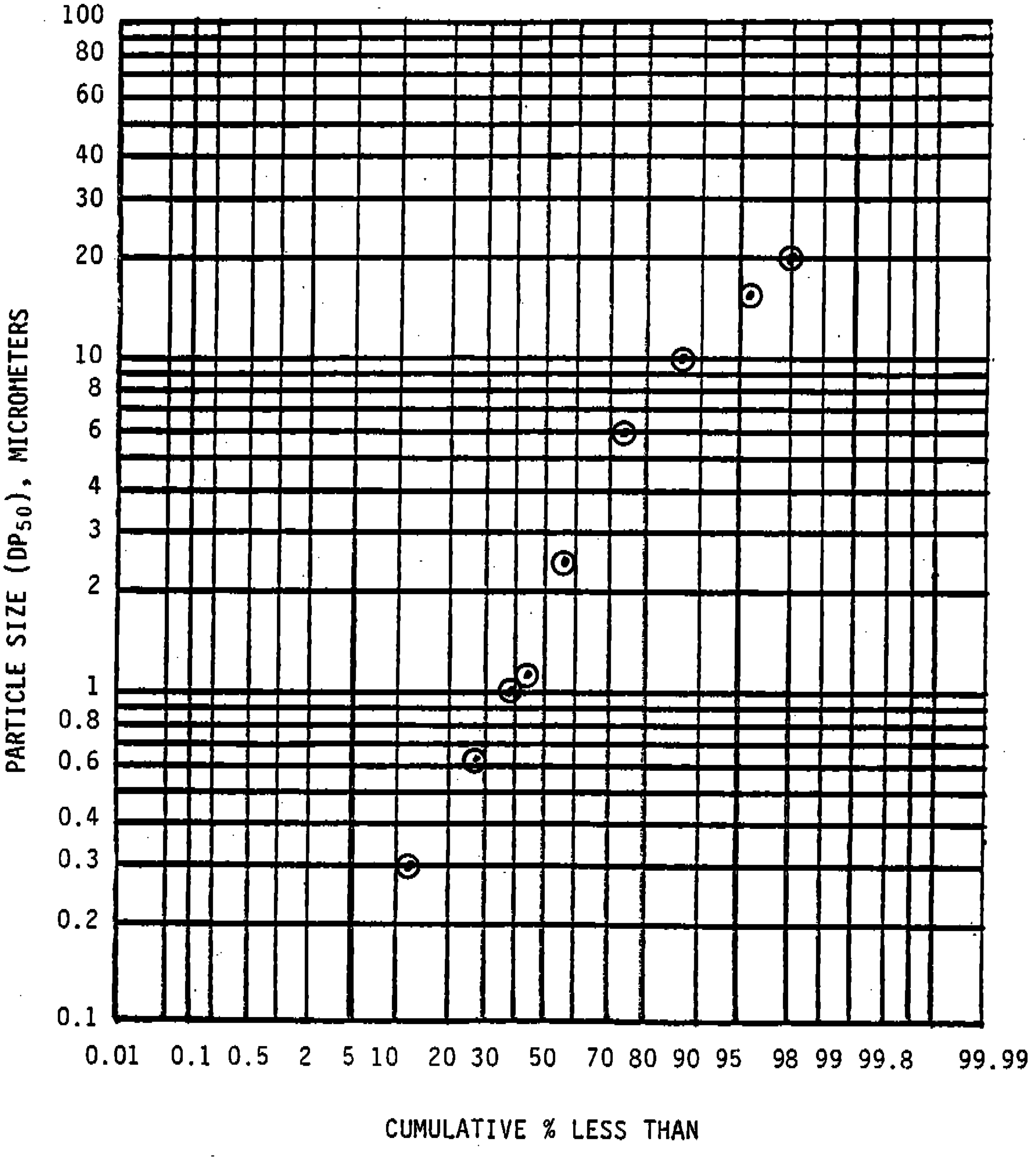

Figure C-61. Particle size distribution data:
No. 1 spray dryer baghouse outlet--Plant P1.

TABLE C-125. SUMMARY OF EMISSION TEST RESULTS--PLANT P1
Industry: Titanium dioxide
Process unit: Spray dryer Nos. 1 and 2--Chloride process
Emission source: Scrubber outlet

Data	Run No. 10[a]	Run No. 11	Run No. 12	Run No. 31	Average for test series
General					
Date	2/9/84	2/11/84	2/11/84	2/16/84	--
Sampling time, minutes	120	120	120	120	--
Isokinetic ratio, percent	107	100	102	106	--
Production rate, Mg/h	b	b	b	b	b
(tons/h)					
Capacity utilization, percent[c]	71	79	79	81	80
Gas stream data					
Temperature, °C	51	58	51	57	54
(°F)	(124)	(136)	(124)	(135)	(130)
Moisture, percent	12.4	15.5	12.7	17.2	15.1
Flow rate, m^3/s	24	22	21	20	22
(acfm)	(51,000)	(47,500)	(44,700)	(41,800)	(46,200)
Flow rate, dsm^3/s	19	17	17	15	17
(dscfm)	(40,500)	(35,600)	(35,300)	(30,800)	(35,600)
Particulate emissions					
g/dsm^3	0.053	0.061	0.067	0.046	0.057
(gr/dscf)	(0.023)	(0.027)	(0.029)	(0.020)	(0.025)
kg/h	3.7	3.7	4.0	2.4	3.4
(lb/h)	(8.1)	(8.1)	(8.9)	(5.3)	(7.6)
kg/Mg	b	b	b	b	b
(lb/ton)					

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[a] Spray dryer malfunction; data not included in average for test series.
[b] Confidential data.
[c] Combined production of two spray dryers.

TABLE C-126. SUMMARY OF VISIBLE EMISSIONS--PLANT P1

Date	2/9/84
Industry	Titanium dioxide
Process unit	Spray dryers
Location of discharge	Scrubber stack
Height of observation point, ft	Ground
Height of point of discharge, ft	80
Distance from observer to discharge point, ft	200
Direction of observer from discharge point	S
Description of background	--
Description of sky	Clear
Wind direction	S
Wind velocity, mph	0-5
Color of plume	White
Duration of observation, min	120
Period of observation	0935-1135
Highest single reading, percent	10
Highest 6-minute average, percent	7.5

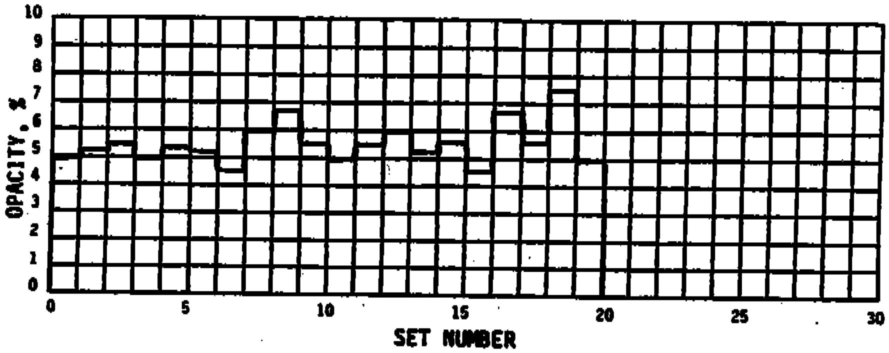

TABLE C-127. SUMMARY OF VISIBLE EMISSIONS--PLANT P1

Date	2/11/84
Industry	Titanium dioxide
Process unit	Spray dryers
Location of discharge	Scrubber stack
Height of observation point, ft	Ground
Height of point of discharge, ft	80
Distance from observer to discharge point, ft	300
Direction of observer from discharge point	SSW
Description of background	--
Description of sky	Clear
Wind direction	W
Wind velocity, mph	5-10
Color of plume	White
Duration of observation, min	120
Period of observation	0902-1102
Highest single reading, percent	25
Highest 6-minute average, percent	19.4

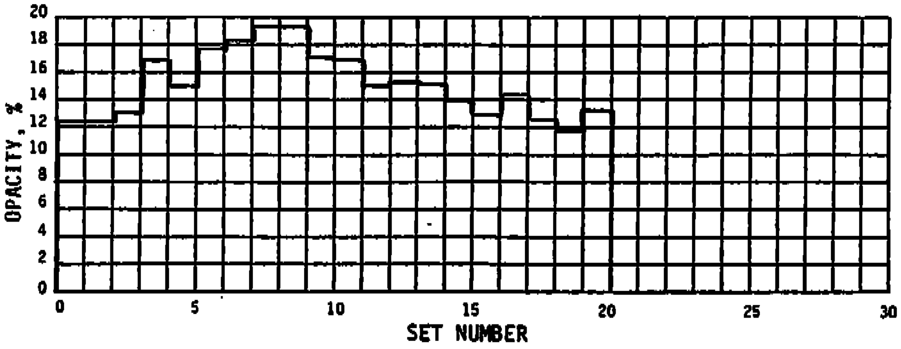

TABLE C-128. SUMMARY OF VISIBLE EMISSIONS--PLANT P1

Date	2/16/84
Industry	Titanium dioxide
Process unit	Spray dryers
Location of discharge	Scrubber stack
Height of observation point, ft	Ground
Height of point of discharge, ft	80
Distance from observer to discharge point, ft	--
Direction of observer from discharge point	E
Description of background	--
Description of sky	Overcast
Wind direction	NW
Wind velocity, mph	10
Color of plume	--
Duration of observation, min	120
Period of observation	1005-1205
Highest single reading, percent	15
Highest 6-minute average, percent	10.0

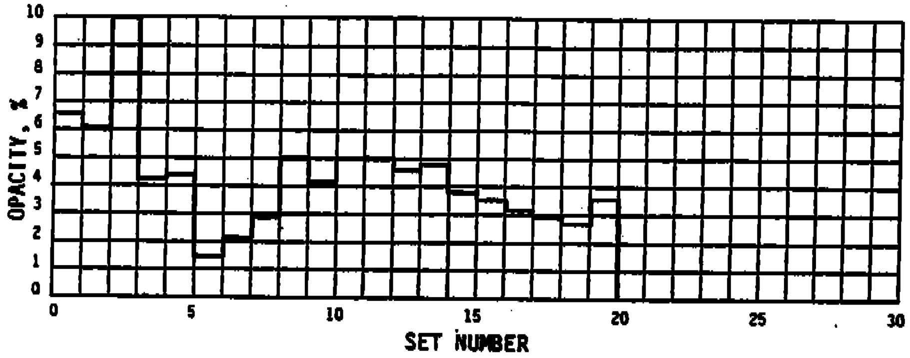

TABLE C-129. SUMMARY OF TRACE METAL ANALYSIS--PLANT P1

Industry: Titanium dioxide
Process unit: Spray dryer Nos. 1 and 2--
Chloride process
Sample source: Method 5 particulate catch

Element	Run No. 28: No. 312 Baghouse inlet[a]	Run No. 29: No. 312 Baghouse outlet[a]	Run No. 30: No. 322 Baghouse outlet[a]	Run No. 31: Scrubber outlet[a]
Aluminum	136,000 (409)	1,080 (0.414)	36,800 (50)	1,330 (0.487)
Beryllium	BDL[b]	BDL[b]	BDL[b]	BDL[b]
Calcium	875 (1.77)	1,261 (0.325)	354 (0.324)	692 (0.171)
Chromium	63 (0.0983)	58 (0.0115)	48 (0.0338)	111 (0.0211)
Fluorine	284 (1.21)	195 (0.106)	116 (0.224)	35.5 (0.0185)
Iron	516 (0.750)	510 (0.0944)	500 (0.328)	1,420 (0.251)
Lead	151 (0.0591)	BDL[c]	BDL[c]	BDL[c]
Magnesium	312 (1.04)	290 (0.123)	283 (0.427)	255 (0.104)
Manganese	BDL[d]	19 (0.00358)	BDL[d]	35 (0.00629)
Mercury	0.71 (0.000287)	0.60 (0.000031)	0.66 (0.000121)	1.07 (0.000053)
Nickel	418 (0.578)	51 (0.00898)	60 (0.0374)	190 (0.0320)
Titanium	756 (1.28)	1,110 (0.240)	510 (0.390)	508 (0.105)
Uranium	e	e	e	12 (0.00233)
Vanadium	BDL[d]	BDL[d]	BDL[d]	BDL[d]
Zinc	3,179 (3.95)	53 (0.00838)	48 (0.0269)	408 (0.0616)

[a] mg (ppm) of impinger solution.
[b] Below detection limit of 0.001 mg.
[c] Below detection limit of 0.005 mg.
[d] Below detection limit of 0.01 mg.
[e] Not reported.

TABLE C-130. SUMMARY OF EMISSION TEST RESULTS--PLANT P1

Industry: Titanium dioxide
Process unit: Rotary calciner--Sulfate process
Emission source: Conditioning tower inlet--East

Data	Run No. 13	Run No. 14	Run No. 15	Average for test series
General				
Date	2/14/84	2/14/84	2/14/84	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	96	95	87	--
Production rate, Mg/h (tons/h)	[a]	[a]	[a]	[a]
Capacity utilization, percent	90	90	90	90
Gas stream data				
Temperature, °C	317	314	293	308
(°F)	(603)	(598)	(560)	(587)
Moisture, percent	22.2	24.2	23.3	23.2
Flow rate, m^3/s	14	15	14	14
(acfm)	(30,700)	(31,500)	(29,800)	(30,700)
Flow rate, dsm^3/s	5.1	5.2	5.0	5.1
(dscfm)	(10,800)	(11,100)	(10,500)	(10,800)
Particulate emissions				
g/dsm^3	4.47	6.84	6.85	6.05
(gr/dscf)	(1.96)	(3.00)	(3.00)	(2.65)
kg/h	82	130	120	110
(lb/h)	(180)	(280)	(270)	(240)
kg/Mg (lb/ton)	[a]	[a]	[a]	[a]

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[a] Confidential data.

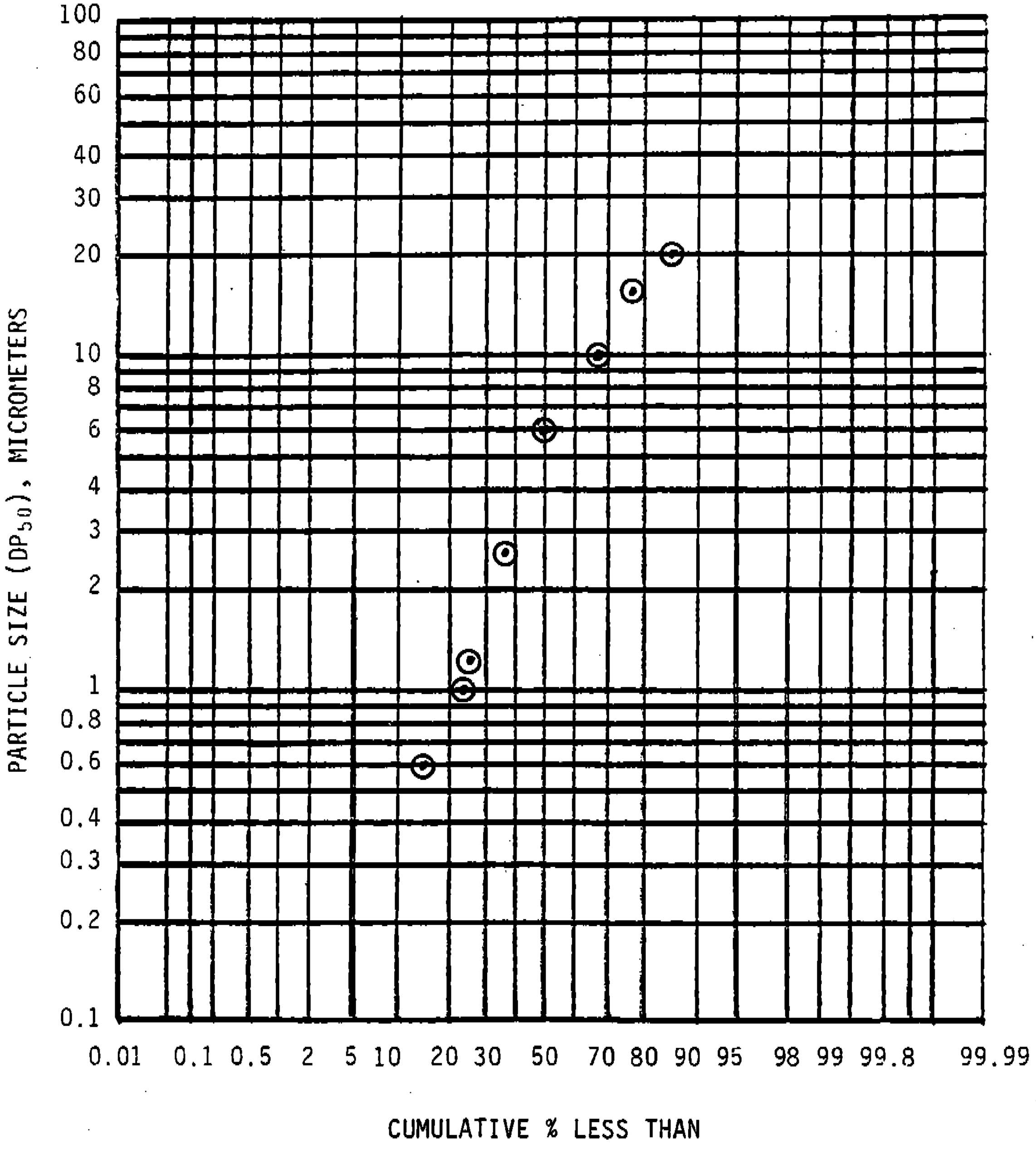

Figure C-62. Particle size distribution data: rotary calciner conditioning tower inlet (East)--Plant P1.

TABLE C-131. SUMMARY OF EMISSION TEST RESULTS--PLANT P1

Industry: Titanium dioxide
Process unit: Rotary calciner--Sulfate process
Emission source: Conditioning tower inlet--West

Data	Run No. 16	Run No. 17	Run No. 18	Average for test series
General				
Date	2/14/84	2/15/84	2/15/84	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	93	96	98	--
Production rate, Mg/h	a	a	a	a
(tons/h)				
Capacity utilization, percent	90	90	90	90
Gas stream data				
Temperature, °C	a	a	a	a
(°F)				
Moisture, percent	18.3	18.1	20.2	[illegible]
Flow rate, m^3/s	9.5	9.1	10	[illegible]
(acfm)	(20,200)	(19,300)	(21,100)	[illegible]
Flow rate, dsm^3/s	3.6	3.4	3.8	[illegible]
(dscfm)	(7,640)	(7,290)	(7,990)	[illegible]
Particulate emissions				
g/dsm^3	3.44	4.14	4.83	[illegible]
(gr/dscf)	(1.50)	(1.81)	(2.11)	[illegible]
kg/h	45	51	66	54
(lb/h)	(99)	(110)	(140)	(120)
kg/Mg	a	a	a	a
(lb/ton)				

[a] Confidential data.

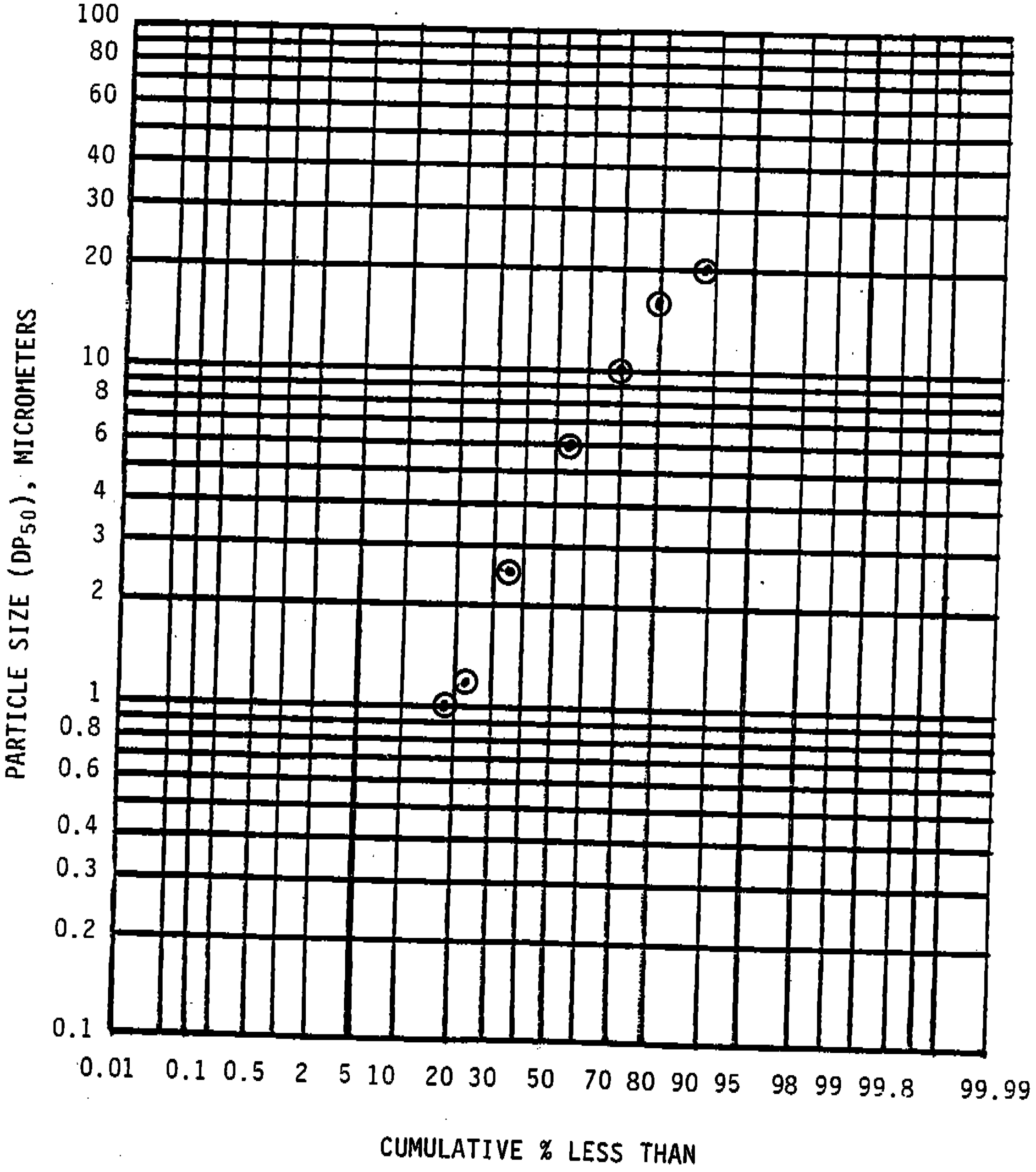

Figure C-63. Particle size distribution data: rotary calciner conditioning tower inlet (West)--Plant P1.

TABLE C-132. SUMMARY OF EMISSION TEST RESULTS--PLANT P1

Industry: Titanium dioxide
Process unit: Rotary calciner--Sulfate process
Emission source: ESP outlet--East

Data	Run No. 19	Run No. 20	Run No. 21	Average for test series
General				
Date	2/14/84	2/15/84	2/15/84	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	100	103	103	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent	90	90	90	90
Gas stream data				
Temperature, °C (°F)	a	a	a	a
Moisture, percent	22.2	25.2	24.0	23.8
Flow rate, m^3/s	9.6	11	7.9	9.4
(acfm)	(20,300)	(22,900)	(16,700)	(20,000)
Flow rate, dsm^3/s	6.4	7.0	5.2	6.2
(dscfm)	(13,600)	(14,900)	(11,100)	(13,200)
Particulate emissions				
g/dsm^3	0.094	0.169	0.103	0.122
(gr/dscf)	(0.041)	(0.074)	(0.045)	(0.053)
kg/h	2.2	4.3	2.0	2.8
(lb/h)	(4.8)	(9.4)	(4.3)	(6.2)
kg/Mg (lb/ton)	a	a	a	a

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[a] Confidential data.

TABLE C-133. SUMMARY OF EMISSION TEST RESULTS--PLANT P1
Industry: Titanium dioxide
Process unit: Rotary calciner--Sulfate process
Emission source: ESP outlet--West

Data	Run No. 22	Run No. 23	Run No. 24	Average for test series
General				
Date	2/14/84	2/15/84	2/15/84	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	99	100	98	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent	90	90	90	90
Gas stream data				
Temperature, °C (°F)	a	a	a	a
Moisture, percent	16.1	15.5	15.1	15.6
Flow rate, m³/s	7.1	6.7	6.8	6.8
(acfm)	(15,000)	(14,200)	(14,400)	(14,500)
Flow rate, dsm³/s	5.2	5.1	5.2	5.2
(dscfm)	(11,100)	(10,700)	(10,900)	(10,900)
Particulate emissions				
g/dsm³	0.092	0.093	0.103	0.096
(gr/dscf)	(0.040)	(0.041)	(0.045)	(0.042)
kg/h	1.7	1.7	1.9	1.8
(lb/h)	(3.8)	(3.7)	(4.2)	(3.9)
kg/Mg (lb/ton)	a	a	a	a

[a] Confidential data.

TABLE C-134. SUMMARY OF EMISSION TEST RESULTS--PLANT P1
Industry: Titanium dioxide
Process unit: Rotary calciner--Sulfate process
Emission source: Scrubber outlet

Data	Run No. 25	Run No. 26	Run No. 27	Average for test series
General				
Date	2/14/84	2/14/84	2/14/84	--
Sampling time, minutes	60	72	72	--
Isokinetic ratio, percent	105	109	106	--
Production rate, Mg/h	[a]	[a]	[a]	[a]
(tons/h)				
Capacity utilization, percent	90	90	90	90
Gas stream data				
Temperature, °C	[a]	[a]	[a]	[a]
(°F)				
Moisture, percent	10.6	12.3	9.6	10.8
Flow rate, m^3/s	26	26	26	26
(acfm)	(55,000)	(55,100)	(55,400)	(55,200)
Flow rate, dsm^3/s	21	20	21	21
(dscfm)	(43,600)	(43,400)	(44,700)	(43,900)
Particulate emissions				
g/dsm^3	0.013	0.003	0.006	0.007
(gr/dscf)	(0.006)	(0.001)	(0.003)	(0.003)
kg/h	0.87	0.19	0.46	0.51
(lb/h)	(2.1)	(0.43)	(1.0)	(1.2)
kg/Mg	[a]	[a]	[a]	[a]
(lb/ton)				

[a] Confidential data.

TABLE C-135. SUMMARY OF VISIBLE EMISSIONS--PLANT P1

Date	2/15/84
Industry	Titanium dioxide
Process unit	Rotary calciner
Location of discharge	Scrubber stack
Height of observation point, ft	Ground
Height of point of discharge, ft	150
Distance from observer to discharge point, ft	600
Direction of observer from discharge point	SW, S
Description of background	--
Description of sky	Clear
Wind direction	WNW--shifting
Wind velocity, mph	5-10
Color of plume	--
Duration of observation, min	60
Period of observation	1416-1516
Highest single reading, percent	5
Highest 6-minute average, percent	0.4

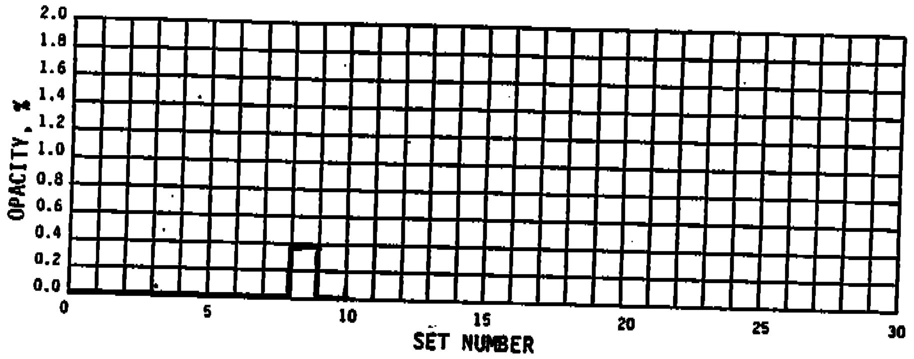

TABLE C-136. SUMMARY OF TRACE METAL ANALYSIS--PLANT P1

Industry: Titanium dioxide
Process unit: Rotary calciner--Sulfate process
Sample source: Method 5 particulate catch

Element	Run No. 13: I. D. fan outlet, East[a]	Run No. 16: I. D. fan outlet, West[a]	Run No. 19: ESP outlet, East[a]	Run No. 22: ESP outlet, West[a]	Run No. 25: Calciner stack[a]
Aluminum	237 (0.382)	1,200 (2.62)	1,210 (0.967)	1,360 (0.804)	340 (0.151)
Beryllium	BDL[b]	BDL[b]	BDL[b]	BDL[b]	BDL[b]
Calcium	417 (0.453)	921 (1.35)	613 (0.330)	608 (0.242)	746 (0.223)
Chromium	108 (0.0904)	82 (0.0929)	588 (0.244)	291 (0.0893)	25 (0.00575)
Fluorine	462 (1.06)	209 (0.648)	275 (0.312)	1,851 (1.55)	80.4 (0.0506)
Iron	937 (0.730)	937 (0.989)	1,649 (0.636)	2,043 (0.584)	182 (0.0390)
Lead	BDL[c]	BDL[c]	139 (0.0145)	279 (0.0208)	BDL[c]
Magnesium	125 (0.224)	484 (1.17)	418 (0.371)	340 (0.223)	272 (0.134)
Manganese	15 (0.0119)	32 (0.0343)	60 (0.0235)	29 (0.00842)	BDL[d]
Mercury	0.47 (0.000102)	0.49 (0.000144)	1.39 (0.000149)	0.87 (0.000069)	0.97 (0.000058)
Nickel	67 (0.0497)	68 (0.0683)	615 (0.226)	379 (0.103)	33 (0.00672)
Titanium	2,330 (2.12)	5,900 (7.26)	1,253 (0.564)	892 (0.297)	200 (0.0499)
Uranium	e	e	e	e	e
Vanadium	BDL[d]	BDL[d]	BDL[d]	42 (0.0132)	BDL[d]
Zinc	157 (0.105)	169 (0.152)	27,066 (8.92)	25,839 (6.31)	44 (0.00805)

[a] mg (ppm) of impinger solution.
[b] Below detection limit of 0.001 mg.
[c] Below detection limit of 0.005 mg.
[d] Below detection limit of 0.01 mg.
[e] Not reported.

TABLE C-137. SUMMARY OF NITROGEN OXIDE EMISSIONS DATA--PLANT P1
Industry: Titanium dioxide
Process unit: Rotary calciner--sulfate
Location of discharge: No. 2 calciner stack

Test location	Date, 1984	Concentration, g/dsm³ (ppm)	Mass emission rate, kg/h (lb/h)
Exhaust stack			
Sample No. 25A	2/14	N/A[a] (0.7)	N/A
Sample No. 25B	2/14	N/A (0.0)	N/A
Sample No. 25C	2/14	N/A (0.0)	N/A
Sample No. 25D	2/14	N/A (7.5)	N/A
Average	--	N/A (2.1)	N/A
Sample No. 26A	2/15	N/A (7.4)	N/A
Sample No. 26B	2/15	N/A (0.0)	N/A
Sample No. 26C	2/15	N/A (0.0)	N/A
Sample No. 26D	2/15	N/A (0.0)	N/A
Average	--	N/A (1.9)	N/A
Sample No. 27A	2/15	N/A (7.5)	N/A
Sample No. 27B	2/15	N/A (3.9)	N/A
Sample No. 27C	2/15	N/A (0.0)	N/A
Sample No. 27D	2/15	N/A (0.0)	N/A
Average	--	N/A (2.9)	N/A

[a] N/A = Information not available.

TABLE C-138. SUMMARY OF EMISSION TEST RESULTS--PLANT P2

Industry: Titanium dioxide
Process unit: Spray dryer
Emission source: Baghouse outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	7/12/84	7/13/84	7/13/84	--
Sampling time, minutes	120	120	120	--
Isokinetic ratio, percent	94	93	97	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent	97	147	143	129
Gas stream data				
Temperature, °C (°F)	a	a	a	a
Moisture, percent	a	a	a	a
Flow rate, m^3/s (acfm)	a	a	a	a
Flow rate, dsm^3/s (dscfm)	a	a	a	a
Particulate emissions				
g/dsm^3	0.016	0.027	0.029	0.024
(gr/dscf)	(0.007)	(0.012)	(0.013)	(0.010)
kg/h (lb/h)	a	a	a	a
kg/Mg (lb/ton)	a	a	a	a

[a] Confidential data.

TABLE C-139. SUMMARY OF VISIBLE EMISSIONS--PLANT P2

Date	7/12/84
Industry	Titanium dioxide
Process unit	Spray dryer
Location of discharge	Baghouse outlet
Height of observation point, ft	Ground
Height of point of discharge, ft	60
Distance from observer to discharge point, ft	300
Direction of observer from discharge point	E
Description of background	--
Description of sky	Variable
Wind direction	NW
Wind velocity, mph	5-10
Color of plume	--
Duration of observation, min	120
Period of observation	1216-1416
Highest single reading, percent	5
Highest 6-minute average, percent	0.6

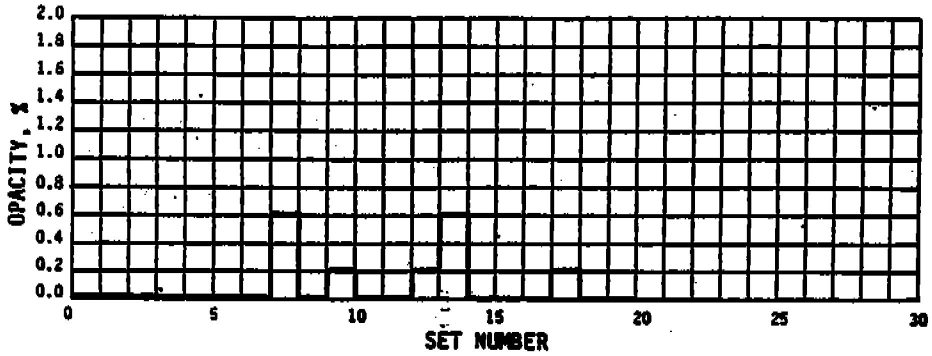

TABLE C-140. SUMMARY OF VISIBLE EMISSIONS--PLANT P2

Date	7/13/84
Industry	Titanium dioxide
Process unit	Spray dryer
Location of discharge	Baghouse outlet
Height of observation point, ft	Ground
Height of point of discharge, ft	60
Distance from observer to discharge point, ft	300
Direction of observer from discharge point	E
Description of background	--
Description of sky	Variable clouds
Wind direction	NW
Wind velocity, mph	10
Color of plume	--
Duration of observation, min	120
Period of observation	0941-1141
Highest single reading, percent	5
Highest 6-minute average, percent	0.8

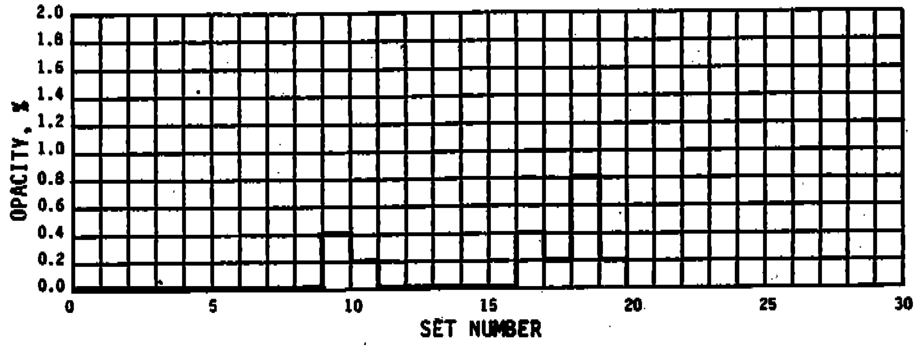

TABLE C-141. SUMMARY OF VISIBLE EMISSIONS--PLANT P2

Date	7/13/84
Industry	Titanium dioxide
Process unit	Spray dryer
Location of discharge	Baghouse outlet
Height of observation point, ft	Ground
Height of point of discharge, ft	60
Distance from observer to discharge point, ft	300-250
Direction of observer from discharge point	SE, SW
Description of background	--
Description of sky	Variable clouds
Wind direction	NE, E
Wind velocity, mph	5-10, 10-15
Color of plume	--
Duration of observation, min	144
Period of observation	1350-1614
Highest single reading, percent	5
Highest 6-minute average, percent	0.4

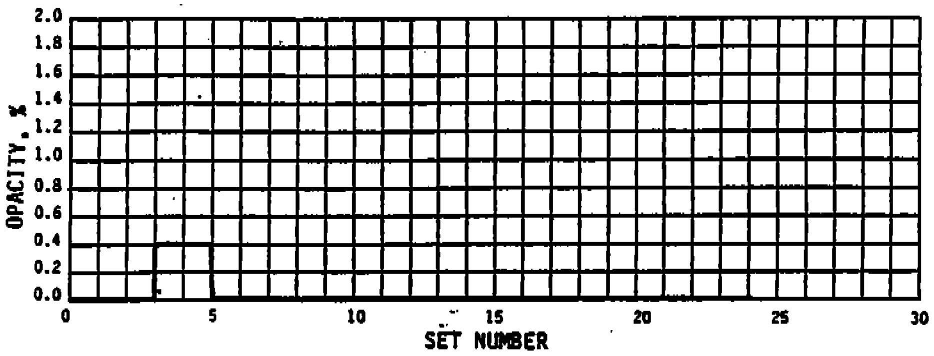

TABLE C-142. SUMMARY OF VISIBLE EMISSIONS--PLANT P2

Date	7/13/84
Industry	Titanium dioxide
Process unit	Spray dryer
Location of discharge	Baghouse outlet
Height of observation point, ft	Ground
Height of point of discharge, ft	60
Distance from observer to discharge point, ft	250
Direction of observer from discharge point	SW
Description of background	--
Description of sky	Variable cloudy
Wind direction	NE
Wind velocity, mph	10
Color of plume	--
Duration of observation, min	96
Period of observation	1713-2013[a]
Highest single reading, percent	5
Highest 6-minute average, percent	2.9

[a] 16 sets of 6-minute observations were made during this period.

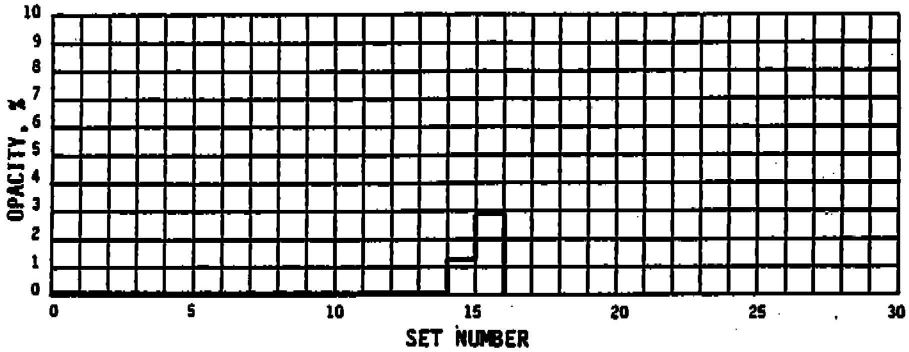

TABLE C-143. SUMMARY OF EMISSION TEST RESULTS--PLANT P3

Industry: Titanium dioxide
Process unit: Flash dryer
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	8/30/83	8/30/83	8/30/83	--
Sampling time, minutes	71	71	67	--
Isokinetic ratio, percent	95	90	99	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent	100	100	80	93
Gas stream data				
Temperature, °C	88	89	88	88.5
(°F)	(190)	(195)	(190)	(192)
Moisture, percent	28.2	28.7	28.3	28.4
Flow rate, m^3/s	32	33	30	32
(acfm)	(67,200)	(70,000)	(63,300)	(66,800)
Flow rate, dsm^3/s	19	19	18	19
(dscfm)	(39,600)	(40,600)	(37,300)	(39,200)
Particulate emissions				
g/dsm^3	0.081	0.066	0.049	0.067
(gr/dscf)	(0.035)	(0.029)	(0.021)	(0.029)
kg/h	5.6	4.7	3.1	4.5
(lb/h)	(12)	(10)	(6.8)	(9.8)
kg/Mg (lb/ton)	a	a	a	a

[a] Confidential data.

TABLE C-144. SUMMARY OF EMISSION TEST RESULTS--PLANT Q1
Industry: Vermiculite
Process unit: Rotary dryer
Emission source: Scrubber outlet

Data	Run No. 1	Run No. 2	Run No. 3	Average for test series
General				
Date	10/27/79	10/27/79	10/27/79	--
Sampling time, minutes	60	60	60	--
Isokinetic ratio, percent	103.5	92.0	101.3	--
Production rate, Mg/h (tons/h)	a	a	a	a
Capacity utilization, percent	84	77	96	86
Gas stream data				
Temperature, °C	55	56	54	55
(°F)	(131)	(133)	(130)	(131)
Moisture, percent	10.5	9.4	11.8	10.6
Flow rate, m^3/s	6.3	6.5	6.0	6.3
(acfm)	(13,300)	(13,800)	(12,700)	(13,300)
Flow rate, dsm^3/s	5.1	5.3	4.8	5.1
(dscfm)	(10,800)	(11,200)	(10,100)	(10,700)
Particulate emissions				
g/dsm^3	0.037	0.038	0.038	0.038
(gr/dscf)	(0.016)	(0.017)	(0.017)	(0.017)
kg/h	0.68	0.73	0.65	0.69
(lb/h)	(1.5)	(1.6)	(1.4)	(1.5)
kg/Mg (lb/ton)	a	a	a	a

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[a] Confidential data.

TABLE C-145. SUMMARY OF SCRUBBER MODELING DATA[23,24]

Industry/ process unit	Particle density, g/cc	Inlet mass conc., g/m^3	Mass mean particle diameter, μm	Standard deviation	Outlet mass concentration and required pressure drop					
					RA I		RA II		RA III	
					gr/dscf	ΔP, in. w.c.	gr/dscf	ΔP, in. w.c.	gr/dscf	ΔP, in. w.c.
Diatomite										
Flash dryer	2.0[1]	9.16	50	8.33	0.08	6	0.04	14	0.025	25
Feldspar										
Rotary dryer	2.7[2]	4.58[3]	50	8.33	0.26	<3	0.04	4	0.025	10
Fire Clay										
Rotary dryer[4]	2.6	11.5	9	3.3	0.15	3	0.04	10	0.025	14
Vibrating grate dryer	2.6[4]	1.6[5]	9[4]	3.3[4]	0.07	<3	0.04	<3	0.025	<3
Rotary calciner[6]	2.65	20.8	9	3.3	0.17	6	0.04	19	0.04	19
Fuller's Earth										
Rotary dryer	2.5[2]	168.42[7]	13[7]	2.2[7]	0.10	5	0.04	8	0.025	11
Industrial Sand										
Fluid bed dryer[8,23]	2.63	22.1	100	6.25	0.21	3	0.04	3	0.025	3
Rotary dryer[8,23]	2.63	0.11	100	6.25	0.39	3	0.04	3	0.025	3
Kaolin										
Multiple-hearth furnace[9]	2.64	8.58	13	5.4	0.12	8	0.04	23	0.04	23
Rotary calciner[10]	2.7	9.16	12	5.2	0.10	10	0.04	24	0.04	24
Lightweight Aggregate										
Rotary calciner	2.55[2]	31.1[11]	85[12]		0.09	10			0.04	23
Roofing Granules										
Fluid bed dryer[8]	2.6	22.1	100	6.25	0.14	3	0.04	3	0.025	3
Rotary dryer[8,23]	2.6	0.11	100	6.25	0.10	3	0.04	3	0.025	3

(continued)

TABLE C-145. (continued)

Industry/ process unit	Particle density, g/cc	Inlet mass conc., g/m³	Mass mean particle diameter, µm	Standard deviation	Outlet mass concentration and required pressure drop					
					RA I		RA II		RA III	
					gr/dscf	ΔP, in. w.c.	gr/dscf	ΔP, in. w.c.	gr/dscf	ΔP, in. w.c.
Titanium dioxide										
Flash dryer	5.87[13]	58.5[13]	4.6[14]	3.3[14]	0.11	20	0.04	34	0.025	43
Rotary dryer[14] (indirect)	3.8	2.3	4.6	4.7	0.77	<3	0.04	10	0.025	17
Rotary calciner[14]	5.7	5.04	4.6	4.7	0.04	17	0.04	17	0.04	17
Vermiculite										
Rotary dryer	2.3[2]	2.3[15]	50	8.33	0.23	<3	0.04	<3	0.025	4

TABLE C-14G. PRODUCT PARTICLE SIZE SIEVE ANALYSIS DATA[a]

Industry/ process unit	Cumulative percent less than																	
	Sieve No.[b]										Micrometers							
	10 (2,000)	20 (850)	30 (600)	40 (425)	50 (300)	60 (250)	70 (210)	100 (150)	140 (106)	200 (75)	10	8	6	4	3	2	1	0.5
Bentonite																		
Rotary dryer[25]	100			97.7	98.6			98			88	90	87	80			69	
Diatomite																		
Flash dryer[16]	52.9	35.0		21.4		14.6			8.0	3.8								
Feldspar																		
Rotary dryer[17]		99.7	94.0	76.6				15.6		3.3								
Fire Clay																		
Rotary dryer[4]	100	99.4		99.2		98.8		98.6		98.4	85.5	83.4	77	66				46
Rotary dryer[c,4]	100	99		97		96		95		95	66	61	55		45		32	
Rotary dryer[c,4]	100	99		98		98		97		98	70	65	60		49		32	
Rotary dryer[c,4]	100	99		98		97		97		96	73	69	63		51		32	
Vibrating-grate[18] dryer	23.0	12.3		6.6		3.3			1.1	0.7								
Rotary calciner[6]	87.3	81.8				79.5			78.8[d]	78.5[e]								
Rotary calciner[6]	8.6	3.3				1.0			0.2[e]									
Fuller's Earth																		
Rotary dryer[19]	60.4	6.9		1.2		0.4			0.2	0.1								
Industrial sand																		
Fluid bed dryer[8]	100	96.2		72.1		21.3		5.0	4.2	0.8								
Fluid bed dryer[8]	100	96.2		70.6		21.3		5.0	2.3	0.8								
Rotary dryer[8]		99.3		89.8	73.0		49.6	16.8	3.1	0.2								
Kaolin																		
Multiple-hearth furnace[9]										99.4								
Rotary calciner[d10]		99.1		92.5		75.6			53.3	14.3[f]					62			
Lightweight aggregate																		
Rotary calciner[20]								40.9										
Roofing granules																		
Fluid bed dryer[21]	51.1	10.9		3.1		1.5			1.2	0.9								
Titanium dioxide																		
Spray dryer[26]											48	40	38	35		31	27	
Rotary calciner[13]											69.2	61.1	50.9	43.8		34.8	22.1	4.6
Vermiculite																		
Rotary dryer[22]	92.8	74.5		49.6		27.2			6.8	3.4								

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[a] Analysis based on guidelines documented in ASTM Designation: D 422-63 (Reapproved 1972), Standard Method for Particle-Size Analysis of Soils.

[b] Numbers in parentheses represent the size of sieve openings in micrometers.

[c] Three different products from the same rotary dryer.

[d] Multiclone product sieve analysis.

[e] Cumulative percent less than sieve No. 120.

[f] Cumulative percent less than sieve No. 230.

REFERENCES FOR APPENDIX C

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2. Handbook of Chemistry and Physics, 55th ed., CRC Press, p. B-192.
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4. EPA emission test report for Plant F1.
5. Unapproved test report for Plant F2.
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7. Unapproved test data from Floridin Co.
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9. EPA emission test report for Plant J1.
10. EPA emission test report for Plant F3.
11. Emission test report for Plant K3.
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16. Product particle size sieve analysis from Grefco, Inc., Lompoc, California.
17. Product particle size sieve analysis provided by Plant E2.
18. Product particle size sieve analysis from Plant F2.
19. Product particle size sieve analysis from Plant G2.
20. Product particle size information provided by Plant K3.
21. Product particle size sieve analysis from Plant N2.
22. Product particle size sieve analysis from Plant Q1.

23. Memo from Sparks, L. E., EPA/PTB, to Neuffer, B., EPA/OAQPS. Estimated Scrubber Performance. December 4, 1984.

24. Memo from Kowalski, A. J., MRI, to Neuffer, W. J., EPA/ISB. Scrubber Modeling. August 27, 1985. 13 pp.

25. EPA emission test report for Plant C1.

26. EPA emission test report for Plant P2.

APPENDIX D. EMISSION MEASUREMENT AND MONITORING

D.1 EMISSION MEASUREMENT METHODS

During the standard support study for calciners and dryers in the mineral industries, the EPA conducted particulate emission tests at nine facilities that included the following process and control equipment combinations:

Process	Industry	Control Equipment
Spray dryer	TiO_2 (chloride)	Baghouse
Spray dryer	TiO_2 (chloride)	Baghouse
Rotary calciner	TiO_2 (sulfate)	Conditioning tower, ESP, scrubber
Rotary calciner	Fire clay	Multiclone and scrubber
Fluid bed dryer	Industrial sand	Scrubber
Rotary dryer	Industrial sand	Scrubber
Expansion furnace	Perlite	Baghouse
Rotary calciner	Fire clay	Scrubber
Rotary dryer	Fire clay	Scrubber
Rotary dryer	Bentonite	Baghouse
Herreshoff furnace	Kaolin	Scrubber
Flash calciner	Kaolin	Baghouse

In addition, tests had been previously conducted by the EPA for the lightweight aggregate industry. Three tests from this group were considered applicable to the calciners and dryers study. These tests included the following process and control equipment:

Process	Control Equipment
Rotary calciner (3 plants)	Scrubber

Another group of tests previously conducted by the EPA for the gypsum industry were also considered to be applicable to the present study. Four test reports were utilized; these included the following process and control equipment:

Process	Control Equipment
Rotary dryer	Baghouse
Flash calciner (2 plants)	Baghouse
Kettle calciner (2 plants)	Baghouse

For most of these tests, three runs were conducted both before and after the control device. Any time a run was determined to be unacceptable, a fourth run was conducted, for a net of three good runs. Particulate tests were run in accordance with EPA Reference Method 5 (40 CFR Part 60-Appendix A). Method 5 provides detailed procedures and equipment criteria, and other considerations necessary to obtain accurate and representative particulate emission data. Particle size distribution and the percentage of emissions less than 10 micrometers in diameter were determined with the use of in-stack impactors in accordance with the protocol, Procedure for Cascade Impactors Calibration and Operation in Process Streams, as modified by the Emissions Measurement Branch of the EPA. (These size fractions are a representative calculation based on an aerodynamic characterization of a unit density particle according to Mercer's definition.) Visible emissions from the source were determined in accordance with EPA Reference Method 9 (40 CFR Part 60-Appendix A). Fugitive emissions were determined in accordance with EPA Reference Method 22 and/or 9 (40 CFR Part 60-Appendix A). Process raw materials were collected as part of the testing program. Particle size distribution of these collected samples was determined by sieving or Stokes settling techniques. To determine the representativeness of raw materials processed at the tested facilities, process raw materials were collected at an additional 23 facilities. The same sieving or Stokes settling techniques were conducted on these raw materials samples to determine the particle size distribution.

The modifications used and problems encountered during testing of the nine facilities are discussed below. With the exception of one test conducted in a stack with cyclonic flow, the particulate tests (Method 5) involved only minor modifications and problems (not significant enough to summarize or affect the test results). During the particle size distribution testing (using the in-stack impactor) three common problems were encountered. First, the presence of water droplets made it difficult to obtain a representative sample and as a result, in some cases particle size testing was not performed. Second, the very low pollutant concentrations encountered after well-controlled sources made it difficult to collect significant amounts of particulate matter on all stages of the impactor. The results of these tests are acceptable; however, a decrease in the precision of the measurements is likely. Finally, the very high pollutant concentrations encountered prior to the control equipment resulted in some very short sample runs. These results are also acceptable, but are representative of a shorter averaging time. In a few cases, the visible emissions determinations were hampered due to inclement weather and/or a lack of sufficient light and were, therefore, not performed. None of the problems described above would be considered industry specific and all are routinely encountered in the course of testing any source category that employs various combinations of process and control equipment.

In addition to the emission testing support of the standard, a total of 79 industry-supplied test reports were reviewed for technical acceptability. Of these, 46 reports were found to be technically acceptable for standards consideration and of these 46, the Industrial Studies Branch of the EPA determined that 33 reports were acceptable for use in standards setting.

D.2 MONITORING SYSTEMS

The opacity monitoring systems that are adequate for other stationary sources, such as steam generators, and that are covered by performance specifications contained in Appendix B of 40 CFR Part 60, Federal Register, October 6, 1975, are also technically feasible for calciners and dryers in the mineral industries, except where condensed moisture is present in the exhaust stream. When wet scrubbers are used for control of emissions from process units in the mineral industries, monitoring of opacity with continuous emissions monitors is not applicable; therefore, another parameter, such as pressure drop, would need to be monitored as an indicator of proper operation and maintenance of the control device.

Equipment and installation costs for opacity monitoring are estimated to be $18,000 to $20,000 per site. The initial cost of a performance specifications test on these monitors is estimated at $3,000 to $5,000 per site. Annual operating costs, which include recording and reducing the data, are estimated at $8,000 to $9,000 per site. Some savings in operating costs may be achieved if multiple systems are used at a given facility.

The equipment and installation costs for monitoring scrubber pressure drop and scrubbing liquid flow rate are estimated to be $7,500 per scrubber. Annual operating costs, including examining and filing the data, would be approximately $3,300.

D.3 PERFORMANCE TEST METHODS

Consistent with the data base upon which the new source standards have been established, the recommended performance test method for particulate matter is Method 5 (40 CFR Part 60-Appendix A, Federal Register, December 23, 1971, as amended August 18, 1977). In order to perform Method 5, Methods 1 through 4 must be used.

Subpart A of 40 CFR Part 60 requires that affected facilities subject to standards of performance for new stationary sources must be constructed to provide sampling ports adequate for a performance test to be conducted. Platforms, access, and utilities necessary to perform testing at those ports must also be provided.

Sampling costs for performing a test consisting of three Method 5 runs are estimated to range from $5,000 to $9,000. When plant personnel are used to conduct the test, the cost will be less.

The recommended performance test method for visible emissions from the source is Method 9 (40 CFR Part 60-Appendix A, or Federal Register, November 12, 1974).

The recommended performance test methods for process fugitive emissions are Method 22 (40 CFR Part 60-Appendix A, or Federal Register, August 6, 1982) or Method 9 (Federal Register, November 12, 1974, as amended February 21, 1984).

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16. ABSTRACT

Standards of performance for the control of emissions from calciners and dryers in mineral industries are being proposed under the authority of Section 111 of the Clean Air Act. These standards would apply to new, modified, or reconstructed calciners and dryers in 17 mineral industries. This document contains background information and environmental and economic impact assessments of the regulatory alternatives considered in developing the proposed standards.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Pollution Control Standards of Performance Particulate Emissions Mineral Processing Plants	Air Pollution Control	13B

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