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Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

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Gypsum Industry — Background Information for Proposed Standards

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NOTICE

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Gypsum Industry — Background Information for Proposed Standards

Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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Background Information
and Draft
Environmental Impact Statement
for Gypsum Industry

Type of Action: Administrative

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF ILLUSTRATIONS

1. SUMMARY

1.1 REGULATORY ALTERNATIVES

New Source Performance Standards (NSPS) for particulate emissions from stationary sources in the gypsum industry are being developed under the authority of Section 111 of the Clean Air Act. This Background Information Document provides support for the standards to be proposed. Emission sources considered in this document include the following:

- ore dryers,
- calciners,
- board end sawing operations,
- stucco mixing operations,
- paper scoring and chamfering operations,
- stucco conveying, and
- stucco storage.

Control equipment used in the gypsum industry for controlling particulate emissions include fabric filters, electrostatic precipitators, and scrubbers. Based on reports in the literature and on available industry test results, fabric filters were selected as the best emissions control system demonstrated on sources in the gypsum industry. EPA and industry source tests were conducted at six gypsum plants to demonstrate the particulate control capabilities of fabric filters. Results of these tests are tabulated in Appendix C.

The analysis of environmental and economic impacts were based on the use of fabric filters to control all particulate emission sources for three regulatory alternatives. These regulatory alternatives were:

1. Control of all sources to the baseline emissions level;
2. Control of the three principal emission sources (ore dryers, calciners and board end sawing) to the best demonstrated level of emissions reduction; and
3. Control of all sources to the best demonstrated level of emissions reduction.

The fabric filters used to attain the best demonstrated level of emissions reduction are identical to those used to meet the baseline emissions level. Increased particulate collection under Alternatives 2 and 3 is accomplished through improved maintenance, more frequent bag replacement, and opacity monitoring.

For Alternatives 2 and 3, two emissions monitoring options were considered. Monitoring option A represents opacity measurements of emissions from each source conducted on a weekly basis by a certified observer using EPA Reference Method 9. Monitoring option B represents continuous opacity monitoring using transmissometers on each source. Emissions reductions achieved under Alternatives 2 and 3 are assumed to be equal for both monitoring options.

Alternative 1 is equivalent to no NSPS regulatory action. Under this alternative, emissions would be controlled to levels established by existing State opacity regulations. The impacts of the other alternatives are calculated based on this alternative.

1.2 ENVIRONMENTAL IMPACT

Standards of performance based on either Alternative 2 or Alternative 3 will result in a beneficial impact on air quality. Implementation of Alternative 2 will reduce particulate emissions by a maximum of 698 Mg/yr (769 TPY) in 1986, representing an 84 percent decrease below the baseline emissions level. Implementation of Alternative 3 will reduce emissions of particulate matter from new sources in gypsum plants by a maximum of 773 Mg/yr (851 TPY) or a 93 percent reduction below emissions under Alternative 1 projected for 1986. These reductions in particulate emissions can be accomplished without causing any adverse environmental impacts.

No water pollution impact will result from implementation of any of the regulatory alternatives since fabric filters do not use water to control particulate emissions.

Solid wastes generated by the fabric filter collection systems are valuable material which is recycled to the process in all cases except some board end sawing operations. Solid waste impacts resulting from implementation of any of the Alternatives are minimal.

No incremental energy impact will result from Alternatives 2 or 3 since the control equipment associated with each alternative is identical.

A more detailed analysis of these environmental and energy impacts is presented in Chapter 7. A summary of the environmental and economic impacts associated with the regulatory alternatives which were considered is presented in Table 1-1.

1.3 ECONOMIC IMPACT

Economic analysis indicates that implementation of Regulatory Alternative 3B would increase the price of gypsum wallboard, currently selling at $114 per 1000 square feet, by 1.1 percent. If the wallboard manufacturer absorbs the cost of NSPS, the estimated net operating profit of new plants would decline by 5.6 percent for this same alternative. This decline in profit is not expected to deter investment in new plants. In addition, cost analysis indicates that the incremental cost effectiveness of Regulatory Alternative 3B over Regulatory Alternative 1 is less than $1650 per megagram ($1500 per ton) of collected particulates for all model plants considered.

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

Administrative Action	Air Impact	Water Impact	Solid Waste Impact	Energy Impact	Noise Impact	Economic Impact
Alternative 3	+3**	0	-1*	0	0	
Alternative 2	+2**	0	-1*	0	0	
Alternative 1 (No NSPS Action)	0	0	-1*	0	0	

KEY

\+ Beneficial Impact
\- Adverse Impact

0 No Impact
1 Negligible Impact
2 Small Impact
3 Medium Impact
4 Large Impact

* Short-term Impact
** Long-term Impact
*** Irreversible Impact

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 economics and well-being of the industry, the impacts on the national economy, and the impacts on the environment. This document summarizes the information obtained through these studies so that interested persons will be able to see the information considered by EPA in the development of the proposed standard.

Standards of performance for new stationary sources are established under Section 111 of the Clean Air Act (42 U.S.C. 7411) as amended, hereinafter 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 reduction achievable which (taking into consideration the cost of achieving such emission reduction, and any nonair quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated for that category of sources." The standards apply only to stationary sources, the construction or modification of which commences after regulations are proposed by publication 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.

1. EPA is required to list the categories of major stationary sources that have not already been listed and regulated under standards of performance. Regulations must be promulgated for these new categories on the following schedule:

a. 25 percent of the listed categories by August 7, 1980.

b. 75 percent of the listed categories by August 7, 1981.

c. 100 percent of the listed categories by August 7, 1982.

A governor of a State may apply to the Administrator to add a category not on the list or may apply to the Administrator to have a standard of performance revised.

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

3. 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.

4. 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.

5. The time between the proposal and promulgation of a standard under Section 111 of the Act may be extended to 6 months.

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 non-air-quality health and environmental impacts, and energy requirements.

Congress had several reasons for including these requirements. First, standards with 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 effectively excluding certain coals from the reserve base because their untreated pollution potentials are high. Congress does not intend that new source performance standards contribute to these problems. Fifth, the standard-setting process should create incentives for improved 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 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 limitations 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 Sections 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, 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, Section 111(j) authorizes the Administrator to grant waivers of compliance to permit a source to use innovative continuous emission control technology. In order to grant the waiver, the Administrator must find: (1) a substantial likelihood that the technology will produce greater emission reductions than the standards require or an equivalent reduction at lower economic energy or environmental cost; (2) the proposed system has not been adequately demonstrated; (3) the technology will not cause or contribute to an unreasonable risk to the public health, welfare, or safety; (4) the governor of the State where the source is located consents; and (5) the waiver will not prevent the attainment or maintenance of any ambient standard. A waiver may have conditions attached to assure the source will not prevent attainment of any NAAQS. Any such condition will have the force of 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 three years to to meet the standards with a mandatory progress schedule.

2.2 SELECTION OF CATEGORIES OF STATIONARY SOURCES

Section 111 of the Act directs the Adminstrator to list categories of stationary sources. The Administrator ". . . shall include a category of sources in such list if in his judgement 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 a system 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, these "areas" are actually pollutants emitted by stationary sources. Source categories that emit these pollutants are evaluated and ranked by a process involving 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 under development during 1977, or earlier, were selected on these criteria.

The Act amendments of August 1977 establish specific criteria to be used in determining priorities for all major source categories not yet listed by EPA. These are: (1) the quantity of air pollutant emissions that 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 standards of performance.

The Administrator is to promulgate standards for these categories according to the schedule referred to earlier.

In some cases it may not be feasible immediately to develop a standard for a source category with a high priority. This might happen when a program of research is needed to develop control techniques or because techniques for sampling and measuring emissions may require refinement. In the developing 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, even late in the development process the schedule for completion of a standard may change. 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 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 some of these facilities may vary from insignificant to very expensive to control. 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 a standard 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 non-air-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 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 developing 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 standard of performance.

During the information-gathering phase, industries are queried through a telephone survey, letters of inquiry, and plant visits by EPA representatives. Information is also gathered from many other sources, and a literature search is conducted. From the knowledge 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.

EPA conducts studies to determine the impact of each regulatory alternative on the economics of the industry and on the national economy, on the environment, and on energy consumption. From several possibly applicable alternatives, EPA selects the single most plausible regulatory alternative as the basis for a standard of performance for the source category under study.

In the third phase of a project, the selected regulatory alternative is translated into a standard of performance, which, in turn, is written in the form of a Federal regulation. The Federal regulation, when applied to newly constructed plants, 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 standard, and a preamble explaining the standard 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 standard is 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.

As a part of the Federal Register announcement of the proposed regulation, the public is invited to participate in the standard-setting process. EPA invites written comments on the proposal and also holds a public hearing to discuss the proposed standard 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 standard of performance is available to the public in a "docket" on file in Washington, D. C.

Comments from the public are evaluated, and the standard of performance may be altered in response to the comments.

The significant comments and 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 or 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 also requires that the economic impact assessment be as extensive as practicable.

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

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 performance 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 counter-productive environmental effects of a proposed standard, as well as economic costs to the industry. On this basis, therefore, the Court established a narrow exemption from NEPA for EPA determination under Section 111.

In addition to these judicial determinations, the Energy Supply and Environmental Coordination Act (ESECA) 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 in this document 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 of Subpart A of 40 CFR Part 60, which were promulgated in the Federal Register on December 16, 1975 (40 FR 58416).

Promulgation of a standard 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 standard for new sources limits 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 provisions outlining 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 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 assure that the standards continue to reflect the best systems 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 GYPSUM INDUSTRY

This chapter presents a description of the domestic gypsum industry. Section 3.1 describes the gypsum industry in general, including a discussion of gypsum products and end uses. Section 3.2 presents the processes and uncontrolled emissions for the gypsum industry. Although emissions associated with fuel combustion are discussed, the emphasis is on particulate emissions from gypsum manufacturing operations. Section 3.3 presents baseline emissions and control.

3.1 GENERAL INDUSTRY BACKGROUND

Gypsum is calcium sulfate dihydrate ($CaSO_4 \bullet 2H_2O$), a white, crystalline, naturally occurring mineral. Raw gypsum ore is processed into a variety of products which include an additive for Portland cement, agricultural fertilizer, industrial and building plasters, and gypsum wallboard. The development of improved gypsum processing methods since around 1835 has led to the rise of gypsum products as the primary wall cladding materials in the United States.[1]

In 1978, upgraded crude gypsum and calcined gypsum products were produced in 73 plants located in 31 states.[2] Seventy-one of the plants partially dehydrate, or calcine, crude gypsum to produce calcium sulfate hemihydrate ($CaSO_4 \bullet \frac{1}{2}H_2O$), which is commonly called stucco, and two plants operate with stucco as a starting material. Stucco is used to produce industrial and building plasters and wallboard. In 1978, 96 percent of the total value of sales and 73 percent by weight of the gypsum products sold or used in the United States were materials used mainly by the building industry that had been calcined. Gypsum wallboard accounted for about 95 percent of pre-fabricated gypsum building materials produced in 1978.[3]

Imported crude gypsum accounted for 33 percent of consumption in 1979.[4] Exports of crude, crushed and calcined gypsum amounted to only 0.9 percent of crude gypsum production in 1979.

As indicated by Figure 3-1, the overall trend for gypsum products is an increasing demand from the present time through 1985 as well as beyond to 2000. This growth rate is estimated at 2.7 percent per year between 1977 and 2000. Production increases will be met by plant expansions and by entirely new plants.

3.2 PROCESS FACILITIES AND THEIR EMISSIONS

As mentioned in Section 3.1, mined gypsum ore is processed into a variety of products. The ore can be (1) sized and screened for use as an additive for Portland cement, (2) sized, screened and possibly dried and ground for use as an agricultural fertilizer, or (3) sized, screened, dried and calcined to calcium sulfate hemihydrate ($CaSO_4 \bullet \frac{1}{2}H_2O$) for use in plasters and pre-fabricated building products. This section discusses the processes used to manufacture these various products and the emissions from these processes.

A flow diagram for a typical gypsum plant process producing both crude and finished gypsum products is shown in Figure 3-2. Some plants produce only finished products. Two plants manufacture finished products from calcined gypsum produced at other gypsum plants.

Primary crushed gypsum ore mined from quarries and underground mines is stockpiled to maintain a one to three month's supply.[8,9] The mined ore is further crushed and screened, with oversize ore returned to the crusher. Some of this crushed rock is sold as an additive for cement. If the free moisture content of the mined rock is greater than about 0.5 weight percent, the sized ore is dried, typically in a rotary dryer.

The dried rock is then conveyed to grinding mills where it is ground to about 90 percent minus 100 mesh. Air is passed through the grinding mills to remove the ground gypsum. The air from the mill is exhausted to product cyclones to recover the ground gypsum which is known as land plaster. Land plaster may be sold directly as an agricultural fertilizer. The bulk of the land plaster is fed to calciners where it is heated to remove three-quarters of the chemically bound water to form stucco. At some plants, the air used in the grinding mills is heated in

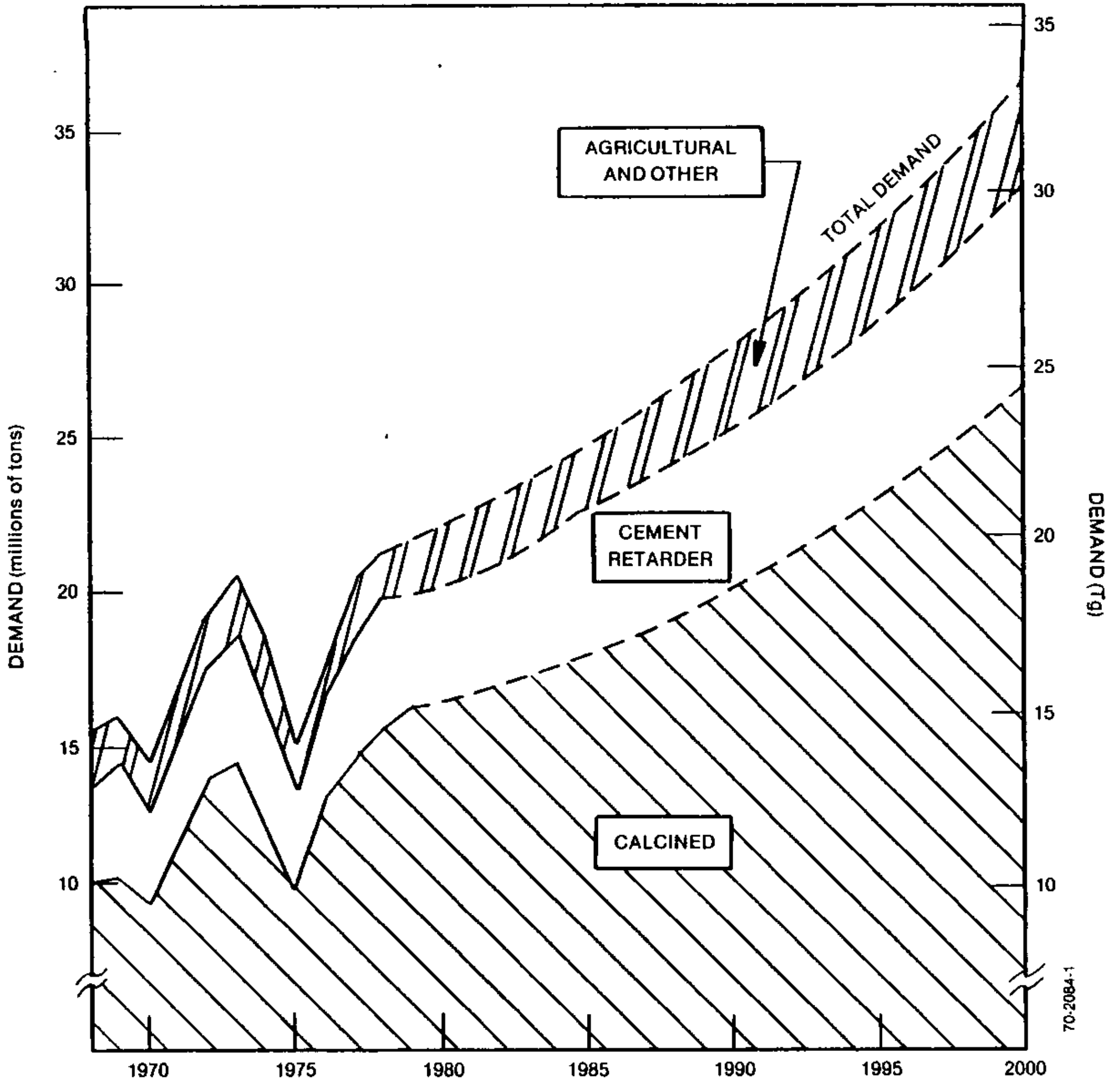

Figure 3-1. U.S. demand for gypsum products projected through 2000.[5,6,7]

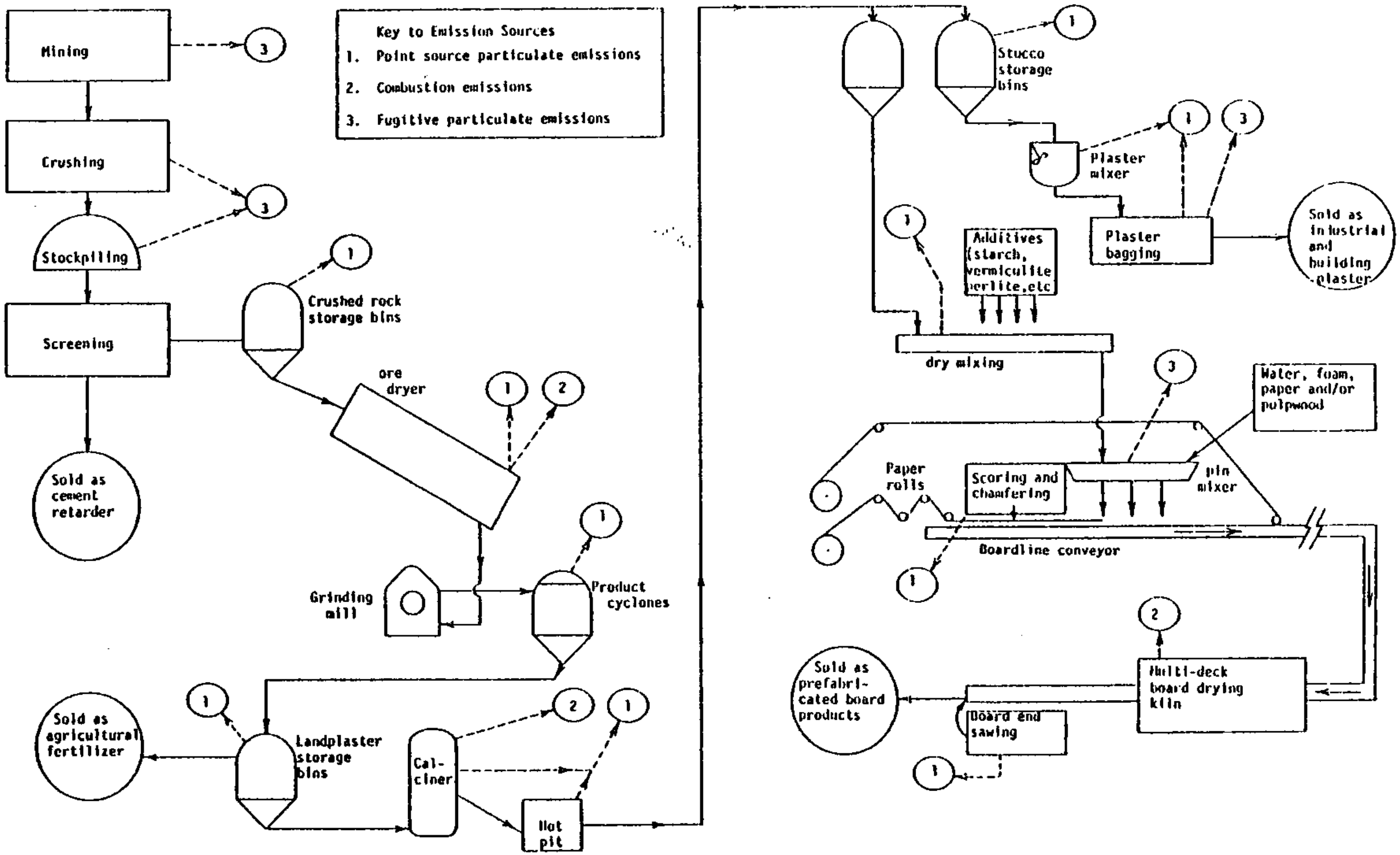

Figure 3-2. Overall process flow diagram.

a gas- or oil-fired heater or in an exchanger recovering waste heat from calciner combustion gases. The hot air dries the rock and, at a few plants, calcines it.

In the manufacture of plasters, the stucco is further ground in a tube mill or ball mill and then mixed with retarders and accelerators to produce plasters with specific setting rates.

In the manufacture of pre-fabricated building products such as wallboard, the stucco from storage is first mixed with dry additives such as perlite, starch, fiberglass, and vermiculite. This dry mix is combined with water, soap foam, and shredded paper or pulpwood in a pin mixer at the head of a board forming line.[10] The slurry is then spread between paper rolls to form wallboard. The edges of the paper are scored and sometimes chamfered, to allow precise folding to form the edges of the board which serves as a mold for the slurry. As the wet board travels the length of a conveying line, the hemihydrate stucco recombines with the water to form the dihydrate, resulting in rigid board. The board is rough cut to length before entering a multi-deck kiln dryer. In the kiln, the board is dried through direct contact with hot combustion gases. The dried board is conveyed to the board end sawing area where it is trimmed and then bundled for shipment.

Many of the processing operations used to manufacture gypsum products are sources of pollutant emissions. The process emission sources being considered in this study include the following:

- ore drying,
- calcining,
- stucco mixing,
- board end sawing,
- paper scoring and chamfering,
- stucco conveying and
- stucco storage in bins or silos.

A number of gypsum process emission sources are not being considered here because control of these sources was assumed to be required by the new source performance standards (NSPS) which were being developed by

EPA for non-metallic mineral processing plants.[11] These emission sources include:

- crushers,
- grinding mills,
- screening operations, and
- bagging operations.

In addition, the non-metallic minerals NSPS was assumed to cover belt conveyor transfer points, bucket elevators, and storage bins. However, the non-metallic mineral NSPS was to apply only to plants that grind or crush mineral ore. Since generally no grinding or crushing is performed at plants that use stucco as a starting material, conveying and storing operations in these plants would not have been regulated by the non-metallic mineral NSPS. Conveying and storing operations are therefore considered in this study for plants that use stucco as a starting material.

Particulate emissions from the use of by-product or synthetic gypsum, generated from other chemical processes such as neutralization of sulfuric acid waste streams, flue gas desulfurization and phosphoric acid manufacture, are not considered in this study. The use of by-product gypsum in wallboard manufacture is expected to progress slowly through 1985 due to poor economics when compared to the use of natural gypsum. No commercial wallboard plants using by-product gypsum have been built in the United States to date.[12] The use of by-product gypsum in the United States is currently limited to agricultural products and appears to have a potential market in the cement industry.[13,14]

Emissions associated with gypsum mining and quarrying, such as emissions from drilling, blasting, stockpiling, loading, and hauling operations are affected by a large number of variables. These variables include material properties as well as meteorological conditions.[15] No accepted test method is currently available to allow full characterization of emissions from mining and quarrying operations. Since a specialized program would be required to (1) identify and study emission controls for mining and quarrying operations and (2) develop a testing method to fully characterize these sources, emissions from mining and quarrying are not considered in this study.

Combustion emissions, including NO_x and SO_x emissions, are not considered in this study because the industry predominantly fires clean fuels such as natural gas and distillate oil. Although one gypsum manufacturer is planning to use high sulfur residual fuel oil in new plants,[16] these plants are expected to be built in only one or two states. The development of national emission standards for SO_2 emissions from gypsum plants would therefore be inappropriate at this time since SO_2 emissions would be more expediently regulated through state implementation plans in the one or two affected states out of 30 gypsum processing states.

Each of the process emission sources considered in this study of the gypsum industry is discussed in the next few sections. The discussion is divided into seven parts, one for each of the seven sources being considered.

3.2.1 Ore Dryers

3.2.1.1 Description. Ore dryers employed in the gypsum industry are continuously fed, direct-fired, cocurrent rotary units. A schematic diagram of a direct-fired, cocurrent rotary dryer is shown in Figure 3-3. The cylinder or rotary section of the dryer is constructed of an outer metal shell and an inner refractory brick lining. All or part of the cylinder may be insulated to reduce heat losses to the environment.

The gypsum ore feed is introduced at the elevated end of the cylinder and moves toward the discharge as a result of gravity and the rotary motion of the cylinder. Lifting flights along the inside of the cylinder aid the movement of the solids and provide intimate mixing of the solids with the hot combustion gases which enter from the furnace.

The feed to the dryer consists of crushed and screened gypsum ore, generally minus five centimeters (minus two inches) in diameter. In its mined form, the calcium sulfate dihydrate ($CaSO_4 \bullet 2H_2O$) ore typically contains from five to ten percent gangue (clays and other insoluble impurities) and varying amounts (usually less than 10 percent) of free water (water other than that which is chemically bound). As the wet ore is heated in the dryer to about 338K (149°F) the free water is evaporated.

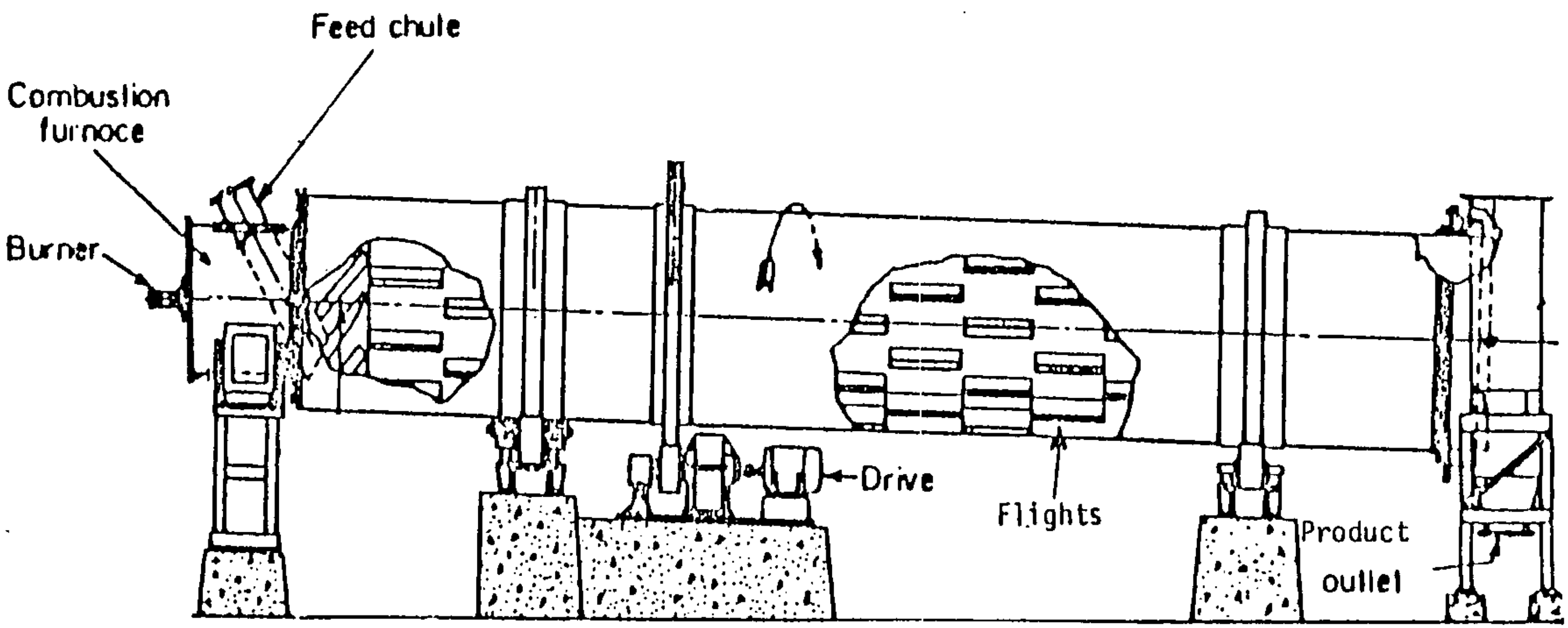

Figure 3-3. Direct fired, cocurrent, rotary dryer.[17]

Essentially complete removal of free water is achieved in the dryer, producing a product containing 19 to 20 percent by weight chemically combined water. 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 eight percent free moisture in a dryer operating at 377K (220°F), the approximate drying time is six to ten minutes.

Gypsum ore may also be dryed in grinding mills, eliminating the need for a rotary kiln. Crushed ore is fed directly to the grinding mill where hot gases and the grinding operation effectively remove the free moisture from the raw ore. By combining ore drying and grinding into a single operation, energy requirements may be reduced and a source of particulate emissions is eliminated. Since this method of ore drying is accomplished in grinding mills, it is assumed to be covered under the study of the non-metallic minerals industry.[18]

3.2.1.2 Dryer Fuel Types. Natural gas- and oil-fired rotary dryers are used in the gypsum industry. In most plants, clean fuels, such as natural gas and distillate oil, are burned. Gas firing is currently most common. Three plants, however, are known to be burning a high sulfur residual oil in their dryers. Information gathered from the U.S. Bureau of Mines[19] and industry indicates that ore dryers will continue to be of the direct-fired type and that natural gas and distillate oil will be the primary fuels.[20,21] Fuel type does not affect uncontrolled particulate emissions from ore dryers.

3.2.1.3 Dryer Capacities. The design capacities of most ore dryers employed by the gypsum industry range from 45.4 Mg/hr to 82 Mg/hr (50 to 90 tons/hr) of ore. Operating factors of these dryers range from 50 to 100 percent of the design capacities.

Dryers at new plants are expected to have design capacities of about 45.4 Mg/hr (50 tons/hr) of rock. A dryer of approximately this size would be required in order to dry 378,000 Mg/yr (416,400 tons/yr) of gypsum ore based on an operating factor of 95 percent or 347 days per year. This capacity would allow production of up to 45.5 million square meters (490 million square feet) of wallboard per year in a contemporary board plant operating on the same 347 day basis.

3.2.1.4 Emissions. Ore dryers are the second largest point source of particulate emissions from plants in the gypsum industry. Particulate matter from dryers consists of calcium sulfate dihydrate and other solids present in the ore. Emissions occur by entrainment of dust fines from gas flow through the dryer.

Particulate emissions from ore dryers are affected by the gas velocity, the production rate, and the particle size distribution of the ore feed. Gas velocity affects the degree of turbulence and the extent to which particles are entrained in the exiting gas. As gas velocity increases at a given production rate, the uncontrolled emission rate increases. The rate of increase in emissions also becomes greater as gas velocity increases. As production rates decrease at a given air flow rate, the uncontrolled emissions from ore dryers, expressed as a percent of the feed, will increase.[22]

The particle size distribution of the ore affects particulate emissions because small particles are more easily entrained in a moving stream of gas than are larger particles.

Uncontrolled particulate emission factors, particulate concentrations, and exit gas flow factors measured in EPA source tests on gas- and oil-fired dryers are presented in Table 3-1. The data shown in Table 3-1 represent two different dryer configurations. One of the dryers (Plant E) uses four process cyclones to prevent an estimated 85 percent of the particulate matter entrained in the process gases from exiting the dryer. The other dryer (Plant Y) has no process cyclones; exit gases that are heavily laden with dust are ducted directly to emission control equipment.

An estimate of uncontrolled ore dryer emissions at various dryer air flow rates and production rates was made using the EPA test data in Table 3-1 and industry data on uncontrolled emissions.[25] This analysis showed that the percent of feed entrained in dryer exit gases is highest when dryers are operated at high air flow rates and low production rates.

TABLE 3-1. UNCONTROLLED EMISSION PARAMETERS FOR ORE DRYERS MEASURED IN EPA SOURCE TESTS

Plant Identification	Fuel Type	Exit Gas Temperature K	Exit Gas Temperature °F	Gas Flow Rate m^3/s	Gas Flow Rate acfm	Exit Moisture Content Percent H_2O	Uncontrolled Particulate Emission Factors g/Kg	Uncontrolled Particulate Emission Factors lb/ton	Particulate Concentrations g/dNm^3	Particulate Concentrations gr/dscf
Plant E[a]	Natural Gas									
Test Run #1		352.	174.	4.69	9,950	9.1	1.49	2.97	7.35	3.21
Test Run #2		351.	173.	4.50	9,550	8.9	1.84	3.67	9.43	4.12
Test Run #3		354.	178.	4.53	9,600	9.0	1.81	3.61	9.05	4.09
Average		352.	175.	4.58	9700	9.0	1.71	3.42	8.71	3.81
		Average fuel usage factor = 19×10^3 Kcal/Mg (0.07×10^6 Btu/ton)								
		Capacity factor in percent[b] = 92								
		Wet rock moisture content in percent = 1.5-2.0								
Plant Y[c]	Residual Oil (No. 6)									
Test Run #1		375.	215.	7.41	15,700	8.5	81.5	163.	117	51.0
Test Run #2		375.	216.	7.55	16,000	8.9	84.5	169.	119	52.0
Test Run #3		375.	215.	7.64	16,200	7.0	86.5	173.	117	51.3
Average		102.	215.	7.53	15,970	8.1	84.0	168.	117	51.3
		Average fuel usage factor = 55×10^3 Kcal/Mg (0.20×10^6 Btu/ton)								
		Capacity factor in percent = 60								
		Wet rock moisture content in weight percent = 6.0-8.0								

[a] Reference 23. Dryer employs cyclones for dust recycle prior to fabric filter.

[b] Capacity factor is fraction of design capacity being used.

[c] Reference 24. Dryer does not use a cyclone prior to fabric filter.

Ref. 4 AP-42

Ref. 3 AP-42

The data in Table 3-1 show that the percentage of ore feed which is entrained in exit gases from ore dryers is significantly reduced by the use of process cyclones. Exit gases downstream of the process cyclones on the Plant E dryer contained only 0.2 percent of the total feed, whereas the exit gases from the Plant Y dryer contained eight percent of the total feed. In both cases, however, this material is routinely recovered in fabric filter dust collectors or electrostatic precipitators. The captured product is returned to the process.

Particle size data for uncontrolled emissions from ore dryers as measured in EPA source tests are presented in Figures 3-4 and 3-5. The particle size data shown in Figure 3-4 were collected downstream of ore dryer process cyclones. Approximately 50 percent of the particles in this gas stream were below 10 μm in diameter. The particle size data shown in Figure 3-5 were collected downstream of a dryer which does not use process cyclones. In this case, only about ten percent of the particles are less than 10 μm in diameter.

The quantities of sulfur oxides produced from dryer fuel combustion depend on the sulfur content of the fuel. The sulfur content of natural gas is generally extremely low, and the sulfur content of distillate oil is typically 0.22 percent by weight. Consequently, sulfur dioxide emissions produced by the combustion of either natural gas or distillate oil are low.

Sulfur dioxide emissions produced by the combustion of residual fuel oil can be high. Sulfur contents of residual or No. 6 fuels range from 0.8 percent by weight in low sulfur residual oil to 4.0 percent in extremely high sulfur residual oil. The sulfur content of residual oils currently used for ore dryers is about 2.0 percent.[26,27] Use of residual fuels with lower sulfur contents would significantly reduce sulfur dioxide emissions from ore dryers.

No major seasonal variations in sulfur oxide levels are expected. However, minor variations in these levels may result when fuel oil is substituted for gas during winter months due to natural gas curtailments.

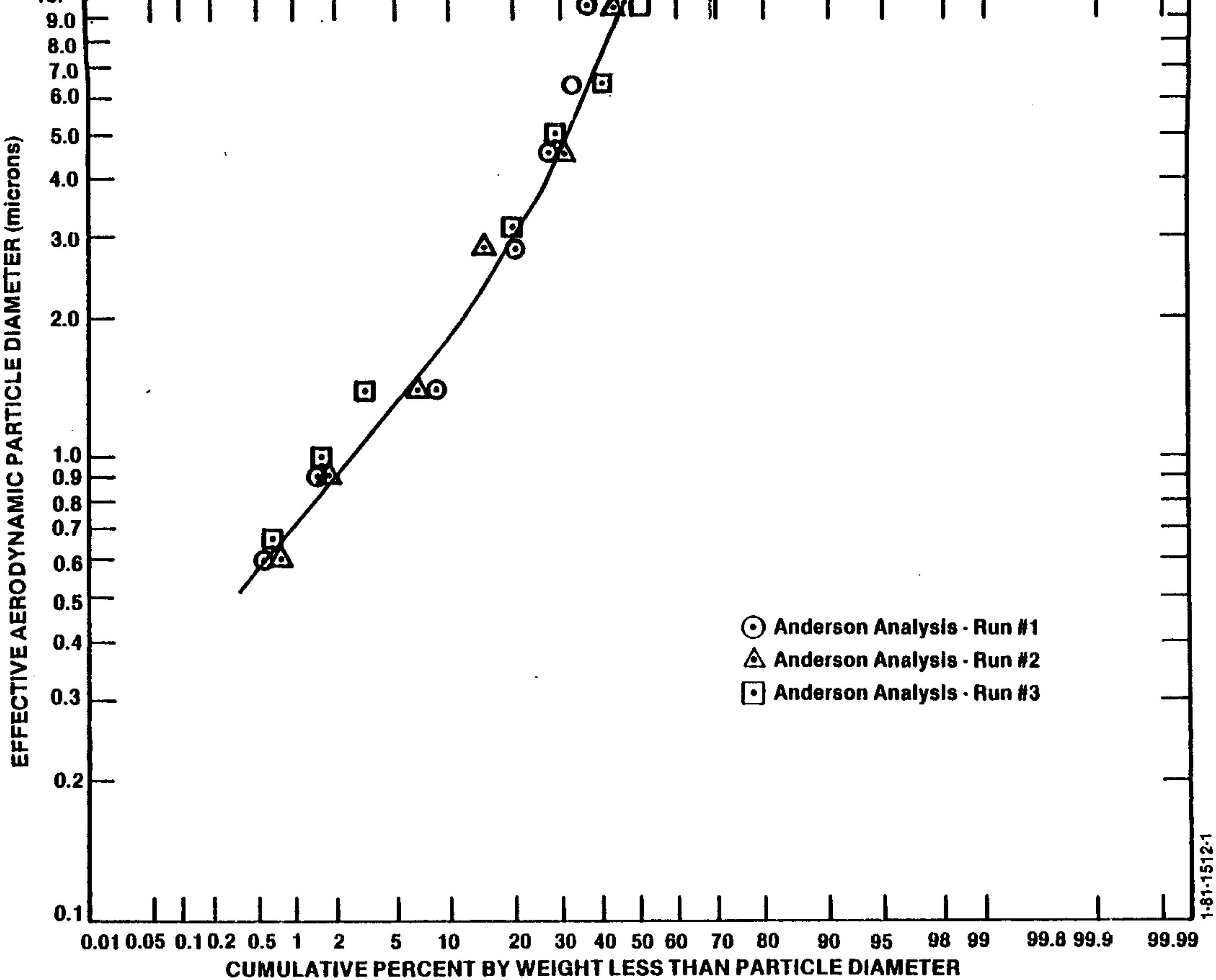

Figure 3-4. Particle size analysis for gas-fired dryer with cyclones.

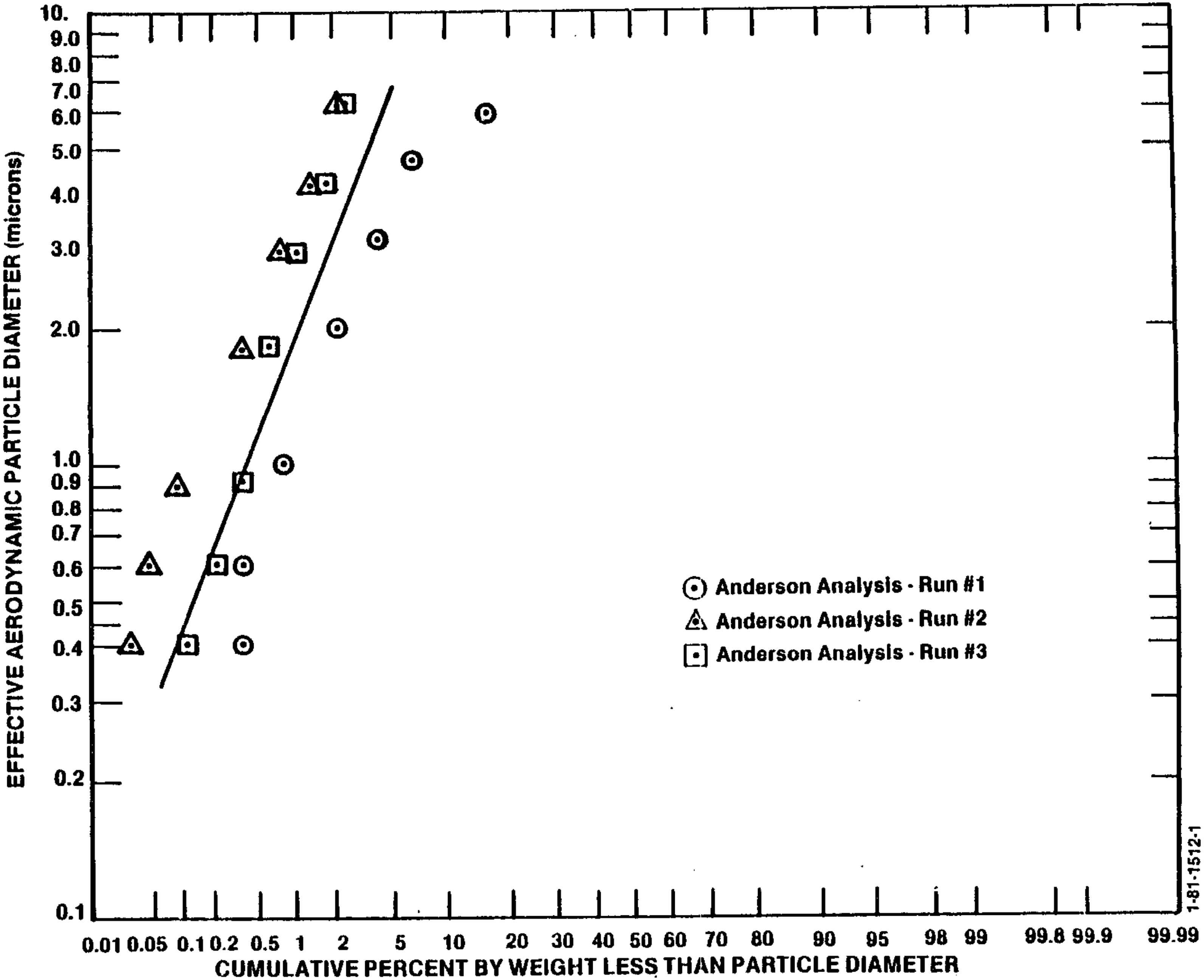

Figure 3-5. Particle size analysis for oil-fired dryer without cyclones.

3.2.2 Calciners

3.2.2.1 Description. Calciners are employed in the gypsum industry to remove three quarters of the chemically bound water of hydration from calcium sulfate dihydrate to form calcium sulfate hemihydrate. Calcining occurs by the following reaction:

$$CaSO_4 \cdot 2H_2O\ (s) \xrightarrow{\text{heat}} CaSO_4 \cdot \tfrac{1}{2}H_2O\ (s) \ + \ 3/2\ (H_2O)\ (g)$$

The heat of reaction is 82.70 kJ/g-mole (35,568 Btu/lb-mole) at 298°K (77°F). Supplying the heat required for the calcination reaction consumes 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 100 mesh (minus 149 µm). The stucco produced contains from four to six percent chemically combined water.

The two most widely used calciner types are kettle calciners and direct contact flash calciners. Kettle calciners are operated in both batch and continuous modes. The direct contact flash calciner is a continuous process patented by the National Gypsum Company.[28]

Less common calciner types include rotary kilns, Holoflight calciners, and Raymond Imp mills. Rotary kilns are direct contact units similar to rotary ore dryers shown in Figure 3-3. Holoflight calciners are units which employ heated oil to indirectly heat the gypsum ore. Raymond Imp mills, often called flash calciners in the gypsum industry, are grinding mills in which the gypsum is directly contacted with hot combustion gases and calcined during the grinding operation.

A general description of batch and continuous kettle calciners and of direct contact flash calciners is given in the following sections. Since the use of rotary calciners and Holoflight calciners has been phased out due to high maintenance costs and since emissions from Raymond Imp mills was assumed to be regulated by the non-metallic minerals NSPS, these three calciner types are not considered further.[29]

Batch and continuous kettles. Kettle calciners are constructed from metal cylindrical shells which are set in masonry brick and surrounded by a steel jacket. The inner wall of the masonry is lined with a refractory. The kettles 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 an indirect transfer of heat to the gypsum ore. Horizontal arms attached to a vertical shaft in the center of the kettle agitate the ore to provide mixing and thus prevent over heating of the gypsum. Air is passed through the inside of the kettle to remove the water liberated by the calcination reaction. The calcined gypsum or stucco is discharged into "hot pits" located below the kettle.

Although some kettle calciners are designed to operate in only a batch mode, most continuous kettles can be operated in either batch or continuous modes. Kettle calciners originally designed specifically for batch operation can be modified to operate continuously.

In batch calcining operations the dry gypsum ore is fed to the kettles by screw type feeders. The gypsum ore is heated to between 422 and 450K (300 and 350°F) before the kettle is emptied. The kettle is emptied by means of a discharge spout. The time required for batch calcination varies from one to three hours depending on the quality of the gypsum feed, the kettle size, and the firing rate.

In continuous kettle calcining operations, the dry gypsum is fed using a variable speed screw feeder. The temperature of the exiting gypsum product or stucco is maintained between 366 and 394K (200 and 250°F) by varying the gypsum feed rate to the kettle while the fuel firing rate is held constant. The stucco is removed continuously either by fluidizing the gypsum particles into an overflow channel which discharges directly into a hot pit or by emptying directly into a discharge spout. A diagram of a continuous kettle with the fluidized discharge is shown in Figure 3-6.

Direct contact flash calciners. National Gypsum Company's patented direct contact flash calciners are continuous units in which fine gypsum

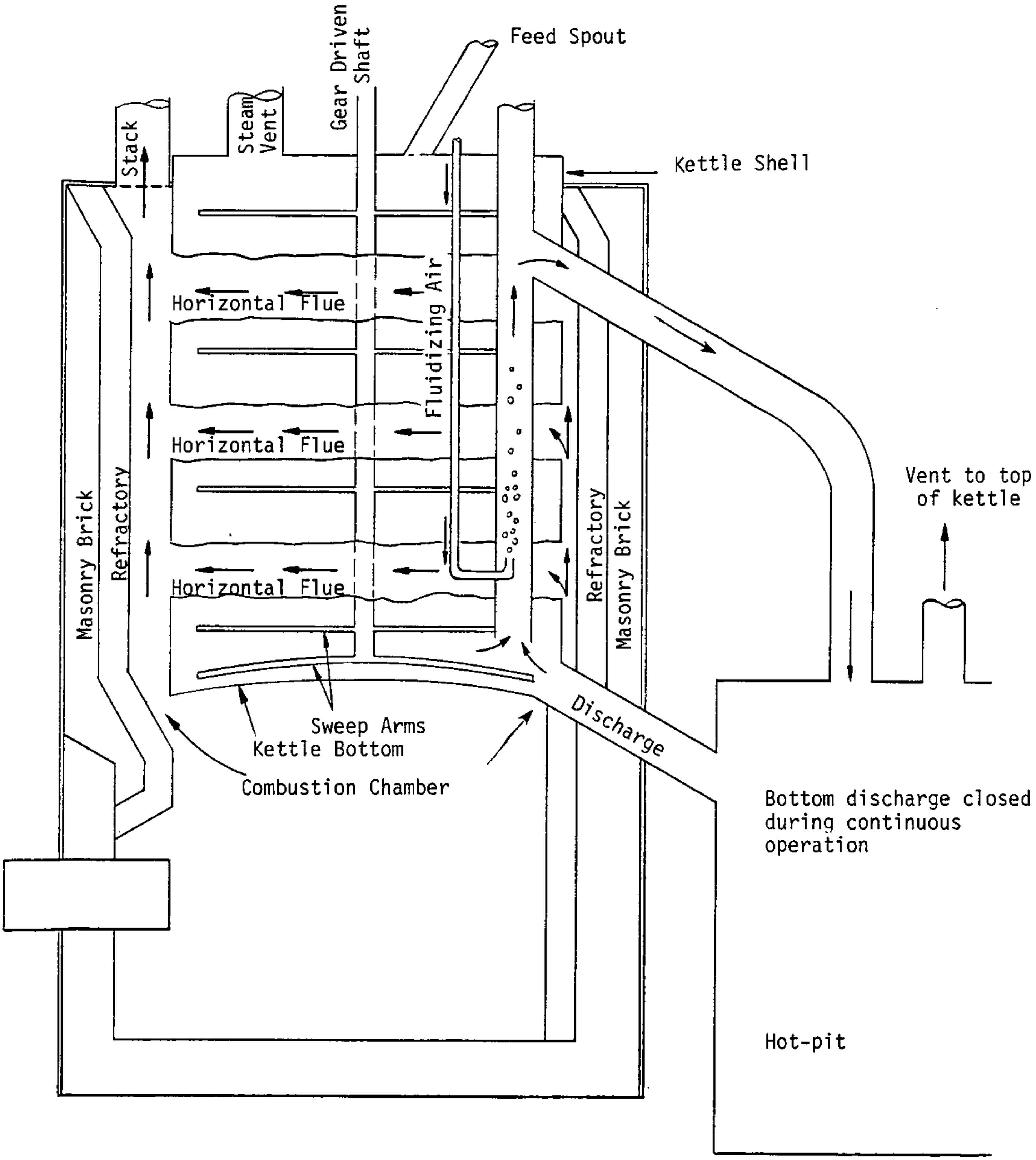

Figure 3-6. Diagram of continuous kettle.
(Modified for continuous operation.)

dust is fed spirally downward through a cylindrical zone into which heated air is injected tangentially.[30] The gypsum dust is fed to the unit by a controllable fixed speed screw feeder.[31] The stucco product formed in the cylindrical heating zone of the calciner is removed at the lower end of the zone by a rotary valve at a temperature of about 456K (360°F).[32,33] A diagram of the direct contact flash calciner is shown in Figure 3-7.

3.2.2.2 Calciner Fuel Types. Batch and continuous kettle and direct contact flash calciners are natural gas- and distillate oil-fired in nearly all cases. Two plants using coal-fired kettles and one plant using residual oil-fired kettles are currently in operation.[34,35] Some direct contact flash calciners are currently firing a high sulfur No. 6 fuel oil. This practice is expected to continue for direct contact flash calciners.[36] Information gathered from industry and the Bureau of Mines indicates, however, that natural gas and distillate fuel oil will continue to be primary fuels for calciners in the future.[37,38,39,40] Usage of high sulfur fuel oil will depend upon fuel availability and local air quality requirements. Fuel type does not affect uncontrolled particulate emissions from calciners.

3.2.2.3 Calciner Capacities. Output capacities of batch kettles range from 4.5 Mg/hr (5 tons/hr) to 11.8 Mg/hr (13 tons/hr) depending on the length of the batch cycle.[41,42] These kettles are typically operated at full capacity. New batch kettles are expected to have output capacities of about 9.1 Mg/hr (10 tons/hr). One of these units would have sufficient capacity to produce 75,000 Mg/yr (83,000 tons/yr) of stucco based on an operating factor of 95 percent or 347 days per year.

Output capacities of continuous kettles range from about 10.9 Mg/hr (12 tons/hr) to as high as 18.2 Mg/hr (20 tons/hr).[43,44] Continuous calciners are typically operated at full capacity. Continuous kettles at most new plants are expected to have output capacities of about 10.9 Mg/hr (12 tons/hr) or greater. A typical new plant would employ two of these units, providing sufficient capacity to produce 182,000 Mg/yr (200,000 tons/yr) of stucco based on 347 days per year. The stucco

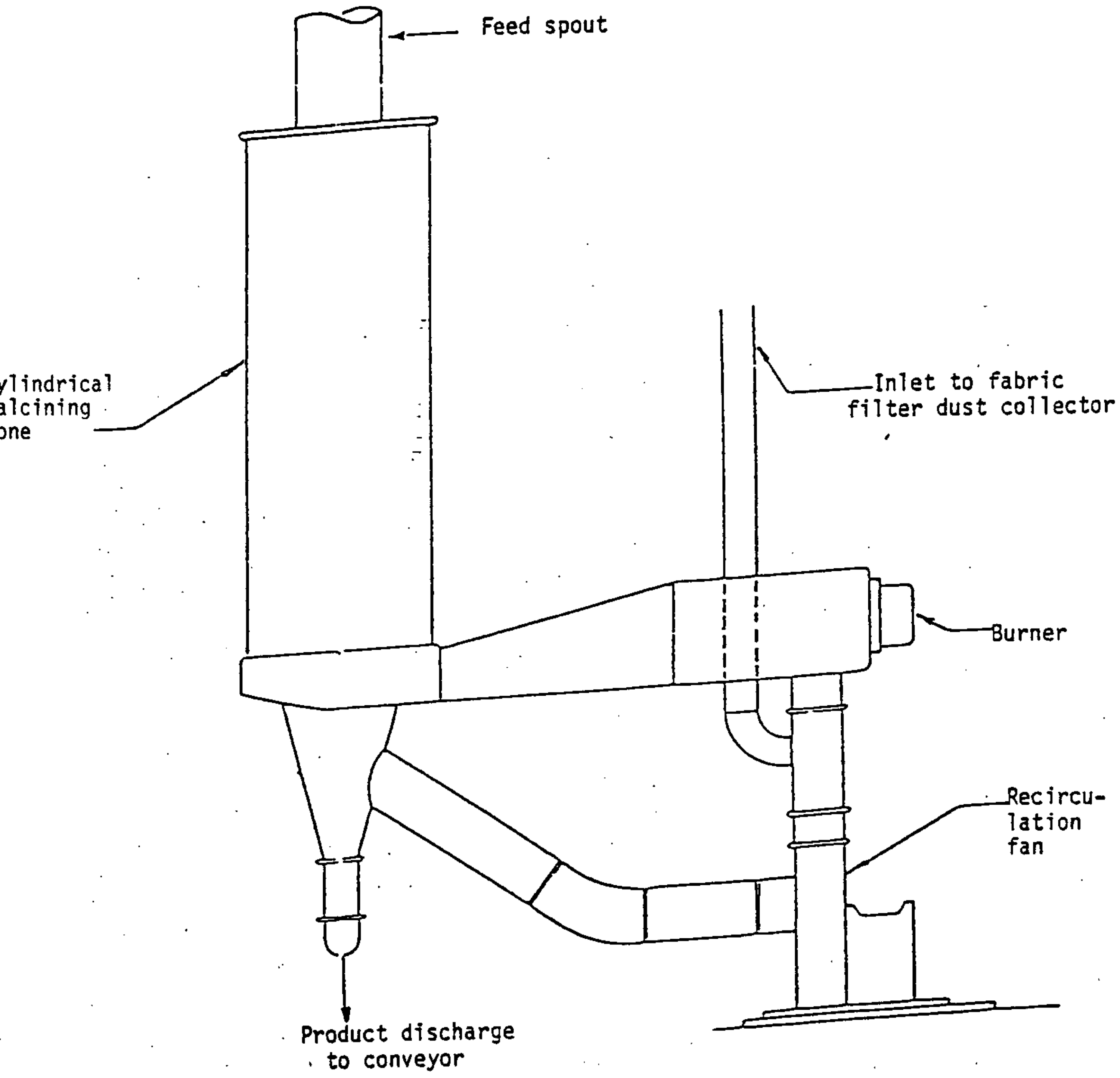

Figure 3-7. Direct contact flash calciner.

produced by these two kettles would allow production of 26.5 million square meters (285 million square feet) of wallboard per year in a contemporary board plant, on a 347 day per year basis.

The output capacity of the direct contact flash calciner is about 6.4 Mg/hr (7 tons/hr).[45,46] Like the other calciner types, these units are operated at full capacity. A typical new plant employing direct contact flash calciners would have three units with a total stucco producing capacity of 159,000 Mg/yr (175,000 tons/yr) on a 347 day per year basis. This stucco capacity would allow production of 23.2 million square meters (250 million square feet) of wallboard per year in a contemporary wallboard plant.

3.2.2.4 Emissions. Calciners are the largest point source of particulate emissions in the gypsum plant. Particulate emissions occur from agitation of solids and the subsequent entrainment of solids in the gas flow from the equipment during dehydration. Particulate matter from calciners consists of calcium sulfate dihydrate, calcium sulfate hemihydrate, anhydrous calcium sulfate, and gangue. Emissions from batch and continuous kettle calciners and from direct contact flash calciners are discussed separately in the following sections.

Kettle calciner emissions. Factors influencing particulate emissions from batch and continuous kettle calciners include the following:

- extent of mechanical agitation,
- gas velocity of air, and
- particle size of gypsum dust.

The extent of mechanical agitation directly affects the quantity of dust available to be entrained in the air passing through the inside of the kettle. An increase in the extent of agitation will increase the turbulence in the kettle and may, to a limited degree, increase the uncontrolled particulate emission rate. No data are available to quantify the affect of mechanical agitation on kettle calciner emissions. Kettle calciners are designed to operate at a fixed agitation rate.

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. However, insufficient data are currently available to quantify the effect of gas velocity and air flow rate on uncontrolled emissions from kettle calciners.

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

Particle size distribution affects emissions because small particles are more easily entrained in a moving stream of gas than are larger particles.

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.[47]

Uncontrolled emission factors, particulate concentrations, and exit gas flow rates for continuous kettle calciners measured in EPA source tests are given in Table 3-2. The test results in Table 3-2 show that increases in production rate increase uncontrolled emissions from continuous kettles. The Plant E kettle was operating at a lower air flow rate and a five percent higher production rate than the Plant TT continuous kettle and the emission factor for the Plant E kettle was 11 percent greater. Both kettle calciners are the same size.

On the basis of the data in Table 3-2 approximately two percent of the total ore entering the calciner exits with the air passed through the inside of the kettle. This material is routinely recovered in fabric filter dust collectors or electrostatic precipitators and is returned to the process.

Moisture content in the gas stream leaving calciners ranged from 51.1 percent to 69.9 percent by volume during EPA testing (see Chapter 4). Particle size data for emissions from batch and continuous kettles could not be measured during the EPA source tests because of the high moisture contents of the calciner exit gases.

TABLE 3-2. UNCONTROLLED EMISSION PARAMETERS FOR KETTLE CALCINERS MEASURED IN EPA SOURCE TESTS

Plant Identification	Kettle Type	Fuel Type	Exit Gas Temperature K	Exit Gas Temperature °F	Exit Gas Flow Rate m^3/s	Exit Gas Flow Rate acfm	Exit Gas Moisture Content % H_2O by Volume	Particulate Emission Factors g/Kg	Particulate Emission Factors lb/ton	Particulate Concentrations g/dNm³	Particulate Concentrations gr/dscf
Plant E	Continuous	Natural Gas									
Test Run #1			402.	264.	1.22	2,590	69.8	20.3	40.6	219	96
Test Run #2			402.	264.	1.23	2,600	72.2	22.1	44.1	256	112
Test Run #3			399.	259.	1.23	2,610	73.4	22.4	44.8	269	118
Average			401.	262.	1.23	2,600	71.8	21.6	43.2	249	109
		Stucco Production Rate = 10.4 Mg/hr (11.5 ton/hr)									
Plant TT	Continuous	Natural Gas									
Test Run #1			399.	258.	1.49	3,156	59.1	18.6	37.2	113	49.5
Test Run #2			404.	268.	1.50	3,182	58.8	21.9	43.8	133	58.1
Test Run #3			397.	256.	1.35	2,865	61.4	17.9	35.8	128	55.7
Average			400.	261.	1.45	3,068	59.8	19.5	38.9	125	54.4
		Stucco Production Rate = 9.9 Mg/hr (11.0 ton/hr)									

Sulfur oxides produced from combustion of fuels for kettle calcination are low in nearly all cases since most kettles use natural gas or distillate oil. Sulfur dioxide emissions from coal-fired or No. 6 fuel oil fired kettles are potentially significant. However, the use of low sulfur coal (less than 1.5 weight percent sulfur) and low sulfur residual fuel oil (less than 1.0 weight percent sulfur) will minimize these sulfur dioxide emissions. The use of high sulfur fuels is dependent upon availability of these fuels and local air quality restrictions.

Direct contact flash calciner emissions. Factors influencing uncontrolled particulate emissions from direct contact flash calciners include gas velocity and particle size. The effect of these two factors on direct contact flash calciner emissions are identical to the effects discussed above for kettle calciners.

Uncontrolled particulate emission factors, particulate concentrations, and exit gas parameters for gas- and oil-fired direct contact flash calciners as measured in EPA source tests are given in Table 3-3.

On the basis of the data in Table 3-3, approximately two percent of the total gypsum entering the direct contact flash calciner exits with the process gases. This material, however, is recovered in a fabric filter dust collector and is returned to the process.

Particle size data for uncontrolled emissions from direct contact flash calciners as measured in EPA source tests are given in Figures 3-8 and 3-9.

As discussed in Section 3.2.1.4, sulfur oxide emissions from combustion vary with the sulfur content of the fuel. While some direct contact flash calciners use clean fuels, such as natural gas and distillate oils, new units may use residual fuel oil.[48] The sulfur dioxide emissions from these new calciners will be minimized if low sulfur residual oil (less than 1.0 weight percent sulfur) is used.

3.2.3 Stucco Mixing

3.2.3.1 Description. Stucco is mixed with various additives to form (1) industrial and building plasters and (2) wallboard. Each of these two mixing processes is described separately in the following sections.

TABLE 3-3. UNCONTROLLED EMISSION PARAMETERS FOR DIRECT CONTACT FLASH CALCINERS MEASURED IN EPA SOURCE TESTS

Plant Identification	Fuel Type	Exit Gas Temperature K	Exit Gas Temperature °F	Exit Gas Flow Rate m^3/s	Exit Gas Flow Rate acfm	Moisture Content Percent H_2O	Particulate Emission Factors g/Kg	Particulate Emission Factors lb/ton	Particulate Concentrations g/dNm^3	Particulate Concentrations gr/dscf
Plant Y	Residual Oil									
Test Run #1		461.	370.	1.85	3,920	38.9	20.5	41.0	50.2	21.9
Test Run #2		462.	373.	1.94	4,110	40.9	20.3	40.6	49.1	21.5
Test Run #3		460.	369.	1.93	4,100	43.0	19.2	38.4	48.2	21.1
Average		461.	371.	1.91	4,043	40.9	20.0	40.0	49.2	21.5
Average fuel usage factors = 236×10^3 Kcal/Mg (0.85×10^6 Btu/ton)										
Plant OO	Natural Gas									
Test Run #1		422.	300.	1.75	3,705	52.6	15.9	31.8	48.7	21.3
Test Run #2		421.	298.	1.75	3,717	45.2	18.4	36.7	48.3	21.1
Test Run #3		425.	306.	1.76	3,731	50.0	18.0	35.9	52.2	22.8
Average		422.	301.	1.75	3,718	49.3	17.4	34.8	49.7	21.7

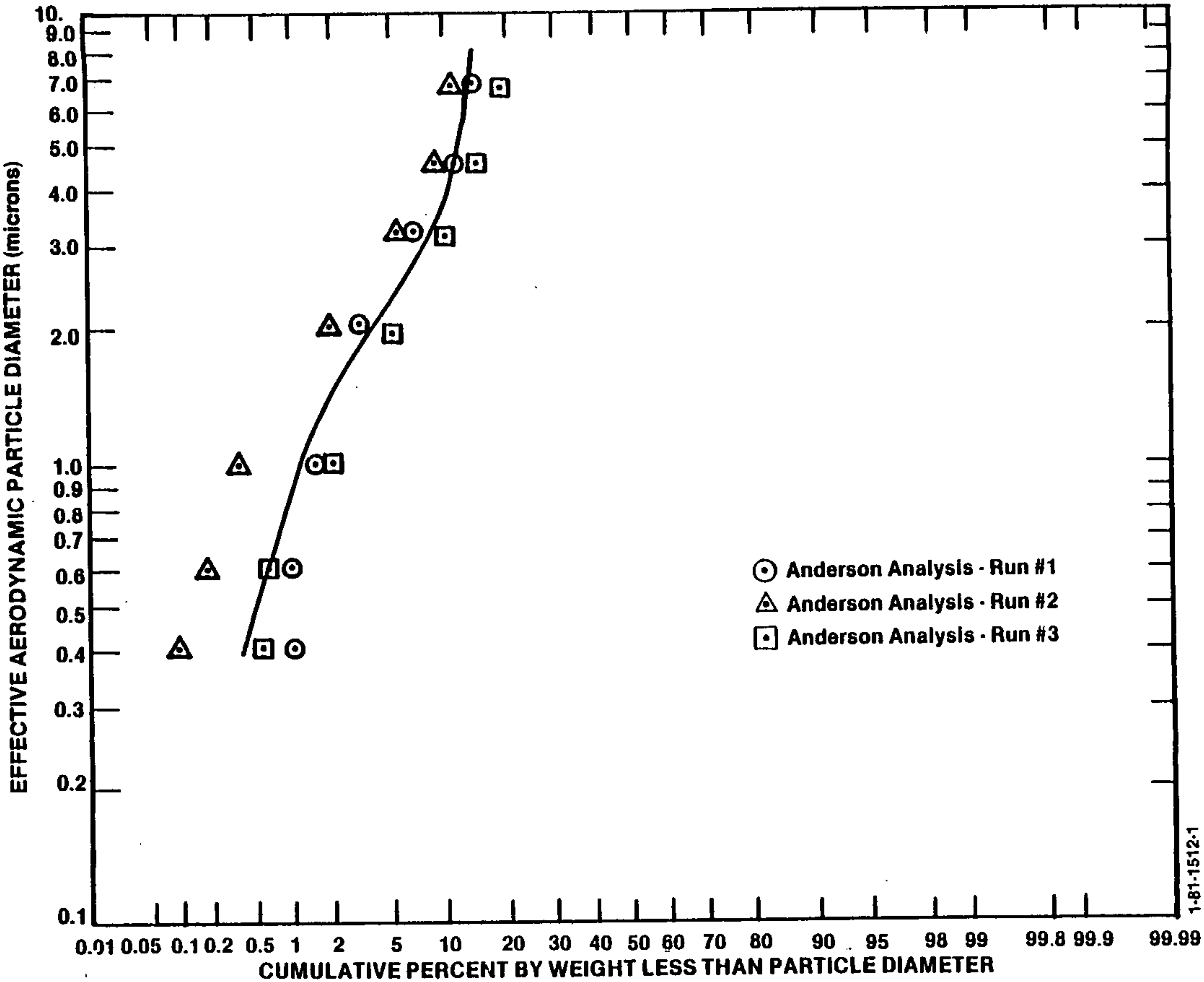

Figure 3-8. Particle size analysis for flash calciner.

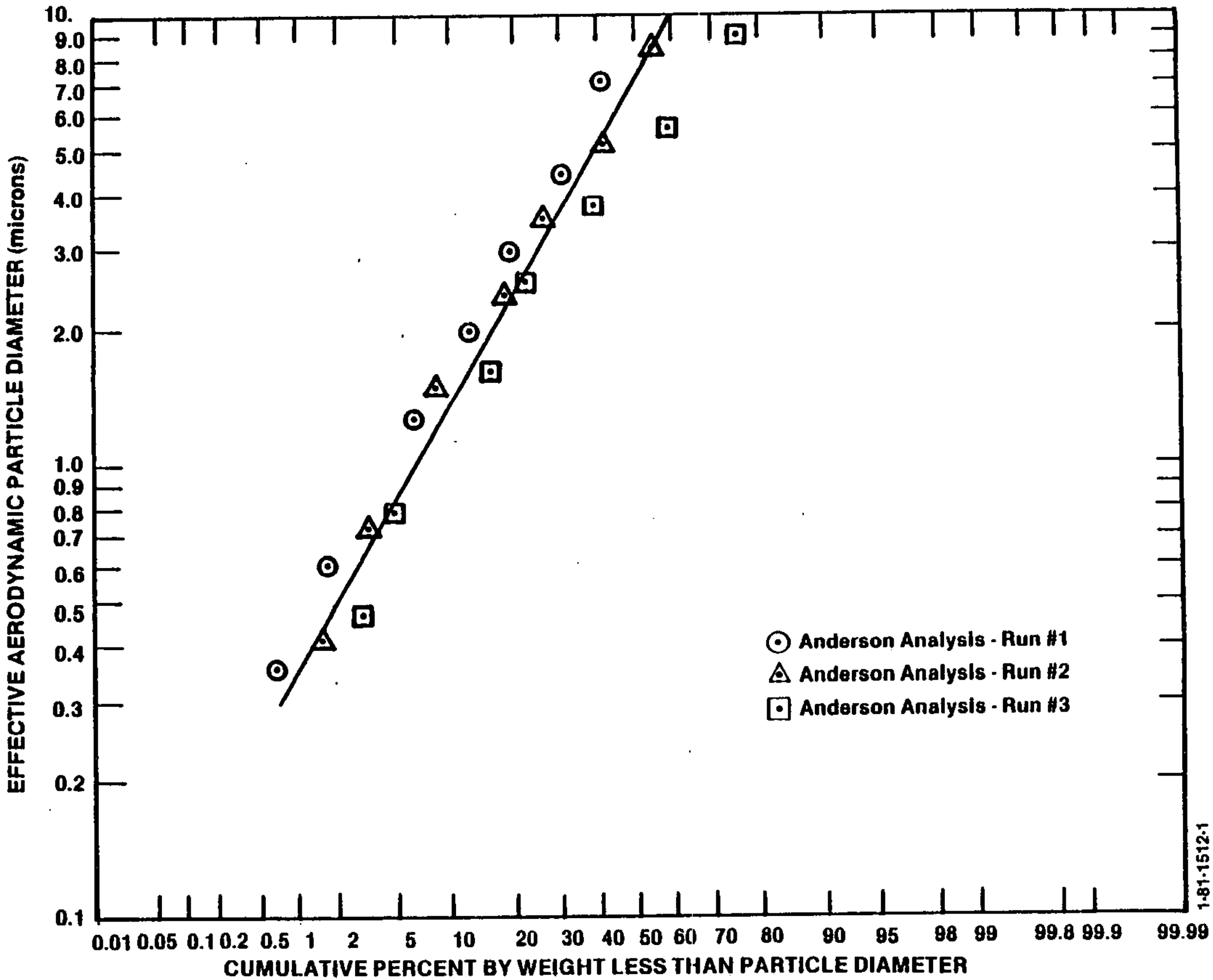

Figure 3-9. Particle size analysis for flash calciner (Plant 00).

Plaster mixing. For production of various industrial and building plasters, stucco is mixed with wetting agents such as detergents and/or lignins. Various retarders and accelerators are also added to give the various plasters specific setting rates.

Plaster mixing is usually done by batch. Stucco and additives are blended in a large paddle mixer. Once thoroughly mixed, the plaster is conveyed by gravity flow to large bins feeding the bagging operation.

Wallboard mixing. For production of wallboard, the mixing of stucco with additives is accomplished in two stages. First, dry additives, such as starch, perlite, raw gypsum, vermiculite, and shredded fiberglass, are mixed with stucco in a screw conveyor. Second, this dry mixture is slurried with an aqueous paper pulp solution in a pin mixer at the head of the boardline. The wet mixture is then spread on paper sheets and formed into the wet wallboard. A brief description of ordinary screw conveyors is given in Section 3.2.6.1. The screw conveyors used for mixing dry additives with the stucco are equipped with cut and folded flights or mixing paddles.[49]

3.2.3.2 Mixer Capacities. Mixers used for plaster production typically have capacities of 0.9 Mg (1 ton) or 1.5 Mg (1.6 ton). New plaster mixers are expected to be of the 1.5 Mg (1.6 ton) size. The likelihood that new mixers will be installed is extremely low due to the expected decline in plaster production over the next twenty years.[50] The 1.5 Mg (1.6 ton) mixer would allow production of about 11 Mg/hr (12 tons/hr) of plaster. This would allow production of 22,000 Mg/yr (24,000 tons/yr) of plaster on an eight hour per day, five day per week basis.

The capacities of screw conveyors used for mixing are essentially the same as the capacities of ordinary conveyors which range from 23 to 64 Mg/hr (25 to 70 tons/hr).

Production rates of boardline pin mixers vary with the capacities of available boardlines, ranging from 20.9 Mg/hr (23 ton/hr) to 68 Mg/hr (75 tons/hr) of plaster slurry.[51] Pin mixers come in two sizes, 42 inches in diameter and 60 inches in diameter.[52] New wallboard pin mixers are expected to produce about 39 Mg/hr (43 tons/hr) of plaster slurry. At this production rate, the mixer will require about 22 Mg/hr (24 tons/hr) of stucco and will feed a boardline producing 26.5 million square meters (285 million square feet) of wallboard per year on a 347 day per year basis.

3.2.3.3 Emissions. Particulate emissions from mixing occur during the feeding and blending of stucco and various additives. This particulate matter consists of calcium sulfate hemihydrate and additive dusts.

The major factor influencing uncontrolled emissions from mixing is the extent of mechanical agitation. An increase in the agitation will increase the turbulence within the mixer and increase the uncontrolled emission rate.

All available data on uncontrolled particulate emissions from mixing operations are given in Table 3-4. These include data from the National Emissions Data System (NEDS) (Plant MM) and a permit application (Plant O). The data from NEDS were estimated from reported controlled emissions and reported control efficiency. The permit application contains a gypsum producer's estimates of the uncontrolled emissions.

3.2.4 Scoring and Chamfering

3.2.4.1 Description. Wallboard formation is accomplished by sandwiching the slurry of aqueous paper pulp, stucco, and additives, between two sheets of paper. The lower sheet of paper is scored, and in some cases, the top sheet is chamfered (beveled), so that it can be easily folded over and glued to the top sheet to form the edges of the board. Scoring is accomplished by a rotating knife-edged wheel and chamfering is accomplished by a sanding or buffing tool. Fugitive emissions occur from around the edges of the wheel and the buffing tool. The practice of chamfering is declining because improved glues have made this process unnecessary. Chamfering is not expected to be used in new plants.

3.2.4.2 Emissions. Particulate emissions from scoring and chamfering consist of paper fibers. The primary factor affecting emissions is boardline speed. Emissions from these operations are captured to

TABLE 3-4. UNCONTROLLED PARTICULATE PARAMETERS FOR MIXING

Plant Identification	Operation	Gas Flow Rate m^3/s	(acfm)	Uncontrolled Particulate Emissions g/Kg	(lb/ton)	g/m^3	(gr/acf)
Plant O[a]	Mixing	2.8	(6000)	10	(19)	34	(15)
Plant MM[b]	Blending	N/A	N/A	33	(65)	N/A	N/A

[a]Reference 53.

[b]Reference 54.

maintain workroom dust levels required by OSHA regulations. Available data on uncontrolled emissions from scoring and chamfering are given in Table 3-5. These data are from two permit applications, which contain two wallboard producers' estimates of the uncontrolled emissions.

3.2.5 Board End Sawing

3.2.5.1 Description. After rough cutting to size and drying the wallboard product, the ends of the dried board are sawed in a trimming operation. Removal of 0.3 to 0.6 cm (1/8 inch to 1/4 inch) of board gives smooth, straight ends. Two boards are usually stacked and then sawed simultaneously. Fugitive emissions are created as the saw blade trims the edge of the boards.

3.2.5.2 Emissions. Particulate emissions from board end sawing include paper fiber and wallboard dust. Emissions from these operations are captured to maintain workroom dust levels required by OSHA regulations. Uncontrolled emission from board end sawing operations are estimated to be 5 g/kg (10 lb/ton) of wallboard formed.[57,58,59] For an average boardline, producing 27.2 Mg/hr (30 ton/hr) of wallboard and using a gas flow rate of 1.4 m^3/s (3,000 acfm), the average uncontrolled emission concentration would be 29 g/dNm^3 (13 gr/dscf).

3.2.6 Stucco Conveying

3.2.6.1 Description. Stucco transfer systems consist of a series of enclosed screw conveyors, bucket elevators, and pnuematic conveyors which transfer stucco from calciners to storage and then from storage bins to boardlines or plaster mixing and bagging operations. Fugitive emissions from conveying systems escape from openings in the enclosures.

A screw conveyor consists of a helicoid (helix rolled from flat steel bar) or sectional (individual sections blanked and formed into a helix from flat plate) flight, mounted on a pipe or shaft and turning in a trough.[60] Enclosed screw conveyors are generally used to transfer stucco horizontally from one location to another.

Pneumatic or air conveyors transfer material by suspending particles in an air stream. This material transfer can be accomplished by either a positive or negative (suction) pressure system. In positive pressure

TABLE 3-5. UNCONTROLLED PARTICULATE EMISSION PARAMETERS FOR SCORING AND CHAMFERING

Plant Identification	Particulate Emission[c] Factor		Particulate Concentration		Exit Gas Flow Factor	
	g/kg	lb/ton	g/m^3	gr/acf	m^3/kg	acf/ton
Plant Y[a]	0.27	0.54	1.4	0.60	0.20	6300
Plant NN[b]	0.20	0.40	1.2	0.53	0.16	5283

[a]Reference 55.
[b]Reference 56.
[c]Based on weight of wallboard formed.

systems an air stream is blown through a pipeline and material is fed into the air stream from a hopper or another device at a controlled rate. In negative pressure systems, material is transferred using a vacuum. A cyclone or cyclone/fabric filter combination collects the conveyed material. Pnuematic conveyors are used to transfer gypsum both horizontally and vertically in some plants. Emissions occur from the outlet of the cyclone or fabric filter for both positive and negative pressure systems. Fugitive emissions from positive pressure systems occur at openings in the enclosure. No data are available on the range of air flow rates used in these pnuematic conveyors.

Bucket elevators consist of a head and foot assembly which supports and drives an endless single or double strand chain or belt to which buckets are attached. Figure 3-10 depicts the three types most commonly used: the high-speed centrifugal-discharge, the slow speed positive or perfect-discharge, and the continuous-bucket elevator.[61]

The centrifugal-discharge elevator has a single strand of chain or belt to which the spaced buckets are attached. As the buckets round the tail pulley, which is housed within a suitable curved boot, the buckets scoop up their load and elevate it to the point of discharge. The buckets are spaced so that at discharge, the material is thrown out by the centrifugal action of the bucket rounding the head pulley. The positive-discharge type also utilizes spaced buckets but differs from the centrifugal type in that it has a double-strand chain and a different discharge mechanism. An additional sprocket, set below the head pulley, effectively bends the strands back under the pulley causing the bucket to be totally inverted resulting in a positive discharge.

The continuous-bucket elevator utilizes closely spaced buckets attached to single or double strand belt or chain. Material is loaded directly into the buckets during ascent and is discharged gently as a result of using the back of the preceding bucket as a discharge chute.

Enclosed bucket elevators are used in gypsum plants to transfer stucco vertically. Fugitive emissions from bucket elevators escape from openings in the enclosure, especially near transfer points.

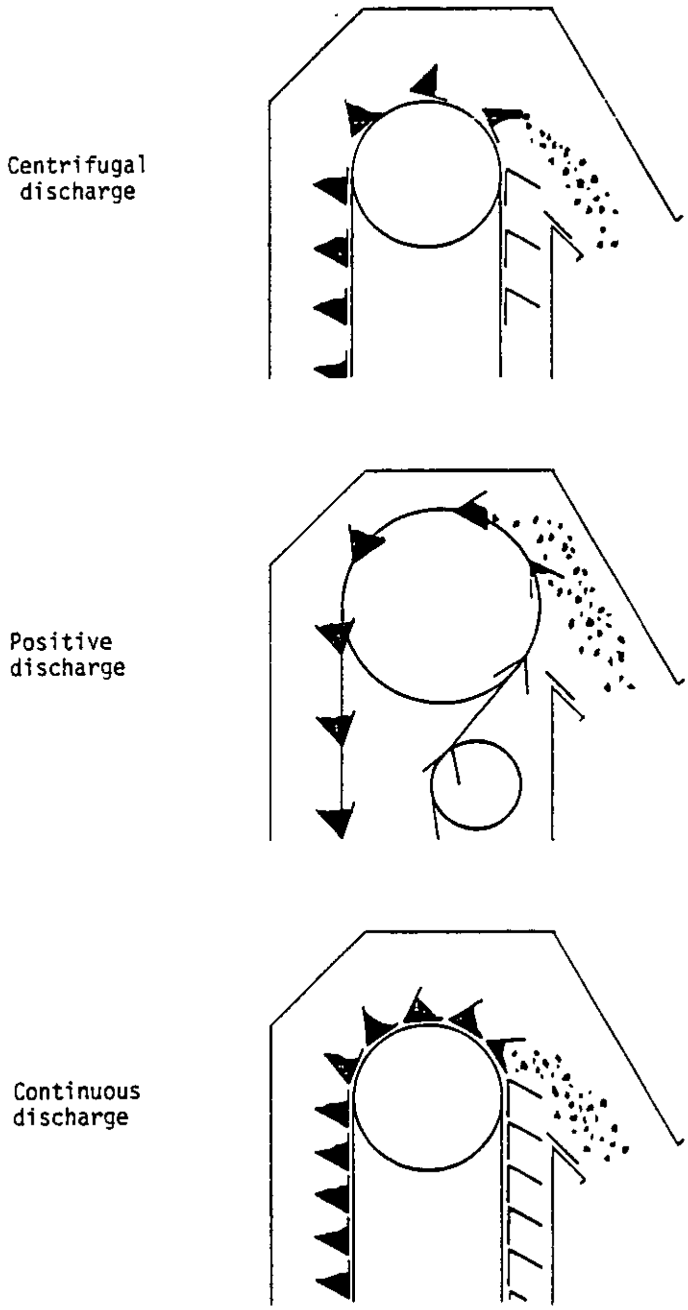

Figure 3-10. Bucket elevator types.

In many plants, stucco transfer systems are operated under negative pressure (suction) to capture fugitive emissions. Emissions are collected for housekeeping purposes as well as to maintain low workroom dust levels. Air flow rates used to collect emissions from stucco transfer systems vary with the size of the conveyors and with the number and type of conveyors in the system. Air flow rates used range from 0.94 to 3.8 m^3/s (2000 to 8000 acfm).

3.2.6.2 Conveyor Capacities. Capacities of stucco conveying systems range from 23 to 64 Mg/hr (25 to 70 tons/hr), depending on the size and section of wallboard plant in which they are employed.

3.2.6.3 Emissions. Particulate emissions from conveying units consist of stucco (calcium sulfate hemihydrate).

Factors influencing emissions from stucco conveying systems include the following:

- air flow rate (particularly in pneumatic conveyors),
- degree of mechanical agitation at transfer points,
- the free fall distance between transfer points,
- the number of transfer points,
- the types of conveyors used, and
- particle size.

Data are not available to quantify the affects of these factors.

Air flow rate directly affects the amount of material entrained in air streams from conveying systems. Increases in air flow rate will increase uncontrolled emissions.

The speed at which conveying units are operated directly affects the degree of mechanical agitation. Particularly in the case of bucket elevators, operation at too high a speed will create a fanning effect and hence increase uncontrolled emissions.[62] Similarly, longer free fall distances between conveyor transfer points will increase emissions by increasing turbulence within the enclosure. As discussed previously, particle size affects emissions because smaller particles are more easily entrained in a moving stream of air than are larger particles.

Uncontrolled emissions from conveying systems are estimated to be 0.35 g/kg (0.7 lb/ton)[63] of material handled.

3.2.7 Stucco Storage

3.2.7.1 Description. Stucco is stored in bins or silos. The stucco is charged to the bins by means of screw conveyors or pneumatic conveyors. Discharge of the stucco is accomplished by means of rotary valves on hoppers at the bottom of the bins or by means of hoppers at the bottom of the silos.

Stucco storage bins are usually operated under negative pressure (suction) to capture emissions which would otherwise escape through the bin vent. Air flow rates used to capture these emissions depend on the size of the bin and on the rate of filling. Air flow rates used range from 0.19 to 0.94 m^3/s (400 to 2000 acfm).

3.2.7.2 Capacities. Most stucco storage bins have capacities ranging from 18 Mg to 318 Mg (20 to 350 tons). Stucco storage bins at new plants could be of any size within this range.

3.2.7.3 Emissions. Particulate emissions from stucco storage bins consist of calcined gypsum.

Factors influencing uncontrolled emissions from storage bins or silos include the following:

- the rate of filling,
- the free fall distance of the material,
- the air flow rate, and
- the type of conveyor feeding the unit.

No data are available to quantify the effects of these factors.

The rate of filling affects the amount of material available to be entrained in displaced air and, in some cases, the rate at which air is displaced. Increases in the rate of filling will increase uncontrolled emissions from storage bins or silos.

The free fall distance depends on both the capacity or size of the bin and on the percentage of the available capacity already utilized. Longer free fall distances will result in higher uncontrolled emissions.

The rate at which air is pulled from the bin also affects uncontrolled emissions. Increases in air flow rate may result in higher uncontrolled emissions.

Emissions from bins fed with pneumatic conveyors will be higher than those fed with screw conveyors. Use of pneumatic conveyors will cause a greater amount of turbulence in the storage unit and will require greater air flow rates to convey material into the bin.

Available data on uncontrolled emissions from stucco storage are shown in Table 3-6. These data are from permit applications which include two gypsum producers' estimates of uncontrolled landplaster storage bin emissions and are taken as representative of uncontrolled stucco storage bin emissions.

3.3 BASELINE EMISSIONS

Baseline emissions are the potential emissions that could occur from a new, modified, or reconstructed facility in the absence of new source performance standards (NSPS). Baseline emission levels reflect the emission levels required under typical State regulations and the levels currently achieved by industry. The control technology used to achieve the baseline emissions level is referred to as baseline control technology. The baseline emission levels established in this section will be used in subsequent chapters to assess the relative benefits and costs of various regulatory alternatives.

3.3.1 Determination of Baseline Emission Level

In selecting baseline emission levels, consideration is first given to the current State regulations which apply to emission sources in the gypsum industry. These regulations, based upon process weight equations or opacity limitations, usually define the primary constraint on emissions from new sources. In some instances, however, the current level of control practiced in the industry indicates that actual emission levels are lower than those required by State process weight regulations. In such cases, the existing level of control may be a better indicator of expected emissions from new gypsum industry emission sources in absence of NSPS regulation.

TABLE 3-6. UNCONTROLLED PARTICULATE EMISSION PARAMETERS FROM STUCCO STORAGE BINS

Plant Identification	Storage Capacity		Process Rate[a]		Uncontrolled Emission Factor		Particulate Concentration		Exit Gas Flow Factor	
	Mg	Tons	kg/s	ton/hr	g/kg	lb/ton	g/dNm^3	gr/dscf	m^3/kg	acf/ton
Plant NN[b]	272	300	7	27	1	2	5.1	2.2	0.03	889
Plant O[c]	--	--	8.5	34	1.5	3	73	32	0.02	706

[a] Rate at which material is added to and removed from bins.

[b] Reference 64.

[c] Reference 65.

Plants may find it advantageous to control emissions to lower levels than are required by State regulations. Gypsum recovered in control devices can be recycled to the process, offsetting some of the cost of control. In some cases, opacity standards may be more difficult to meet than the process weight regulations. In addition, the mass emission standards are generally enforced using opacity. Therefore, the State mass emission standards would not be the governing constraint and would have little effect on the controlled emission level expected for new plants in the absence of NSPS.[66]

3.3.2 Existing Emissions Limitations

Standards limiting particulate emissions from sources in gypsum plants are in effect in all 50 States. The regulations are of three types: opacity limits, exhaust gas particulate concentration limits, and particulate emission limits calculated from process weights. The process weight regulations can take the form of an allowable emission factor expressed as kg (lb) of particulate allowed per Mg (ton) of production. In nearly all of the States, industrial source emissions are limited by both opacity standards and process weight standards.

A review of regulations for States involved in gypsum production indicates that 76 percent of the states have a common industrial process weight regulation for particulate matter emissions:

$$E = 4.1\ (p)^{0.67} \qquad p < 30 \text{ tph}$$
$$E = 55\ (p)^{0.11} - 40 \qquad p \geq 30 \text{ tph}$$

where p is the process weight capacity in tons/hour. In addition, at least 22 of the 25 State regulations examined for this study have a 20 percent opacity regulation.

The regulations of the six major gypsum producing States (California, New York, Texas, Iowa, Indiana, and Michigan) are representative of both stringent and average regulatory environments. Table 3-7 summarizes these regulations.

TABLE 3-7. SUMMARY OF STATE PARTICULATE EMISSION REGULATIONS FOR SIX MAJOR GYPSUM STATES.

State	Type of Regulation	Regulation
California[a]	Process Weight Rate	Allowable emission rates are approximately defined by the equation $E = 3.74\ P^{0.37}$ where E = allowable emission rate in lb/h and P = process weight in tons/h.
	Opacity	Opacity is limited to 20%.
Indiana	Process Weight Rate	Allowable emission rates for process weights up to 30 ton/h are defined by the equation $E = 4.10\ P^{0.67}$ where E = allowable emission rates in lbs/h and P = process weight in tons/h. For process weights exceeding 30 tons/h, the allowable emission defined by the equation $E = 55.0\ P^{0.11} - 40$.
	Opacity	Opacity is limited to 40% for sources located in attainment areas, in non-attainment areas, opacity is limited to 30%.
Iowa	Process Weight Rate	Allowable emission rates for process weights up to 30 ton/h are defined by the equation $E = 4.10\ P^{0.67}$ where E = allowable emission rates in lbs/h and P = process weight in tons/h. For process weights exceeding 30 tons/h, the allowable emission is defined by the equation $E = 55.0\ P^{0.11} - 40$.
	Opacity	Opacity is limited to 40%.
Michigan	Process Weight Rate	Allowable emission rates for process weights up to 30 tons/h are defined by the equation $E = 4.10\ P^{0.67}$ where E = allowable emission rates in lbs/h and P = process weight in tons/h. For process weights exceeding 30 tons/h, the allowable emission is defined by the equation $E = 55.0\ P^{0.11} - 40$.
	Opacity	Opacity is limited to 20%.
New York	Process Weight Rate (Dryers only)	Allowable emission rates for process weights up to 125 tons/h (31.3 kg/s) are defined by the equation $E = 0.24\ P^{0.67}$ where E = allowable emission rate in lb/h and P = process weight in lb/h. Dryers with process weights greater than 125 tons/h are subject to concentration regulation.
	Opacity	Opacity is limited to 20%.
Texas	Process	Allowable emission rates for process weights up to 20 tons/h are defined by the equation $E = 3.12\ P^{0.985}$ when E = rate of emission in lb/h and P = process weight in tons/h. For process weights exceeding 20 tons/h, the allowable emission is defined by $E = 25.4\ P^{0.287}$.
	Opacity	Opacity is limited to 20%.

[a]Rules and Regulations of the South Coast Air Quality Management District.

[b]Equivalent to about 0.11 gr/scf (0.25 g/Nm^3).

A study was also made to determine the number of new gypsum plants which would be located in particulate matter (total suspended particulate/non-attainment areas. According to the Clean Air Act provisions for non-attainment areas (Section 173) new plants located in non-attainment areas must comply with the "lowest achievable emission rate" (LAER). For gypsum plants, LAER would imply the use of a fabric filter operated at peak efficiency. Therefore, if a large percentage of new gypsum plants were predicted to be located in non-attainment areas, a baseline based on the LAER emission level and a high efficiency fabric filter would be appropriate.

For purposes of predicting the location of new gypsum plants, new plants were assumed to be distributed geographically in the same way as existing plants. The study revealed that 70 percent of the existing plants are located outside non-attainment areas. Thus, since the majority of new plants would probably not be subject to the non-attainment provisions, a baseline based on the LAER emission level and corresponding level of control would be less representative than a baseline selected on the basis of other factors, such as SIPs or industry practices.

3.3.3 Baseline Emission Levels and Technologies

In selecting an appropriate baseline emission level, a comparison was made of emission factors resulting from State process weight regulations and State opacity limitations. Examination of the available test data on sources in the gypsum industry indicated that plants meeting the 20 percent opacity limitation were operating well below the allowable emissions level defined by the State process weight equation.[67]

Since existing plants currently meet the opacity limitation and plant operating practices indicate industry's intent to maintain these visible emissions levels, it was assumed for the purpose of this study that new plants would also be operated to meet this visible emission limit. Therefore, a baseline emission level was established using the 20 percent opacity limit. A baseline emission concentration representative of this opacity limit was determined by examining available test data. Considering the variability inherent in the test procedures, an exhaust stream grain loading of 0.43 g/m^3 (0.19 gr/acf) was chosen for this study.[68] Baseline emission factors were computed for each source of particulate emissions using this grain loading and typical operating parameters for the particular piece of equipment. This results in baseline emission factors ranging from 0.07 g/kg (0.03 lb/ton) to 2.4 g/kg (1.22 lb/ton), depending upon air flow rate and production rate of each source. The results are listed in Table 3-8.

In order to meet the baseline emission level, some form of emission control would be necessary. The fabric filter was chosen as the baseline control device for all sources in the gypsum industry, since this is the emission control device most widely applied in the gypsum industry. A survey of emission control devices used for various sources in the industry is presented in Table 3-9.

TABLE 3-8. BASELINE EMISSION FACTORS FOR SOURCES IN THE GYPSUM INDUSTRY

Emission Source	Baseline Emission Factor, g/kg (lb/ton)
Ore dryer - small	0.29 (0.57)
Ore dryer - medium	0.29 (0.57)
Ore dryer - large	0.21 (0.41)
Kettle calciner	0.27 (0.54)
Direct contact flash calciner	0.47 (0.93)
Board end sawing - small	0.16 (0.31)
Board end sawing - medium	0.10 (0.20)
Board end sawing - large	0.09 (0.18)
Dry mixing - small	0.03 (0.05)
Dry mixing - medium	0.02 (0.03)
Dry mixing - large	0.02 (0.03)
Scoring and chamfering - small	0.08 (0.15)
Scoring and chamfering - medium	0.05 (0.10)
Scoring and chamfering - large	0.05 (0.09)
Stucco conveying and storage	0.21 (0.41)
Plaster mixing and bagging	0.61 (1.22)

TABLE 3-9. APPLICATION OF CONTROL TECHNIQUES TO EMISSION SOURCES IN THE GYPSUM INDUSTRY[a]

Emission Source	Number of Plants[b]	Control Method Used on Emission Source[c]						
		ff	cy/ff	cy	ESP	cy/ESP	WS	None
Ore Dryers	23	9	3	2	5	2	2	--
Calciners[d]	37	23	1	--	10	3	2	--
Dry Mixing								
Boardline	10	8	1	--	--	--	--	1
Plaster	8	8	--	--	--	--	--	--
Scoring and chamfering	14	6	3	4	--	--	--	1
Board end sawing	23	21	1	1	--	--	--	--
Conveying	22	16	--	--	2	--	--	4
Storage bins	14	14	--	--	--	--	--	--

[a]The data in this table are from the National Emissions Data System, permit applications, plant visits, and emission source test reports. Reference 69.

[b]This number represents the total number of plants for which data on the emission source were available.

[c]ff = fabric filter; cy = cyclone; ESP = electrostatic precipitator; WS = wet scrubber

[d]Represents kettle calciners and direct contact flash calciners

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60. Perry, R. H. and C. H. Chilton. Chemical Engineers' Handbook, Fifth Edition. New York, McGraw-Hill Book Company, 1973. p. 7-6.

61. Reference 11, p. 3-41.

62. Reference 44, p. 7-11.

63. U. S. Environmental Protection Agency. Compilation of Air Pollutant Emission Factors, Third Edition. Research Triangle Park, North Carolina. EPA AP-42. August 1977. p. 18-14-1.

64. Reference 57.

65. Reference 54.

66. Memo from Stelling, J., Radian Corporation, to file. November 21, 1980. Examination of emission data for gypsum plants - baseline considerations.

67. Reference 66.

68. Reference 66.

69. Memo from Palazzolo, M. A., Radian Corporation, to file. October 6, 1980. 2 p. Information about control techniques.

4. EMISSION CONTROL TECHNIQUES

Techniques for controlling particulate emissions from facilities in the gypsum industry are discussed in this chapter. Significant design variables and factors that affect the performance of applicable control devices are discussed in Section 4.1. The applicability and effectiveness of the various techniques are discussed in Section 4.2 and Section 4.3.

4.1 DESCRIPTION OF CONTROL TECHNIQUES

The results of a survey to determine the emission control techniques currently used in the gypsum industry are presented in Table 4-1. The study showed that the particulate emission control techniques which are applicable to emission sources in gypsum plants include the following:

- fabric filtration,
- centrifugal separation,
- electrostatic precipitation, and
- wet scrubbing.

These techniques are described in this section.

The most widely applied particulate control method in the gypsum industry is fabric filtration. The second most widely applied method is electrostatic precipitation. However, electrostatic precipitators (ESP's) are not normally used on dry mixing, scoring and chamfering, board end sawing, stucco conveying or stucco storage. Centrifugal separation (cyclone) is primarily used in conjunction with other control methods except in the case of scoring and chamfering. Wet scrubbing is the least used control method.

4.1.1 Fabric Filtration

4.1.1.1 Basic Description. A fabric filtration system (baghouse) consists of a number of filtering elements (bags) along with a bag cleaning system contained in a main shell structure with dust hoppers. Particulate-laden gases are passed through the bags so that the particles

TABLE 4-1. APPLICATION OF CONTROL TECHNIQUES TO EMISSION SOURCES IN THE GYPSUM INDUSTRY[a]

Emission Source	Number of Plants[b]	Control Method Used on Emission Source[c]						
		ff	cy/ff	cy	ESP	cy/ESP	WS	None
Ore Dryers	23	9	3	2	5	2	2	--
Calciners[d]	37	23	1	--	10	3	2	--
Dry Mixing								
Boardline	10	8	1	--	--	--	--	1
Plaster	8	8	--	--	--	--	--	--
Scoring and chamfering	14	6	3	4	--	--	--	1
Board end sawing	23	21	1	1	--	--	--	--
Conveying	22	16	--	--	2	--	--	4
Storage bins	14	14	--	--	--	--	--	--

[a]The data in this table are from the National Emissions Data System, permit applications, plant visits, and emission source test reports. Reference 1.

[b]This number represents the total number of plants for which data on the emission source were available.

[c]ff = fabric filter; cy = cyclone; ESP = electrostatic precipitator; WS = wet scrubber

[d]Represents kettle calciners and direct contact flash calciners

are retained on the upstream side of the fabric, thus cleaning the gas. A schematic diagram of a common type of fabric filter unit or baghouse is presented in Figure 4-1.

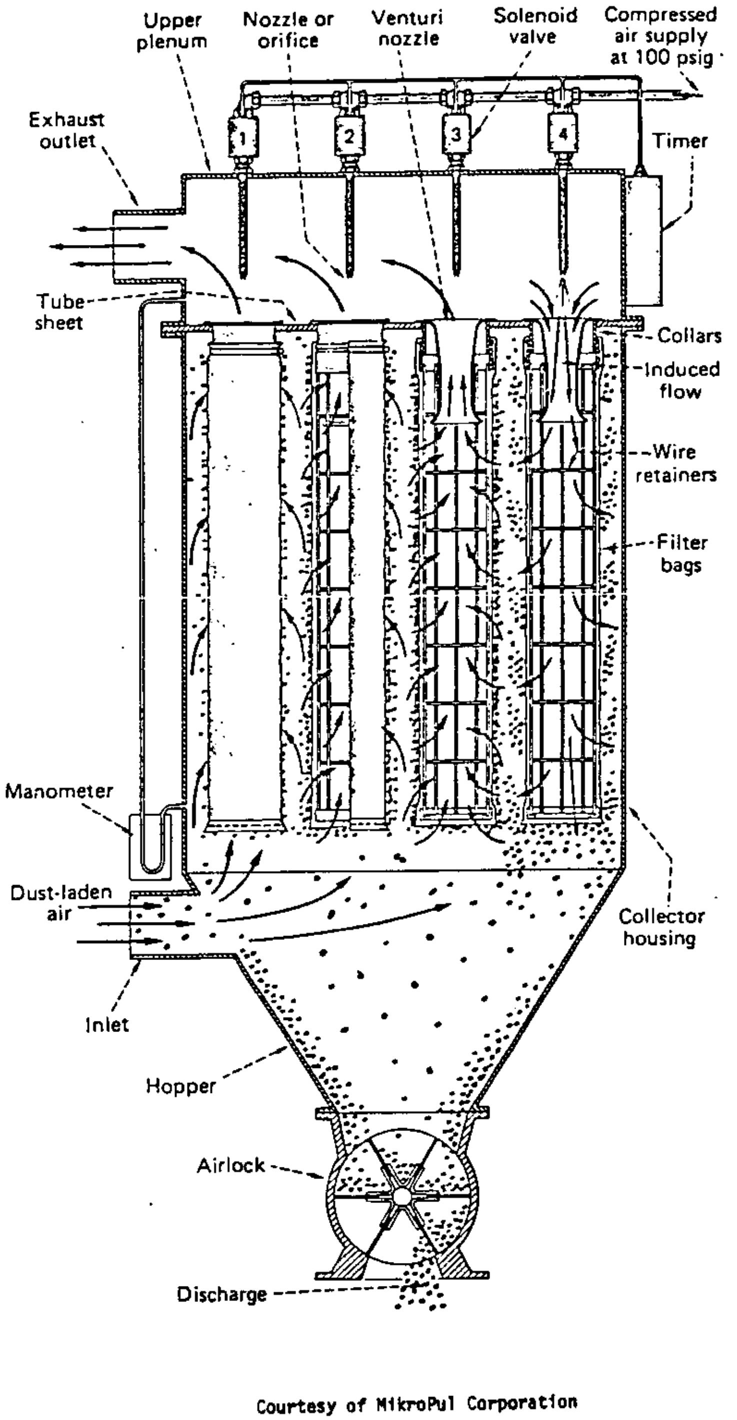
The basic mechanisms available for filtration are inertial impaction, diffusion, direct interception, and sieving. The first three processes prevail only briefly during the first few minutes of filtration with new or recently cleaned fabrics, while the sieving action of the dust layer accumulating on the fabric surface soon predominates. This is particularly true at high dust loadings, >1 g/m^3 (0.473 gr/ft^3).

In fabric filtration both the collection efficiency and the pressure drop across the bag surface increase as the dust layer on the bag builds up. Since the system cannot continue to operate with an increasing pressure drop, the bags are cleaned periodically.

Fabric filters are cleaned in one of three ways. The first method is shaker cleaning where the bags are shaken by a motor driven rocker arm-lever assembly to remove most of the collected dust. In the second method, reverse-air cleaning, backflow air is introduced into the bags to expand them and fracture the dust cake. Both shaker cleaning and reverse-air cleaning require a compartmented baghouse to permit cleaning of one section while other sections are functioning normally. The third cleaning method is pulse-jet cleaning. In this method a short pulse of compressed air is introduced through venturis and directed from top to bottom of each bag. The primary pulse of air entrains secondary air as it passes through the venturis. The resulting expansion of the bag fractures the cake. The pulse is so rapid that little interruption of filtration occurs. Bags are pulsed cyclically, individually or in group, so that separate baghouse compartments are not required.[3]

4.1.1.2 <u>Factors Affecting Performance</u>. The most important parameters affecting baghouse performance are:

- filter medium,
- air-to-cloth ratio (superficial filtration velocity),
- operational pressure drop,



Courtesy of MikroPul Corporation

Figure 4-1. Diagram of a pulse-jet fabric filter baghouse.[2]

- cleaning method,
- inlet loading, and
- particle size.

The selection of the filter medium or fabric type affects the collection efficiency of the baghouse and the useful life of the filter bags. Important properties considered in selecting fabric types include permeability, mechanical strength, corrosion resistance, and heat resistance.[3]

The air-to-cloth ratio, the operational pressure drop and the cleaning method directly affect the mechanisms by which dust particles are collected. Lower air-to-cloth ratios generally result in higher efficiencies once a filter cake has developed on the fabric because the particles are more easily intercepted at lower filtration velocities. For a given cloth area, increases in gas flow rate will result in decreases in efficiency because the higher filtration velocity will allow more particles to penetrate the fabric and/or the filter cake.[4]

The pressure drop and the cleaning method affect the thickness and compactness of the filter cake. The degree to which the filter cake collects additional dust particles is directly dependent on the thickness and compactness of the cake.[5]

The effect of inlet loading or inlet concentration on baghouse performance depends on the cleaning method. For mechanical shaker cleaning, substantial changes in inlet concentration will result in minimal changes in the outlet concentration.[6] However, with pulse jet systems, the exhaust concentration is dependent on inlet loading. The outlet concentration approximately follows the equation

$$\text{outlet concentration} = k\,(\text{inlet concentration})^n$$

where k is some constant and n varies from 0.5 to 1.[7] Thus, pulse jet systems operate at nearly constant efficiency and mechanical shaker systems operate at nearly constant outlet concentration.

When operated and maintained properly, fabric filters regularly exhibit collection efficiencies of 99 percent or greater.[8,9,10] Although the particle collection efficiency of a fabric filter decreases as particle size decreases, fabric filters are capable of controlling submicron particles with approximately 99 percent efficiency.[11] Particles in this size range contribute significantly to visible emissions.[12]

The effect of particle size distribution on mass emissions from fabric filters is dependent on the cleaning method and frequency. Larger, heavier particles usually penetrate the fabric immediately following the cleaning cycle. This is particularly evident for pulse-jet fabric filters, where little residual filter cake remains on the filter after cleaning and where cleaning cycles are more frequent than for other cleaning mechanisms. Particles which remain in the interstices of the fabric are often loosened during the cleaning cycle and are entrained in the exit gases when filtration is resumed.[13]

Major operating problems associated with some fabric filters are excessive bag caking and bag blinding. Both of these problems result from condensation and can generally be avoided if the gas temperature is maintained 28 to 39K (50 to 70°F) above the dew point.[14] In some cases, an inlet gas heater may be required to avoid caking and blinding. For existing high temperature streams, maintaining temperatures above the dew point can often be achieved by insulating fabric filter units and upstream ducting and control devices. Increases in the operating temperature will result in higher volumetric flow rates of gas and will consequently require an increased filter area (more fabric) to maintain a satisfactory filtering velocity.

The removal efficiency of fabric filters is reduced significantly when bags leak. The existence of worn or torn bags is easily detected by routine observation of visible emissions from fabric filter discharge stacks and by regular inspections of bags.

4.1.2 Centrifugal Separation

Centrifugal separators, or cyclones, rely on centrifugal forces to effect particle separation from the gas stream. Cyclones are frequently used upstream of a fabric filter or electrostatic precipitator to reduce the dust loading to the device and hence reduce the required frequency of cleaning.

4.1.2.1 Basic Description. A typical cyclone is illustrated in Figure 4-2. Dust-laden gases enter a conical-shaped vessel tangentially and leave through a central opening. As the gas flows in a vortex down through the cyclone, the inertia of the particles causes them to move outward across the gas streamlines towards the cyclone shell. As the vortex is reversed in the conical portion of the cyclone, most of the particles continue to travel downward along the outer shell into a receiving chamber.[15]

4.1.2.2 Factors Affecting Performance. The most important variables in the design of a cyclone are the cyclone dimensions. Small diameter cyclones have greater removal efficiencies and higher pressure drops due to the greater angular velocity (or inertia) of the gas stream and entrained particles. Banks of small-diameter cyclones in parallel, with common gas inlets and outlets, are frequently used to achieve higher efficiencies. Long cyclones exhibit greater removal efficiencies than short cyclones due to the increased time in which particles are subject to separating forces. Cyclone pressure drops typically range from 0.5 to 1.5 kPa (2 to 6 inches of water).

Cyclone efficiency is highly dependent on the size of the particulates being collected. Cyclones collect large particles more efficiently than small particles. For example, a high efficiency cyclone may remove 95-99 percent of particles greater than 40 µm, 90-99 percent of particles from 15-50 µm, 80-90 percent of particles from 5-20 µm, and only 50-80 percent of particles less than 5 µm. Typical cyclone overall collection efficiencies range from about 55 to 95 percent.[16]

Various factors limit the effectiveness of cyclonic collectors. If the cyclone is designed for peak efficiency at peak flow, lower flows will result in lower efficiencies due to the reduced gas velocity in the cyclone. Similarly, temperature increases may reduce removal efficiency by increasing the viscosity of the gas. Collection efficiency may also be reduced by re-entrainment of dust if the dust is not adequately removed from the receiving chamber.

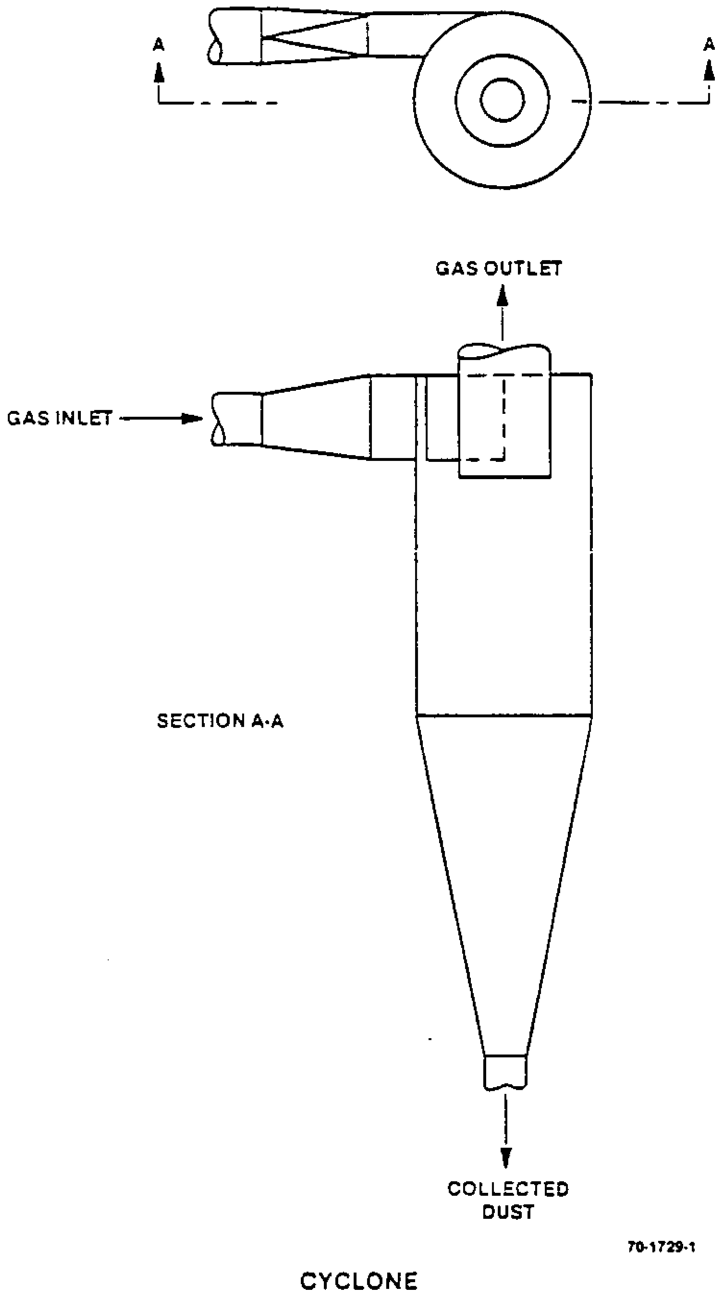


Figure 4-2. Conventional centrifugal separator (cyclone)

4.1.3 Electrostatic Precipitation

4.1.3.1 Basic Description. Particulate collection in an electrostatic precipitator occurs in three steps: suspended particles are given an electrical charge; the charged particles migrate to a collecting electrode of opposite polarity while subjected to a diverging electric field; and the collected particulate matter is dislodged from the collecting electrodes. A schematic diagram of an electrostatic precipitator is given in Figure 4-3.

An electric field or corona is generated by the application of a high voltage to a discharge electrode system consisting of rows of vertical wires strung between rigid plates. The strength of the corona depends in part on the gas composition. While passing through the corona, the suspended particles receive an electric charge. The charging of particles depends on local conditions in the electrostatic precipitator (ESP) such as strength of the corona and on the resistivity of the particles. The charged particles migrate to collecting plates of an opposite electrical charge. This migration depends on the particle size, particle resistivity, gas velocity, gas distribution, and field strength.

The collecting electrodes are rigid, baffled plates. Baffles on the collecting electrodes provide shielded air pockets that reduce re-entrainment of particles after rapping. Electromagnetic or pneumatic hammers are used to rap the electrodes, dislodging the collected dust which then falls into hoppers.[17]

4.1.3.2 Factors Affecting Performance. The key design variable for electrostatic precipitator design is the area of the collecting plate. The overall removal efficiency of the ESP can then be defined by the plate area, migration (or drift) velocity, and gas flow rate according to the Deutsch-Anderson equation:

$$n = 1 - e^{\frac{-WA}{Q}}$$

where n = removal efficiency

Q = gas flow rate

W = migration velocity

A = collecting plate area.

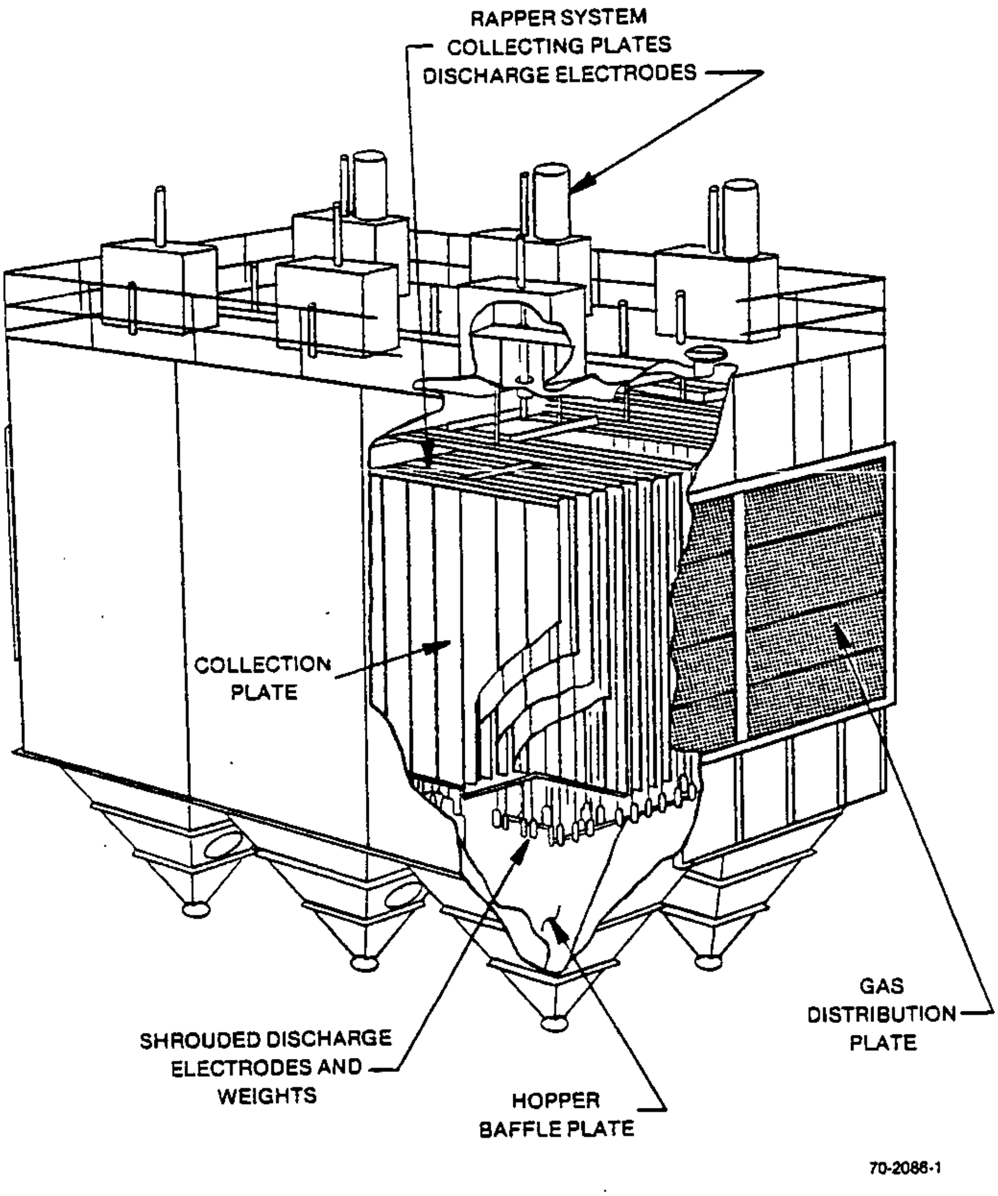


Figure 4-3. View of a typical electrostatic precipitator.

As indicated by this equation, ESP efficiency increases with increasing plate area relative to gas flow rate and with increasing migration velocity.

Another key design variable is proper determination of the rapping cycle. If the cycle is too short, material that collects on the plates will not be compacted enough to settle to the bottom of the precipitation chamber and will be re-entrained. This re-entrainment can be minimized by proper design of collecting electrodes and rappers, minimizing rapping, and rapping only a small section of the total precipitator plate area at a time. If the time between rapping is too long, however, the material on the collecting plates will become too thick and collection efficiency will be reduced.

Other design parameters that affect ESP performance include plate spacing and type, plate height and length, applied voltage, corona strength, and residence time. ESP's typically have gas-phase pressure drops less than 0.13 kPa (0.5 in. of water).

The suitability of particulate collection by electrostatic precipitation depends on the resistivity of the particles. Particulates with resistivities in the range of 10^4 to 10^{10} ohm-cm have been shown by experience to be the most suitable for electrostatic precipitation.[18] Particles with lower resistivities will give up their charge too easily and will be re-entrained in the gas stream. Particles with higher resistivities will coat the collecting plates and will be hard to dislodge, thereby reducing the ability of the electrode to further collect particles. The resistivity of a given particle will vary with temperature and moisture.

The particulate collection efficiency of an ESP is also a function of particle size. Although an ESP's collection efficiency decreases as particle size decreases, ESP's regularly achieve overall control efficiencies of 95 percent or greater, when properly operated. For submicron particles, ESP's regularly achieve control efficiencies of 90 percent or greater.[19]

Gas flow distribution also has a strong impact on ESP efficiency. Poor flow distribution between the collecting electrodes results in differing gas flow rates between each plate and therefore differing efficiencies for each section of the ESP. In addition, high velocities in the vicinity of hoppers and collecting electrodes can result in re-entrainment of collected dust. Poor gas flow distribution can result in ESP efficiency losses ranging from 20 to 30 percent.[20] Gas flow distribution problems can be corrected by proper inlet design, such as adding straighteners, splitters, vanes, and diffusion plates to the duct work before the ESP.

4.1.4 Wet Scrubbing

4.1.4.1 Basic Description. In wet scrubbers, particles are contacted with a wetted surface or atomized liquid droplets. The particulate laden liquid is then separated from the gas stream, and either recycled to the production process or discharged as waste.

Scrubbers are usually classified by energy consumption in terms of gas phase pressure drop. Low-energy scrubbers, represented by spray chambers and towers, have pressure drops less than 1.3 kPa (5 in. of water). Medium-energy scrubbers such as centrifugal scrubbers have pressure drops of 1.3-3.7 kPa (5-15 in. of water). High-energy scrubbers such as venturi scrubbers have pressure drops exceeding 3.7 kPa (15 in. of water).

A typical venturi scrubber is shown in Figure 4-4. Scrubbing liquid is injected into the gas stream and mixes with the gas in the high turbulence zone associated with the venturi throat. The particulates are collected by the atomized liquid droplets. The liquid is subsequently separated from the gas in a cyclonic separator which is usually equipped with a mist eliminator.[21]

4.1.4.2 Factors Affecting Performance. The design of a scrubber depends on the physical and chemical properties of the dust being collected and the gas being cleaned. The most important particle characteristics are particle size distribution and particulate loading in the gas stream.

Larger particles are removed more efficiently than small ones. The principal factors affecting the performance of venturi scrubbers are the operating pressure drop across the scrubber, the liquid-to-gas ratio, the water/gas separation achieved in the separator, and the scrubber liquor saturation level. Higher removal efficiencies are achieved with

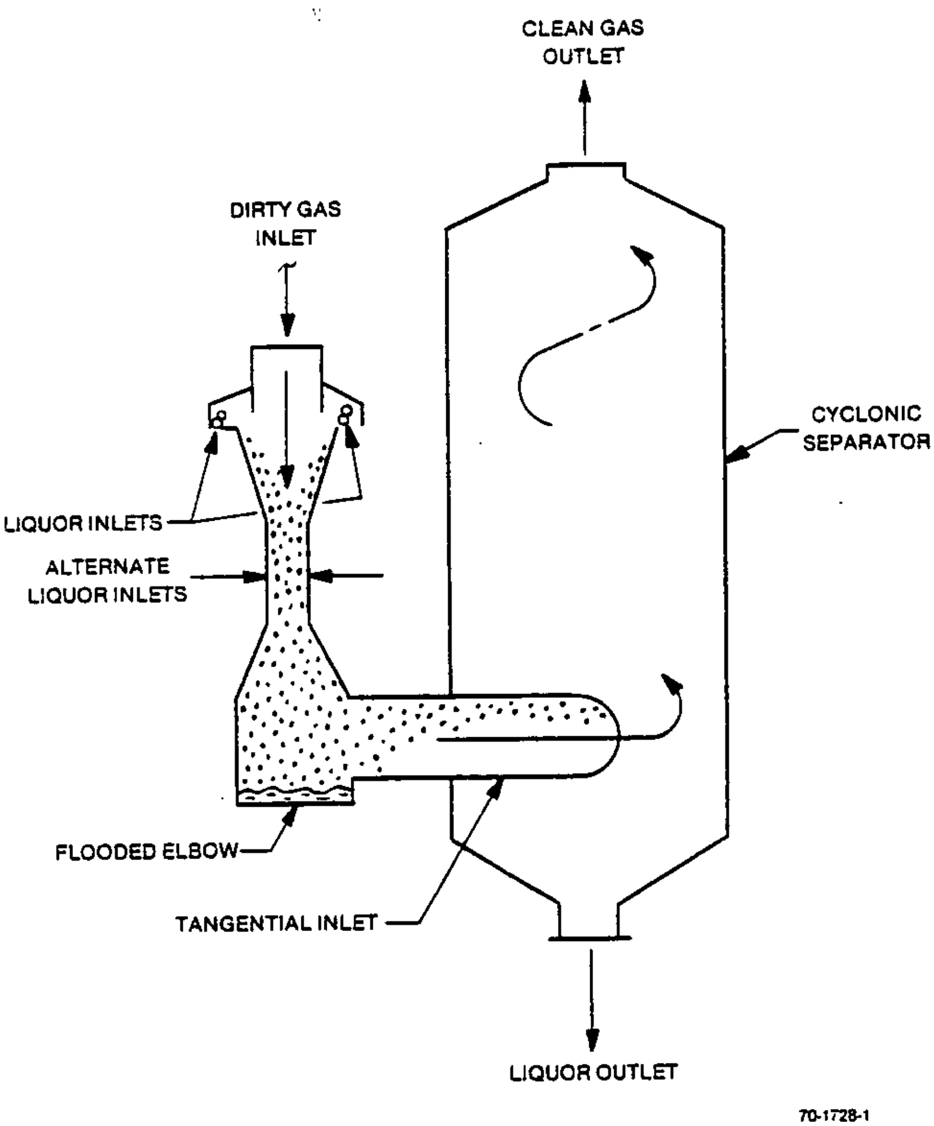


Figure 4-4. View of a venturi scrubber with centrifugal separator chamber.

scrubbers operated at higher gas-phase pressure drops and higher liquid-to-gas ratios. Overall particulate removal efficiency is reduced if the downstream mist eliminator is unable to separate finely-atomized water droplets from the exit gas. These uncollected droplets evaporate and release their particulate contents to the air.

4.2 APPLICATION OF CONTROL TECHNIQUES TO EMISSION SOURCES IN THE GYPSUM INDUSTRY

The applicability of the control techniques discussed in Section 4.1 to emission sources in the gypsum industry is discussed in this section. Each of the four control techniques discussed is considered separately in the following sections.

4.2.1 Use of Fabric Filters

As discussed previously, fabric filtration is the most widely applied particulate control method in the gypsum industry. Fabric filters or baghouses are used to control particulate emissions from ore dryers, calciners, mixing, board end sawing, conveying, and storage. Gypsum dust is well suited to fabric filtration and, in properly designed installations, does not cause caking and bag blinding problems. Paper fiber emissions from scoring and chamfering are also controlled with fabric filters in some plants.

Baghouses used to control dust from ore dryers and calciners must be well insulated to prevent moisture condensation that would lead to caking and blinding of the bags. In some installations, where ore dryer exit gases are near the dew point, small heaters are used to reheat process gases before they enter the baghouse.[22] In the case of calciners, baghouse insulation is particularly important because moisture content of calciner exit gases can be as high as 60 percent by volume.

Dust laden gases from ore dryers and calciners are relatively high in temperature. Maximum exit gas temperatures for ore dryers and calciners are about 377K (220°F) and 453K (350°F), respectively. Consequently, high temperature-resistant filter fabrics are required. Fabric filters treating gases from ore dryers and calciners use Nomex or Orlon felt bags. Bag replacement frequencies for dryers and calciners typically range from four to twelve months, depending on the temperature and dust loading of the gases being treated.[23,24]

Due to the high operating temperatures of the dryers and calciners, fabric filter dust collectors controlling these units must be allowed to cool before filter bags can be replaced. To insure the safety of maintenance personnel, the process is typically shut down for at least four to six hours before the filter bags are removed.

In fabric filters treating gases from the remaining processes, all of which are at ambient or low temperatures, filter bags used are either Dacron or Orlon.[25,26] The life of these bags is typically one to one and one-half years.[27,28]

Operating air-to-cloth ratios of baghouses used in the industry range between 1:1 and 5:1 (cfm:ft^2), depending on the cleaning method used.[29,30,31] Although all three types of cleaning methods (shaker, reverse-air and pulse-jet) are currently used on baghouses collecting gypsum dust, the current trend of major gypsum producers is toward the use of reverse-air and pulse-jet fabric filters with design air-to-cloth ratios of about 5:1 (cfm:ft^2) for most sources. However, for one source, board end sawing, mechanical shaker baghouses with air-to-cloth-ratios of about 2:1 (cfm:ft^2) are generally used.

4.2.2 Use of Centrifugal Separators

Cyclones are applied to a number of emission sources in the gypsum industry. These sources include ore drying, boardline mixing, scoring and chamfering and, in a few installations, board end sawing. When used cyclones are normally installed to remove larger particles in dust-laden gases upstream of fabric filters or electrostatic precipitators. Removal of the majority of the entrained dust reduces maintenance and operating costs by lessening the amount of material that must be handled by subsequent control equipment and associated conveying equipment.

In some cases dust-laden gases from ore dryers and boardline mixing and/or paper particles from scoring and chamfering are treated with a cyclone and vented directly to the atmosphere. Normal removal efficiencies of cyclones range from 55 to 95 percent, depending on the size range of the particles being collected.[32]

4.2.3 Use of Electrostatic Precipitators

Electrostatic precipitators (ESP) are applied to emissions from grinding mills, ore dryers, and kettle calciners in the gypsum industry. It is common for multiple sources to be controlled by one ESP because ESP's are most economical when used to treat large volumes of gas. In several plants the ESP's are preceded by cyclones to remove a majority of the entrained dust as discussed in Section 4.2.2.

As discussed in Section 4.1.3.2, particulates with resistivities in the range of 10^4 to 10^{10} ohm-cm have been shown by experience to be the most suitable for collection by electrostatic precipitation. Under certain conditions, gypsum dust has a resistivity within this optimal range. The data in Figure 4-5 shows that dry gypsum dust has a resistivity which could potentially be high enough to present a collection problem. However, dry vent gases are usually combined with the moisture-laden gases from the calciner. The moisture content of the calciner gases, ranging from 30 to 60 percent by volume, "conditions" the dust and the problem of high resistivity is usually avoided.[34,35] Overall control efficiencies of ESP's used by the gypsum industry typically range from 98 to 99.5 percent.[36]

Because the majority of precipitators used in the industry treat gases from more than one source, special care must be taken to assure good gas flow distribution into the precipitator.

A possible "puffing" problem may occur when the calcining kettles are operated batch-wise. One industry source reported that simultaneous discharging of all kettles resulted in puffs of visible emissions from the ESP treating the calciner gases. To prevent such occurrences, the discharging of the kettles must be staggered.[37]

One gypsum company that uses both fabric filters and ESP's to control emissions from dryers, grinding mills and calciners has found that ESP's are less expensive to operate and maintain than fabric filters.[38,39,40]

4.2.4 Use of Wet Scrubbers

Wet scrubbers are not being used to control particulate emissions from gypsum plants built in the last ten years. In a few older installations,

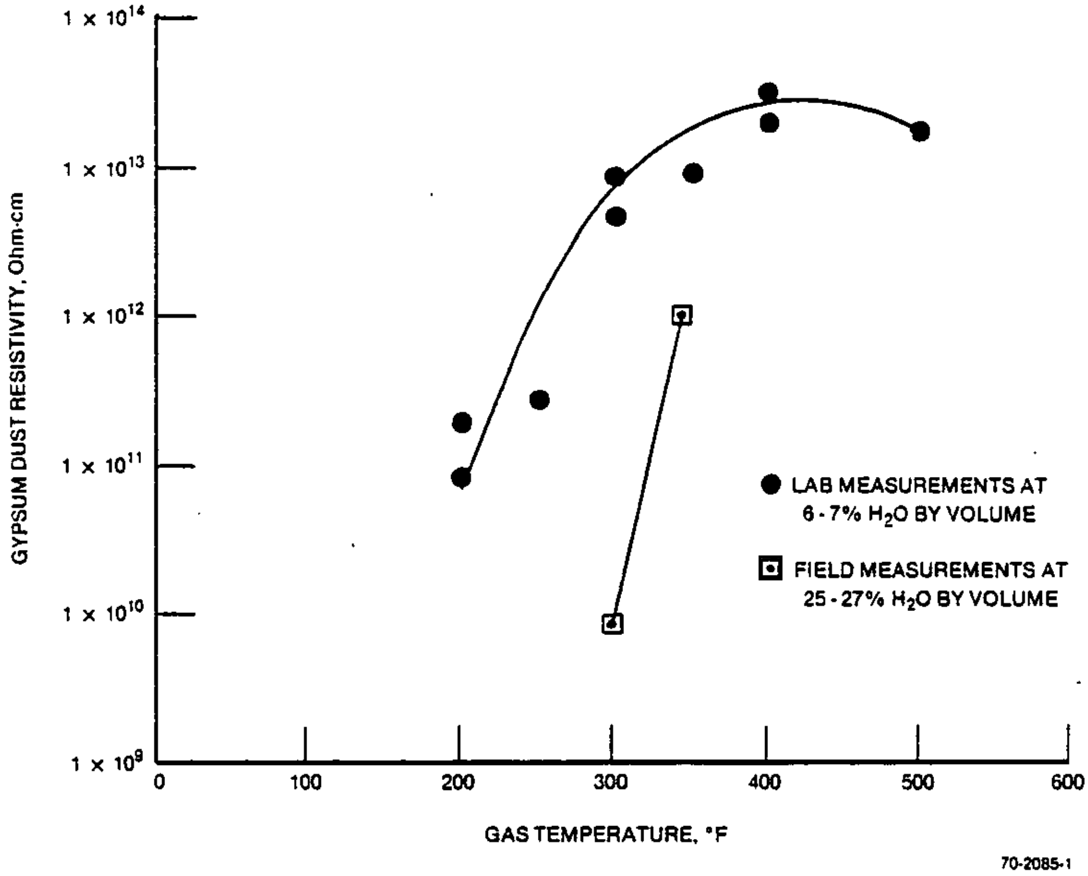


Figure 4-5. Resistivity of gypsum dust.[33]

low energy wet scrubbers are used to control calcining and drying particulate emissions. Scrubbers are not used in newer installations primarily because particulate matter collected using wet scrubbers cannot be easily recycled to the process. The disposal of waste water effluents from scrubbers controlling gypsum emissions is also a problem.

4.3 PERFORMANCE DATA

Source test data demonstrating the emission control levels achievable with fabric filters and ESP's are discussed in this section. These data were obtained from emission source tests conducted by both EPA and industry. The results of the EPA source tests are presented in more detail in Appendix C.

An examination of available test data and permit applications indicated that fabric filters achieve higher particulate removal efficiencies than ESPs when applied to gypsum emission sources. In addition, fabric filters are more commonly used than other devices to control emissions from sources in the gypsum industry. Therefore, source testing during this study was limited to fabric filters. The application of fabric filters to the control of gypsum emissions is emphasized in this section.

Following a presentation of the data available for fabric filters on each principal source, ore dryers, calciners and board end sawing, variations between individual source tests are discussed in detail. The degree to which the test data represent actual control situations in the industry is also discussed.

A summary of the mass emission data available for fabric filters on ore dryers, calciners, and board end sawing operations is given in Table 4-2. The average inlet and outlet emissions measured during the individual source tests are given in this table. Production rates used to determine emission factors are estimates based on records of previous process operation or on back-calculations from boardline production rates. The overall removal efficiencies and factors affecting baghouse performance, such as air-to-cloth ratio, fabric type and gas moisture content are also included.

TABLE 4-2. EMISSION CONTROL LEVELS EXHIBITED BY FABRIC FILTERS (Metric Units)[a]

Emission Source	Plant Identification	Fabric Filter Inlet Loadings g/dNm^3	Fabric Filter Inlet Loadings kg/hr	Fabric Filter Outlet Loadings g/dNm^3	Fabric Filter Outlet Loadings kg/hr	Fabric Filter Outlet Loadings g/kg	Efficiency Percent	Exit Gas Moisture Content (% by vol.)	Actual Air-to-Cloth Ratios (ft/min)	Fabric Type	Data Source
Ore Dryer	Plant Y	116	2293	0.050	0.99	0.035	99.96	8.9	5.5	Nomex	EPA
Ore Dryer	Plant E	8.69[b]	109[b]	0.009	0.12	0.002	99.87[b]	9.2	6.4	Orlon	EPA
Ore Dryer	Plant J	81.4[b]	1169[b]	0.021	0.30	0.012	99.97[b]	5.9	2.3	Dacron[c]	Ind.
Ore Dryer	Plant E	11.1[b]	359[b]	0.072	1.0	0.024	99.35[b]	5.9	7.0	Orlon	Ind.
Calciners											
Continuous kettle	Plant E	223[d]	225[d]	0.030	0.03	0.003	99.99[d]	69.3	2.9	Orlon	EPA
Continuous kettle	Plant E	189[d]	225[d]	0.034	0.03	0.004	99.98[d]	63.7	2.3	Orlon	Ind.
Continuous kettle	Plant TT	84.3	194	0.242	0.44	0.044	99.78	42.0	5.1	Nomex	EPA
Batch kettle	Plant TT	N/A[f]	N/A[f]	0.044	0.13	0.030	N/A[f]	26.0	5.2	Nomex	EPA
Direct contact	Plant Y	47.2	127	0.053	0.14	0.023	99.89	40.7	4.2	Nomex	EPA
Direct contact	Plant OO	50.0[d]	111[d]	0.013	0.03	0.006	99.97[d]	47.7	4.3	Nomex	EPA
Direct contact	Plant C	45.2[d]	280[d]	0.084	0.45	0.029	99.81[d]	37.0	3.2	Nomex	Ind.
Board end sawing	Plant E	15.8	91.7	0.014	0.09	0.003	99.91	1.6	1.5	Dacron	EPA
Board end sawing and paper scoring	Plant TT	13.1	86.7	0.023	0.16	0.006	99.81	1.1	4.6	Cotton	EPA

[a]This data is a summary of the mass emission data reported in Section 4.3.

[b]Values estimated using EPA and industry test data. Reference 41 and Reference 42.

[c]Reference 43.

[d]Values estimated using EPA test data.

[e]All Plant TT data is preliminary and may change slightly.

[f]This data for the Plant TT test is not available.

TABLE 4-2. EMISSION CONTROL LEVELS EXHIBITED BY FABRIC FILTERS (English Units)[a]

Emission Source	Plant Identification	Fabric Filter Inlet Loadings gr/dscf	Fabric Filter Inlet Loadings lb/hr	Fabric Filter Outlet Loadings gr/dscf	Fabric Filter Outlet Loadings lb/hr	Fabric Filter Outlet Loadings lb/ton	Efficiency Percent	Exit Gas Moisture Content (% by vol.)	Actual Air-to-Cloth Ratios (ft/min)	Fabric Type	Data Source
Ore Dryer	Plant Y	50.8	5050	0.022	2.19	0.070	99.96	8.9	5.5	Nomex	EPA
Ore Dryer	Plant E	3.80[b]	239[b]	0.004	0.26	0.004	99.87[b]	9.2	6.4	Orlon	EPA
Ore Dryer	Plant J	35.6[b]	2575[b]	0.009	0.65	0.023	99.97[b]	5.9	2.3	Dacron[c]	Ind.
Ore Dryer	Plant E	4.8[b]	359[b]	0.031	2.3	0.047	99.35[b]	5.9	7.0	Orlon	Ind.
Calciners											
Continuous kettle	Plant E	97.3[d]	496[d]	0.013	0.06	0.005	99.99[d]	69.3	2.9	Orlon	EPA
Continuous kettle	Plant E	82.4[d]	496[d]	0.015	0.06	0.007	99.98[d]	63.7	2.3	Orlon	Ind.
Continuous kettle	Plant TT	36.3	428	0.106	0.96	0.087	99.78	42.0	5.1	Nomex	EPA
Batch kettle	Plant TT	N/A[f]	N/A[f]	0.019	0.29	0.059	N/A[f]	26.0	5.2	Nomex	EPA
Direct contact	Plant Y	20.6	280	0.023	0.31	0.045	99.89	40.7	4.2	Nomex	EPA
Direct contact	Plant OO	21.9[d]	244[d]	0.006	0.07	0.011	99.97[d]	47.7	4.3	Nomex	EPA
Direct contact	Plant C	19.7[d]	280[d]	0.037	0.99	0.058	99.81[d]	37.0	3.2	Nomex	Ind.
Board end sawing	Plant E	6.9	202	0.006	0.19	0.006	99.91	1.6	1.5	Dacron	EPA
Board end sawing and paper scoring	Plant TT	5.7	191	0.010	0.35	0.012	99.81	1.1	4.6	Cotton	EPA

[a] This data is a summary of the mass emission data reported in Section 4.3.

[b] Values estimated using EPA and industry test data. Reference 41 and Reference 42.

[c] Reference 43.

[d] Values estimated using EPA test data.

[e] All Plant TT data is preliminary and may change slightly.

[f] This data for the Plant TT test is not available.

The data in Table 4-2 represent a wide range of inlet loadings and air-to-cloth ratios, several cleaning methods and fabric types, and three different emission sources. The consistently high removal efficiencies exhibited by fabric filters at these varied operating conditions is an indication that fabric filters are an effective means of controlling gypsum emissions to low levels.

4.3.1 Performance Data for Fabric Filters on Ore Dryers

Results of EPA and industry source tests on ore dryers controlled with fabric filters are summarized in Table 4-3 and are presented graphically in Figure 4-6. Two different dryer configurations were tested, one which employs process cyclones and one which does not. Two separate source tests were conducted at the site which employs process cyclones prior to the fabric filter. Two different sites were tested which do not use cyclones. In each of the EPA source tests fabric filters achieved overall control efficiencies greater than 99.8 percent.

The source test data in Table 4-3 show average controlled particulate emissions ranging from 0.002 g/kg of dry rock (0.004 lb/ton) to 0.035 g/kg of dry rock (0.07 lb/ton). The average particulate concentrations range from 0.009 g/dNm^3 (0.004 gr/dscf) to 0.072 g/dNm^3 (0.031 gr/dscf).

During the source tests shown in Table 4-3, the ore dryers were operated at capacity factors ranging from 56 to 92 percent of design capacity. These source tests are representative of the range of ore dryer operating rates normally used in the gypsum industry.[47]

4.3.1.1 Variations in Ore Dryer Test Results. The variations in the test results presented in Table 4-3 are discussed in this section. No significant variation is shown between the particulate concentrations in the three test runs of any source test in Table 4-3. The variations between tests, however, are discussed below in terms of ore dryer operating parameters and factors which affect fabric filter performance, such as air flow rates, inlet dust loadings, air-to-cloth ratios and cleaning frequencies.

As shown in Table 4-3, a higher concentration was measured on the Plant E dryer during the industry source test than during the EPA test.

TABLE 4-3. PARTICULATE EMISSION PARAMETERS FOR ORE DRYERS CONTROLLED WITH FABRIC FILTERS

Plant Identification	Data Source	Fuel Type	Control Used	Exit Gas Temperature K	Exit Gas Temperature °F	Exit Gas Flow Rate m^3/s	Exit Gas Flow Rate acfm	Exit Gas Moisture Content Volume % H_2O	Particulate Emission Factors[a] g/Kg	Particulate Emission Factors[a] lb/ton	Particulate Concentrations g/dNm^3	Particulate Concentrations gr/dscf	Control Efficiency[b] Percent
Plant E	EPA	Natural Gas	Fabric Filter with Process Cyclone										
Test Run 1				350	172	4.88	10,350	9.0	.002	.004	.009	.004	99.86
Test Run 2				349	169	4.86	10,300	9.2	.002	.004	.009	.004	99.89
Test Run 3				352	174	4.69	9,950	9.4	.003	.005	.009	.004	99.87
Average				350	172	4.81	10,200	9.2	.002	.004	.009	.004	99.87
Average Fuel Usage Factor = 0.08 KJ/g (0.07 million BTU/ton); Capacity Factor in Percent[c] = 92; Wet rock moisture content in weight percent = 1.5 - 2.0; Actual air-to-cloth ratio = 6.4:1 (cfm:ft²); Filter Fabric was Orlon													
Plant E[d]	Industry	Natural Gas	Fabric Filter with Process Cyclone										
Test Run 1				361	190	5.31	11,267	5.4	.025	.050	.080	.035	N/A
Test Run 2				360	189	5.26	11,147	5.2	.015	.030	.045	.019	N/A
Test Run 3				360	188	5.32	11,271	7.1	.030	.060	.094	.041	N/A
Average				360	189	5.30	11,228	5.9	.023	.047	.072	.031	N/A
Average Fuel Usage Factor = N/A[e]; Capacity Factor in Percent = 70; Wet rock moisture content in weight percent = 1.5 - 2.0; Actual air-to-cloth ratio = 7.0:1 (cfm:ft²); Filter Fabric was Orlon													
Plant Y	EPA	Residual Oil (No. 6)	Fabric Filter										
Test Run 1				366	200	7.55	16,000	8.3	.045	.090	.062	.027	99.95
Test Run 2				367	202	7.41	15,700	9.5	.031	.061	.044	.019	99.96
Test Run 3				368	203	7.64	16,200	9.0	.030	.059	.041	.018	99.97
Average				367	202	7.53	15,970	8.9	.035	.070	.050	.022	99.96
Average Fuel Usage Factor = 0.23 KJ/g (0.20 million BTU/ton); Capacity Factor in Percent = 60; Wet rock moisture content in weight percent = 6.0 - 8.0; Actual air-to-cloth ratio = 5.5:1 (cfm:ft²); Filter Fabric was Nomex													

(continued)

TABLE 4-3. (Cont.)

Plant Identification	Data Source	Fuel Type	Control Used	Exit Gas Temperature K	Exit Gas Temperature °F	Exit Gas Flow Rate m^3/s	Exit Gas Flow Rate acfm	Exit Gas Moisture Content Volume % H_2O	Particulate Emission Factors[a] g/Kg	Particulate Emission Factors[a] lb/ton	Particulate Concentrations g/dNm^3	Particulate Concentrations gr/dscf	Control Efficiency Percent[b]
Plant J[f]	Industry	Residual Oil (No.6)	Fabric Filter										
Test Run 1				355	179	5.25	11,140	6.7	.011	.022	.018	.008	N/A
Test Run 2				357	183	5.11	10,836	5.7	.011	.022	.021	.009	N/A
Test Run 3				354	177	5.04	10,678	5.4	.013	.026	.023	.010	N/A
Average				355	180	5.13	10,885	5.9	.012	.023	.021	.009	N/A

Average Fuel Usage Factor = N/A
Capacity Factor in Percent = 56
Wet rock moisture content in weight percent = 3.3-3.8

Actual air-to-cloth ratio = 2.3:1 (cfm:ft^2)
Filter Fabric was Dacron[g]

[a]Based on production rate of dry rock.

[b]Two of the fabric filter efficiencies could not be calculated because inlet data are not available.

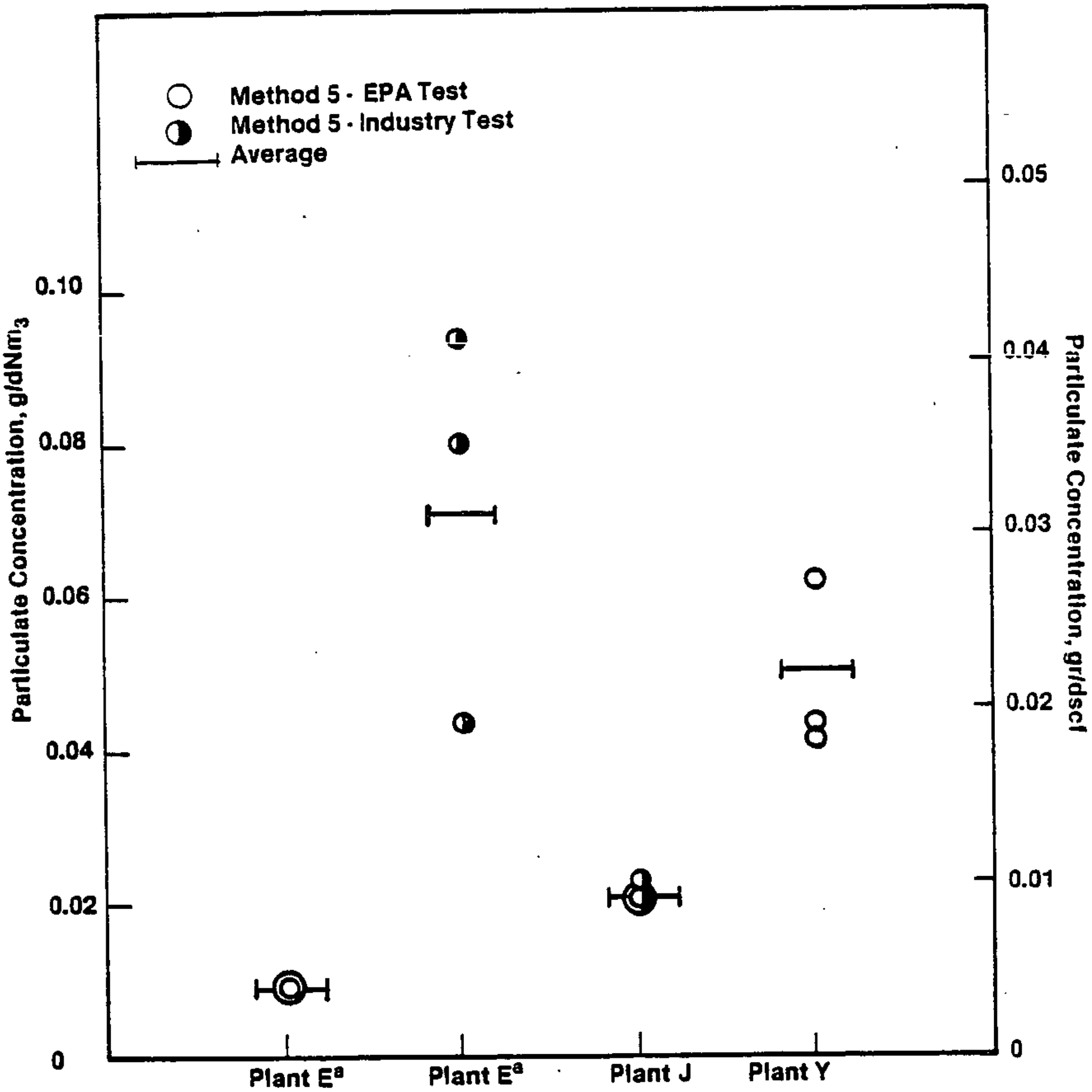
[c]Capacity factor is the fraction of design capacity being used.

[d]Reference 44.

[e]N/A - not available.

[f]Reference 45.

[g]Reference 46.



[a]Plant E uses process cyclones prior to the fabric filter.

Figure 4-6. Particulate emission rates for ore dryers controlled with fabric filters.

The operating data show that the dryer was operated at a higher air flow rate and a lower production rate during the industry test. At these operating conditions, the particulate concentration into the fabric filter was estimated to be about the same during both Plant E tests.[48] Therefore, the change in ore dryer operating conditions alone would not be expected to affect the outlet concentration measured during the industry test.

A portion of the higher outlet particulate concentration measured during the Plant E industry test is probably directly attributable to the increase in air flow rate. Larger air flow rates result in higher air-to-cloth ratios and are expected to reduce overall collection efficiencies for a given baghouse.[49] Increasing the air-to-cloth ratio of the baghouse from 6.4 to 7.0 ($ft^3/min:ft^2$) may result in a measurable change in the outlet particulate concentration. However, this change is not expected to be large enough to account for the entire difference in the two Plant E dryer tests. Another factor that may have caused the higher particulate concentration measured during the industry test of the Plant E dryer is bag wear. However, data on the age of the filter bags tested are unavailable.

The outlet concentration measured during the EPA test of the Plant Y dryer is somewhat higher than the concentration measured during the EPA Plant E test and the industry Plant J test. The higher outlet loading measured for the Plant Y dryer is probably due to the higher inlet loading. While the fabric filter achieved high overall removal efficiency (99.96 percent), the inlet loading of 116 g/dNm^3 (51 gr/dscf) resulted in an outlet concentration which appears to be abnormally high when compared with the other tests. Since the outlet concentration of pulse-jet fabric filters is reported to be dependent on the inlet concentration, the higher outlet concentration from the Plant Y dryer is expected.

The outlet emission factors for the source tests shown in Table 4-3 vary over a relatively wide range. The variations between the emission factors are attributable to the same factors discussed previously for the variations in the outlet concentrations. The highest outlet concentration measured, 0.094 g/dNm^3 (0.041 gr/dscf), was from the Plant E dryer during the EPA test.

4.3.1.2 Representativeness of Ore Dryer Tests. The degree to which the test data in Table 4-3 represent ore dryer emission control situations encountered in the gypsum industry is discussed in this section. This representativeness is discussed in terms of factors which affect uncontrolled ore dryer emissions and factors which affect fabric filter performance. The factors discussed include the following:

- inlet dust loading,
- air flow rate and production rate,
- ore free moisture content,
- gas moisture content,
- air-to-cloth ratio and cleaning method,
- operational pressure drop, and
- particle size distribution.

As discussed in Section 3.2.1.4, uncontrolled emissions factors from gypsum ore dryers will be highest when ore dryers are operated at higher air flow rates and low operating capacities.[50] The EPA Plant Y test represents an extreme situation. The dryer was operated at an air flow rate of 7.55 m^3/s (16,000 acfm) and a capacity factor of 60 percent. Operation of new dryers below this capacity factor is unlikely because of economic considerations. In the event that ore dryer operating conditions which result in more severe uncontrolled emissions are encountered, the use of process cyclones prior to the fabric filter would ensure that particulate concentrations as low as those measured at Plant Y are achieved.

Uncontrolled particulate emissions will be lowest from ore dryers which employ process cyclones. The test data from the Plant E dryer represent this control situation.

The free moisture content of gypsum ore fed to dryers ranges from 1.0 to 8.0 percent.[51,52] The range of free moisture content in ore fed to the dryers during the EPA and industry tests was 1.5 to 8.0 percent which is within the range expected. The moisture content of the gas ranged from 5.2 to 9.4 percent by volume, which should not affect the operation of fabric filters unless condensation occurs. Removing all free moisture from ore containing eight percent moisture, however, could result in a relative humidity as high as 39.5 percent in the exhaust gas stream. Although increases in relative humidities in the range of 20 to 60 percent may enhance fabric filter performance, these test results did not indicate any improvements with variations in relative humidity.[53]

Currently recommended air-to-cloth ratios for large gypsum sources range from 4:1 to 6:1 ($cfm:ft^2$) for pulse-jet systems and 2.5:1 to 3:1 ($cfm:ft^2$) for reverse-air systems.[54,55,56] Although both types are used on gypsum dryers, pulse-jet systems are more common. Operation at air-to-cloth ratios significantly above this range may result in low removal efficiencies and baghouse overloading unless process cyclones are used. The Plant J dryer used a reverse-air fabric filter and had an air-to-cloth ratio of 2.3:1 ($cfm:ft^2$) during the test. The other two dryers both used pulse-jet fabric filters and were tested at air-to-cloth ratios ranging from 5.5:1 to 7.0:1 ($cfm:ft^2$). Although the air-to-cloth ratios of the Plant E tests are outside the recommended range, the Plant E dryer employs process cyclones to reduce the inlet dust loading to the fabric filter.

Filter fabrics best suited to the operating conditions of ore dryers include Nomex, Dacron, and Orlon.[57] The filter fabrics used on the ore dryers tested include all three of these fabrics.

Typical operating pressure drops for pulse-jet baghouses are around 0.75 to 0.87 kPa (3.0-3.5 inches of water).[58] The pressure drops on the fabric filters during the Plant E and Plant Y EPA tests were 0.95 kPa (3.8 inches of water) and 0.62 kPa (2.5 inches of water) respectively.

The particle size distribution in dust laden gases exiting ore dryers can vary due to changes in air flow rate or the use of process cyclones. At higher air flow rates (velocities) larger particles are more easily entrained in the gas stream and the mean particle size is increased. In general, cyclones tend to remove only the largest particles in the gas stream and therefore the mean particle size is decreased.[59] The EPA tests on the Plant E dryer, which uses process cyclones, and the Plant Y dryer, which operates at a higher air flow rate, demonstrate the ability of fabric filters to achieve high levels of particulate removal for both particle size distributions. Particle size distributions in the exit gases from these two dryers are presented in Section 3.2.2.4.

4.3.1.3 Summary of Visible Emissions from Fabric Filters on Ore Dryers. A summary of the highest visible emissions data recorded for the source tests shown in Table 4-3 is given in Figure 4-7. The data show the average percent opacity recorded over six minute intervals during the ore dryer test at Plant Y. The highest six minute average recorded was 1.9 percent opacity. Opacity data are not available for the Plant E industry test.

4.3.2 Performance Data for Fabric Filters on Kettle Calciners

Data obtained from EPA and industry tests on kettle calciners controlled with fabric filters are presented in Table 4-4 and Figure 4-8. In each of the EPA source tests, the overall control efficiency achieved by fabric filters on kettle calciners was greater than 99.7 percent.

The source test data in Table 4-4 show controlled particulate emission rates ranging from 0.001 g/kg of stucco produced (0.002 lb/ton) to 0.064 g/kg (0.128 lb/ton) of stucco produced. The corresponding particulate concentrations range from 0.010 g/dNm^3 (0.004 gr/dscf) to 0.314 g/dNm^3 (0.137 gr/dscf) in these tests.

During the source tests shown in Table 4-4, all of the kettle calciners were operated at 100 percent of design capacity. The test data are therefore representative of normal operating conditions for kettle calciners.

4.3.2.1 Variations in Continuous and Batch Kettle Calciner Test Results. The variations in the test results presented in Table 4-4 are discussed in this section. These variations are discussed in terms of kettle calciner operating parameters and factors which affect fabric filter performance. No significant variation is shown between any of the three test runs in Table 4-4.

The average outlet concentrations measured for the continuous kettle calciner tests at Plant TT vary from measurements made on other continuous kettle calciners. The outlet concentration for the Plant TT

TABLE 4-4. PARTICULATE EMISSION PARAMETERS FOR KETTLE CALCINERS CONTROLLED WITH FABRIC FILTERS

Plant Identification	Data Source	Fuel Type	Kettle Type	Exit Gas Temperature K	Exit Gas Temperature °F	Exit Gas Flow Rate m^3/s	Exit Gas Flow Rate acfm	Exit Gas Moisture Content Volume % H_2O	Particulate Emission Factors[a] g/Kg	Particulate Emission Factors[a] lb/ton	Particulate Concentrations g/dNm^3	Particulate Concentrations gr/dscf	Control Efficiency Percent[b]
Plant E	EPA	Natural Gas	Continuous (Kettle #4)										
Test Run 1				391	245	1.10	2,340	68.9	.004	.008	.049	.021	99.98
Test Run 2				393	248	1.11	2,360	69.1	.001	.002	.010	.004	99.99
Test Run 3				387	238	1.12	2,370	69.9	.002	.004	.020	.009	99.99
Average				390	244	1.11	2,357	69.3	.002	.005	.030	.013	99.99
Average Fuel Usage Factor = 0.8 KJ/g (0.7 million BTU/ton) Actual Air-to-Cloth Ratio = 2.9:1 ($ft^3/min:ft^2$) Filter Fabric was Orlon													
Plant E	Industry	Natural Gas	Continuous (Kettle #1)										
Test Run 1				391	245	0.875	1,856	65.6	.001	.002	.018	.008	N/A[a]
Test Run 2				391	245	0.885	1,877	64.6	.001	.001	.009	.004	N/A
Test Run 3				391	244	0.885	1,877	60.8	.009	.018	.078	.034	N/A
Average				391	245	0.882	1,870	63.7	.003	.007	.034	.015	N/A
Average Fuel Usage Factor = 0.8 KJ/g (0.7 million BTU/ton) Actual Air-to-Cloth Ratio = 2.3:1 ($ft^3/min:ft^2$) Filter Fabric was Orlon													
Plant TT	EPA	Natural Gas	Continuous (Kettle #5)										
Test Run 1				386	235	1.32	2,801	53.0	.038	.075	.220	.096	N/A
Test Run 2				383	230	1.34	2,845	51.1	.040	.079	.218	.095	99.82
Test Run 3				384	232	1.34	2,851	51.1	.038	.075	.206	.090	99.79
Average				384	232	1.33	2,832	51.7	.038	.076	.215	.094	99.80
Average Fuel Usage Factor = 0.9 KJ/g (0.8 million BTU/ton) Actual Air-to-Cloth Ratio = 5.5:1 ($ft^3/min:ft^2$) Filter Fabric was Nomex													
Plant TT	EPA	Natural Gas	Batch (Kettle #5)										
Test Run 1				341	154	1.37	2,911	25.1	.064	.128	.089	.039	N/A[b]
Test Run 2				341	154	1.35	2,852	23.6	.007	.013	.010	.005	N/A
Test Run 3				353	176	1.38	2,922	29.1	.019	.037	.027	.012	N/A
Average				345	161	1.37	2,895	26.0	.030	.059	.044	.019	N/A
Average Fuel Usage Factor = 1.2 KJ/g (1.0 million BTU/ton) Actual Air-to-Cloth Ratio = 5.2:1 ($ft^3/min:ft^2$) Filter Fabric was Nomex													

[a] Control efficiency could not be calculated because inlet data is not available.

[b] The results of inlet test data are not yet available to calculate these efficiencies.

[c] Reference 60.

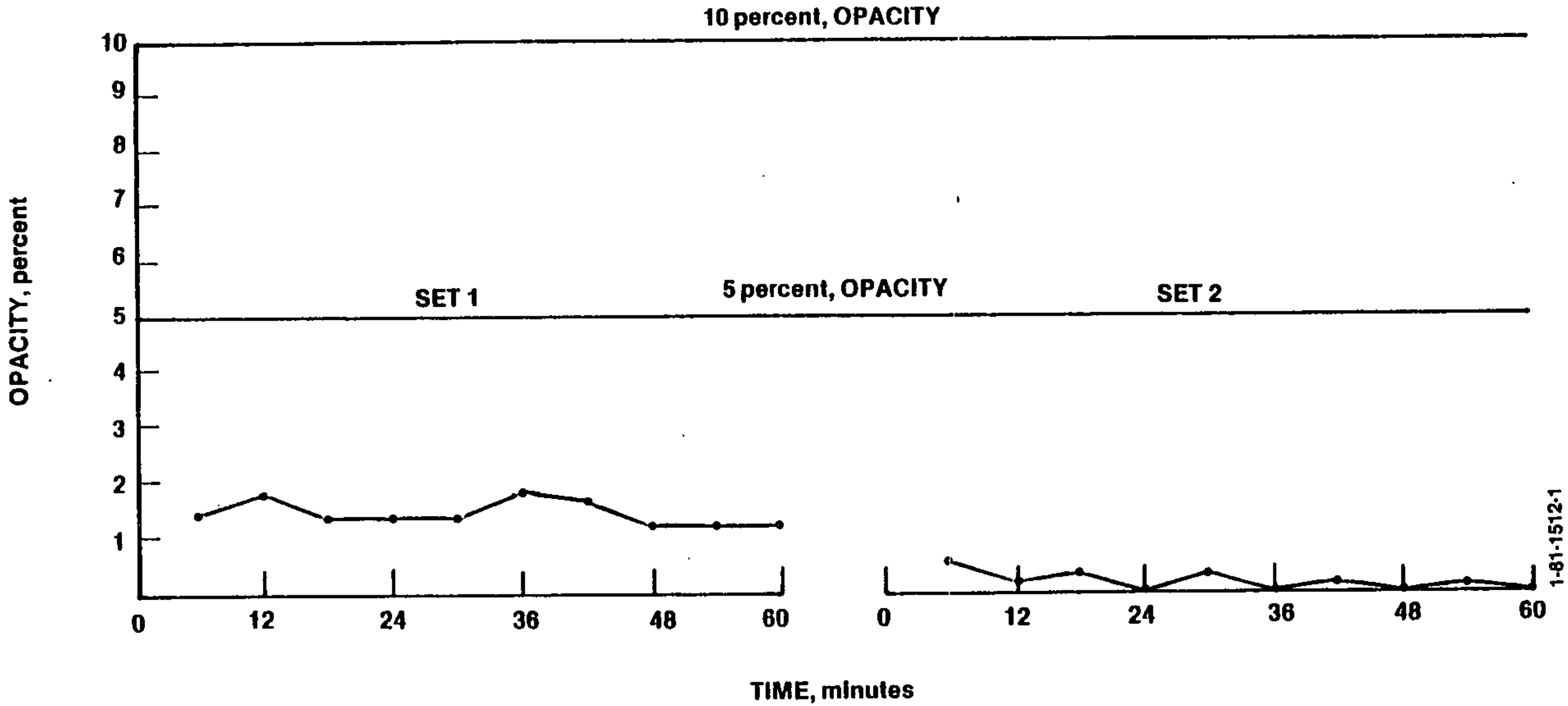


Figure 4-7. Summary of visible emissions recorded during EPA test on ore dryer at Plant Y.

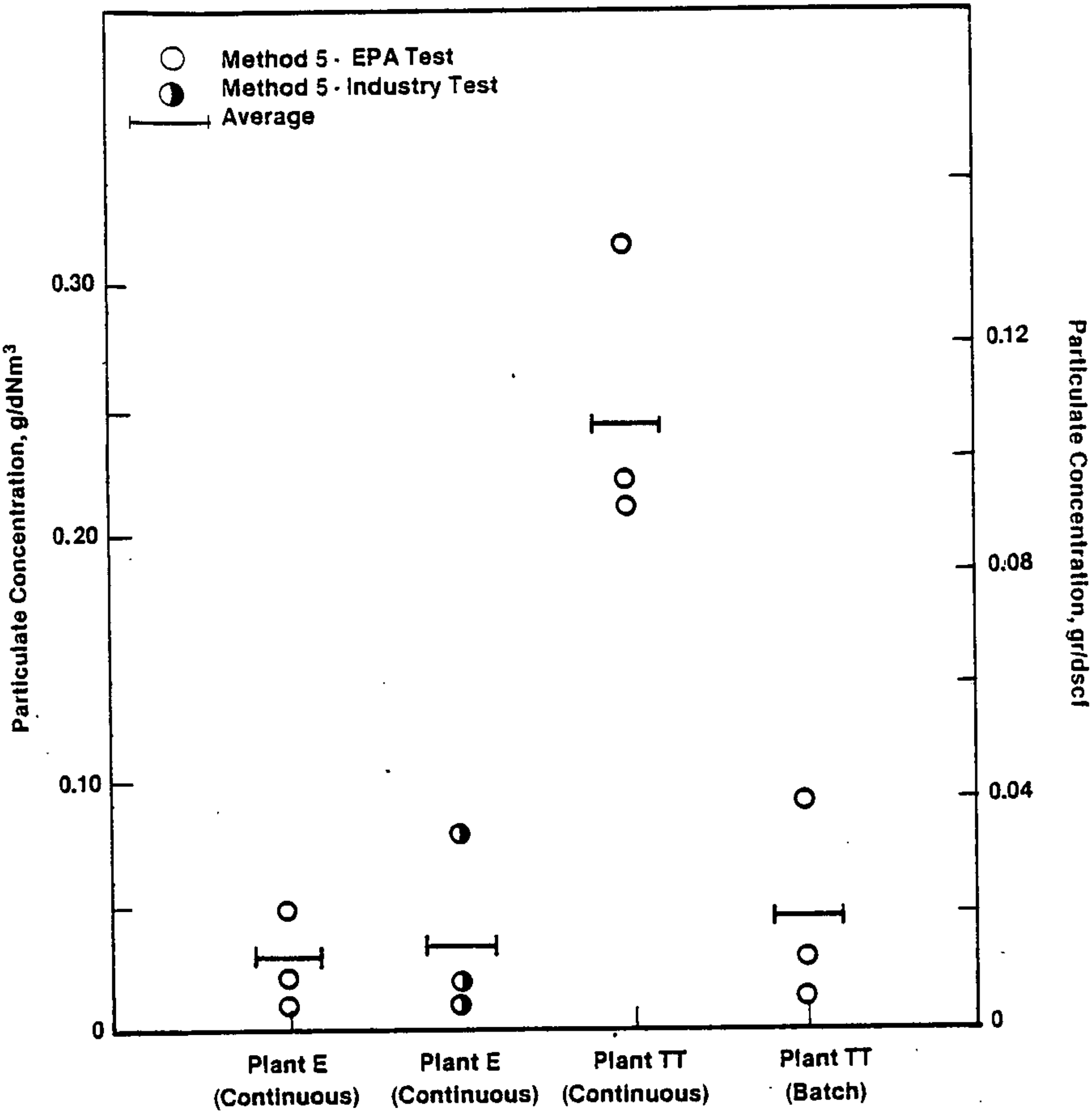


Figure 4-8. Particulate emission rates for kettle calciners controlled with fabric filters.

test is a factor of ten higher than the concentrations measured during the continuous kettle tests at Plant E. Correspondence with Plant TT personnel following EPA testing indicates that the fabric filter on the kettle tested was not operating properly. Both the batch and continuous kettle tests at Plant TT were conducted on the same kettle and the same control equipment. The higher outlet concentrations measured at Plant TT are expected to be the result of leaks around the cups on which three of the bags were attached and leaks around the rachet and clamps of two filter bags which had become loose enough to allow some gases to pass through the baghouse untreated.[61] Other factors which are expected to have resulted in a higher outlet concentration at Plant TT include a higher air-to-cloth ratio and a lower operating pressure drop.

Consistent outlet concentrations were measured for both batch and continuously operated kettles. Because of the sequencing of the tests conducted at Plant TT, the problem of when non-representative fabric filter operations began is avoided and a comparison between kettles operated in batch and continuous modes may be made. As seen in Table 4-4 and in Figure 4-8, the controlled emissions from the Plant TT kettle operated in batch mode are less than the controlled emissions from the same kettle operated in continuous mode. Thus, emissions from batch kettles are less than emissions from continuous kettles.

The outlet concentrations and the emission factors measured for the two Plant E continuous kettle tests are essentially identical. These test data probably demonstrate the highest removal efficiencies attainable with fabric filters on kettle calciners.

4.3.2.2 Representativeness of Kettle Calciner Test Results. The degree to which the test data in Table 4-4 represent kettle calciner emission control situations is discussed in this section. This representativeness is discussed in terms of the following factors:

- air flow rate,
- production rate,
- inlet dust loading,

- air-to-cloth ratio,
- cleaning method,
- fabric type,
- gas moisture content,
- operational pressure drop, and
- particle size distribution.

Air flow rates for kettle calciners will vary with the design production rate of the kettle and therefore with the size of the kettle. The test results in Table 4-4 represent the range of air flow rates used on fabric filter controlled kettles which have a continuous stucco production capacity of 10 Mg/hr (11 ton/hr).

Kettles with capacities greater than those tested by EPA will probably require higher air flow rates to ensure that the moisture in the exit gas does not condense in the fabric filter. The results of an industry test on uncontrolled emissions from a larger kettle operated at an air flow rate of 2.0 m^3/s (4292 acfm) and a stucco production rate of 14.5 Mg/hr (16 ton/hr) indicate that the uncontrolled emission factor for this kettle is about 25 g/kg (50 lb/ton) of stucco produced with a corresponding concentration of 140 g/dNm^3 (61.4 gr/dscf).[62] This concentration falls within the range of uncontrolled emissions from continuous kettle calciners measured during EPA testing. At the removal efficiency demonstrated by the fabric filters on the Plant E kettle calciners, the expected concentration of controlled emissions from this larger kettle calciner is 0.02 g/dNm^3 (0.01 gr/dscf).[63]

Recommended design air-to-cloth ratios for pulse-jet fabric filters on calciners range from 4:1 to 6:1 ($cfm:ft^2$). The actual air-to-cloth ratios exhibited by the fabric filters during the industry and EPA tests ranged from 2.3 to 5.5 ($cfm:ft^2$). However, the design air-to-cloth ratios ranged from 5:1 ($cfm:ft^2$) at Plant E to 6.4:1 ($cfm:ft^2$) at Plant TT. The actual air-to-cloth ratios are lower than the design ratios because the calciners were not operated at design air flow rates.

Fabric filters used on kettle calciners normally have pulse-jet cleaning mechanisms. The test data in Table 4-4 are for fabric filters of this type.

Normal operating pressure drops for pulse-jet fabric filters are about 0.75 to 0.87 kPa (3.0 to 3.5 inches of water). The operating pressure drop on the Plant E fabric filter was 0.62 kPa (2.5 inches of water). However, the pressure drop on the Plant TT fabric filter during both the batch and continuous tests was 0.32 kPa (1.3 inches of water). This low pressure drop on the Plant TT fabric filter, probably due to leaks found in the baghouse immediately following the testing, indicates that these test data are not be representative of normal fabric filter operation on calciners. In addition to leaks found in the baghouse, condensation of moisture in the kettle exit gases during the second batch test run caused all of the filter bags in the collector to become blinded and consequently require replacement immediately following the testing.[64]

Exit gas moisture contents measured on the continuous kettle calciners ranged from 51.1 to 69.9 percent by volume. Moisture contents in gases exiting other continuous kettle calciners should not vary widely from this range. Moisture content of the gas exiting a batch kettle will vary with time of the cycle. This, coupled with an operating temperature lower than that for continuous kettles, causes batch kettles more operating problems due to condensation in the exhaust gas stream as noted above. In many cases, condensation is avoided by the addition of heat to the exhaust stream to raise it above the dew point. This can be done directly by dilution of the exhaust stream with combustion gases or indirectly by cross-exchanging combustion gases with the process stream.

Cross-exchange and dilution had also been used in the past to improve the collection characteristics of gypsum dusts controlled with ESPs. In recent years, newer flue designs have provided improved heat transfer in kettle calcincers, making cross-exchange or dilution of the exhaust stream unnecessary. The excess heat from flue gases is now used in preheating combustion air or in drying gypsum ore in grinding mills.

Data on the particle size distribution of dust in kettle calciner exit gases could not be obtained because of the high moisture content of these gases. However, due to the similarity in grinding methods used in gypsum plants, particle size distributions in kettle calciner exit streams should not vary significantly from plant to plant.

4.3.2.3 Summary of Visible Emissions from Kettle Calciners. The visible emissions measurements recorded during the EPA source tests at Plant TT were all zero percent opacity. However, due to the existence of a dense steam plume on the Plant TT calciner baghouse stack, the representativeness of the opacity data recorded during the Plant TT test is questionable.

The maximum six-minute average opacity measurements for the EPA tests on the Plant E kettle calciner was less than one percent. These opacity measurements, however, are not representative of the mass concentrations measured since the opacities were read on a discharge stack through which both combustion gases and fabric filter exhaust gases were vented. Accounting for the dilution by combustion gases, the maximum opacity estimated to correspond to the highest concentration measured on the Plant E calciner is two percent.[65] No opacity data are available for the Plant E industry tests.

4.3.3 Performance Data for Fabric Filters on Direct Contact Flash Calciners

Data obtained from EPA and industry source tests on direct contact flash calciners controlled with fabric filters are presented in Table 4-5 and Figure 4-9. The three direct contact flash calciners tested by EPA and industry are identical units with identical fabric filter baghouses. The results of the EPA source tests indicate that fabric filters controlling flash calciner emissions achieve overall control efficiencies greater than 99.8 percent.

The source test data in Table 4-5 show average controlled particulate emission rates ranging from 0.006 g/kg of stucco produced (0.011 lb/ton) to 0.029 g/kg of stucco produced (0.058 lb/ton). The average particulate concentrations measured range from 0.013 g/dNm^3 (0.006 gr/dscf) to 0.084 g/dNm^3 (0.037 gr/dscf).

During the source tests shown in Table 4-5, the flash calciners were operated at greater than 95 percent of design capacity. The test data are therefore representative of normal operating capacities for flash calciners.

TABLE 4-5. PARTICULATE EMISSION PARAMETERS FOR DIRECT CONTACT FLASH CALCINERS CONTROLLED WITH FABRIC FILTERS

Plant Identification	Data Source	Fuel Type	Exit Gas Temperature K	Exit Gas Temperature °F	Exit Gas Flow Rate m^3/s	Exit Gas Flow Rate acfm	Exit Gas Moisture Content Volume % H_2O	Particulate Emission Factors[a] g/Kg	Particulate Emission Factors[a] lb/ton	Particulate Concentrations g/dNm^3	Particulate Concentrations gr/dscf	Control Efficiency Percent[b]
Plant Y	EPA	Residual Oil (No. 6)										
Test Run 1			445	341	1.84	3,910	38.1	.020	.040	.050	.022	99.90
Test Run 2			444	340	1.92	4,070	41.5	.023	.046	.053	.023	99.89
Test Run 3			445	341	1.89	4,010	42.5	.024	.048	.060	.026	99.88
Average			445	341	1.89	4,000	40.7	.022	.045	.053	.023	99.89
Average Fuel Usage Factor[a] = 0.9 KJ/g (0.8 million BTU/ton) Actual Air-to-Cloth Ratio = 4.2:1 ($ft^3/min:ft^2$) Filter Fabric was Nomex												
Plant C[b]	Industry	Residual Oil (No. 6)										
Test Run 1			452	355	1.49	3,158	39.0	.026	.052	.075	.033	N/A[c]
Test Run 2			452	354	1.46	3,103	33.0	.033	.065	.090	.039	N/A
Test Run 3			452	354	1.46	3,094	39.0	.029	.058	.087	.038	N/A
Average			452	354	1.47	3,118	37.0	.029	.058	.034	.015	N/A
Average Fuel Usage Factor[a] = 0.9 KJ/g (0.8 million BTU/ton) Actual Air-to-Cloth Ratio = 3.2:1 ($ft^3/min:ft^2$) Filter Fabric was Nomex												
Plant OC	EPA	Natural Gas										
Test Run 1			438	329	1.98	4,198	46.2	.009	.017	.019	.008	99.96
Test Run 2			439	331	1.90	4,037	47.6	.005	.009	.013	.006	99.98
Test Run 3			439	331	1.90	4,019	49.3	.004	.007	.014	.006	N/A[d]
Average			439	330	1.93	4,085	47.7	.006	.011	.013	.006	99.97
Average Fuel Usage Factor[a] = 0.9 KJ/g (0.8 million BTU/ton) Actual Air-to-Cloth Ratio = 4.3:1 ($ft^3/min:ft^2$) Filter Fabric was Nomex												

[a] These values are from a permit application - reference 66.

[b] Reference 67.

[c] Efficiencies for Plant C could not he calculated because inlet data is not availahle.

[d] The third outlet test run at Plant OO was not run simultaneous with an inlet run.

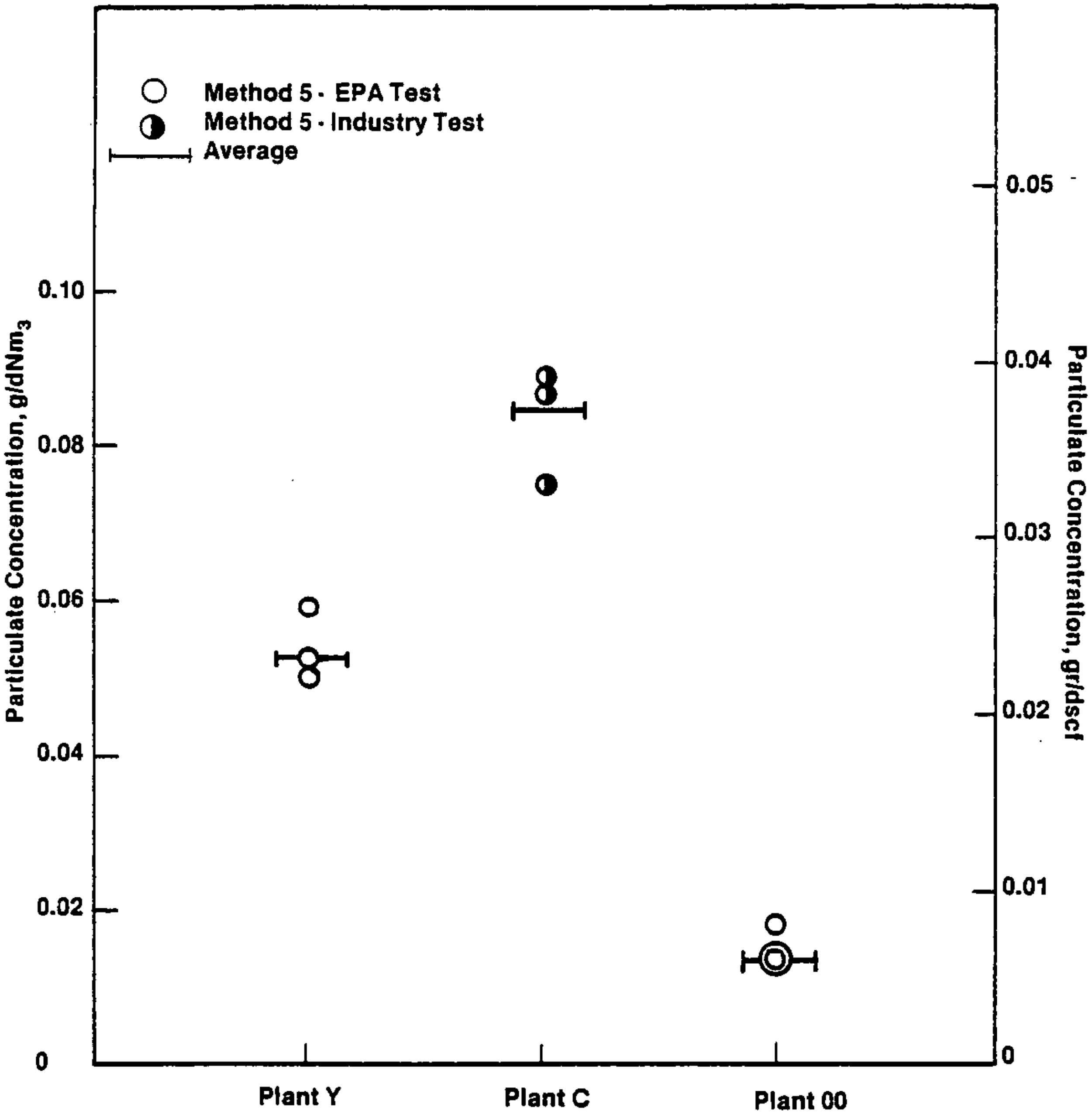


Figure 4-9. Particulate emission rates for direct contact flash calciners controlled with fabric filters.

4.3.3.1 Variations in Flash Calciner Test Results. The variations in the test results presented in Table 4-5 are discussed in this section. No significant variation is shown between the three test runs of any source test in Table 4-5. The variations among tests are discussed in terms of direct contact flash calciner operating parameters and factors which affect fabric filter performance.

The outlet particulate concentrations measured during the three direct contact flash calciner tests vary only slightly with a maximum concentration of 0.090 g/dNm^3 (0.039 gr/dscf). However, the outlet concentrations measured at Plant C are higher than expected for the calciner operating conditions. The Plant C flash calciner was operated at a lower exit gas flow rate than the Plant Y and Plant 00 calciners. All three units were operated at the same production rate. At the lower air flow rate, the actual air-to-cloth ratio of the Plant C fabric filter was lower than during the EPA tests on the Plant Y and Plant 00 calciners. Although this lower air-to-cloth ratio would be expected to result in a lower outlet concentration, the outlet concentrations measured at Plant C were higher than for the calciners operating at higher air-to-cloth ratios.

The gas moisture content measured during the Plant C test was lower than that measured during EPA tests at Plant Y and Plant 00. At the same production rate and a 22 percent lower exit gas flow rate, the gas moisture content was expected to be higher during the Plant C test.

The outlet particulate concentrations measured during the EPA direct contact flash calciner tests differ by 0.040 g/dNm^3 (0.017 gr/dscf). The two flash calciners were operated at the same production rates and air flow rates during the EPA tests.

The slightly higher outlet concentration measured during the Plant Y test is probably the result of fabric wear. The filter bags in the Plant Y flash calciner baghouse were approximately four months old. The life of Nomex bags in flash calciner baghouses is four to six months.[68] The filter bags in the Plant Y calciner fabric filter were consequently more worn than the two month old filter bags tested on the Plant 00 calciner baghouse.

Another factor which may have affected the outlet concentration from the Plant Y calciner is gas moisture content or relative humidity. The relative humidities of the Plant Y and Plant 00 calciner exit gases were 5.0 and 6.8 percent respectively. Increases in relative humidity in the 20 to 60 percent range have been shown to improve fabric efficiencies.[69] Although data on the effect of relative humidity in the range of humidity measured in the calciner exit gases are not available, the difference between the relative humidity of the two streams may have affected the overall removal efficiencies of the fabric filters.

4.3.3.2 Representativeness of Direct Contact Flash Calciner Tests. The degree to which the test data in Table 4-5 represent direct contact flash calciner emission control situations is discussed in this section. This representativeness is discussed in terms of the following factors:

- air flow rate,
- production rate,
- inlet dust loading,
- air-to-cloth ratio,
- cleaning method,
- fabric type,
- gas moisture content,
- operational pressure drop, and
- particle size distribution.

Design production rates of direct contact flash calciners are the same for all units, since the calciners tested are of an identical patented design. During the source tests presented in Table 4-5, the calciners were operated at normal production rates.

The inlet dust loadings to fabric filters controlling emissions from flash calciners may be affected by exit gas flow rates. The test data from Plant Y and Plant 00 represent exit gas flow rates used on direct contact flash calciners installed since May 1979. The difference between the inlet particulate concentrations measured at these two plants was less than eight percent, with an average concentration of 50 g/dNm^3 (22 gr/dscf). Due to the similarity in the design and operation of direct contact flash calciners, inlet loadings from new flash calciners differing significantly from those measured at Plant Y and Plant 00 are not expected.

Baghouses used on all direct contact flash calciners are pulse-jet systems. Fabric filters used on flash calciners installed since May 1979 have air-to-cloth ratios of 4.2:1 ($cfm:ft^2$) and use Nomex filter bags. Two of these fabric filters were tested.

Moisture contents measured during the outlet source tests at Plant Y and Plant 00 ranged from 38.1 to 49.3 percent by volume. Gas moisture contents differing greatly from those measured at Plant Y and Plant 00 are not expected since production and gas flow rates for these units are the same and the amount of chemically-bound water removed is the same.

Typical operating pressure drops for pulse-jet systems are around 0.75 to 0.87 kPa (3.0 to 3.5 inches of water).[70] The pressure drops for the Plant Y and Plant 00 calciner fabric filters were 1.02 and 0.70 kPa (4.1 and 2.8 inches of water) respectively.

Particle size distributions from direct contact flash calciners were presented in Section 3.2.2.4. The inlet particle size distribution in the Plant Y gas stream contained a greater percentage of large particles than the Plant 00 gas stream. The two EPA source tests in Table 4-5 consequently represent different control situations in terms of particle size distribution. Due to the similarity in flash calciner operating conditions and the similarity in grinding methods used in gypsum plants, other flash calciner particle size distributions should not vary significantly from those measured during the EPA tests.

4.3.3.3 Summary of Visible Emissions From Flash Calciners. A summary of the highest visible emissions data recorded during the EPA source tests shown in Table 4-5 is given in Figure 4-10. The data shows the average percent opacity recorded over six minute intervals during the flash calciner test at Plant Y. The highest six minute average recorded was 2.3 percent opacity.

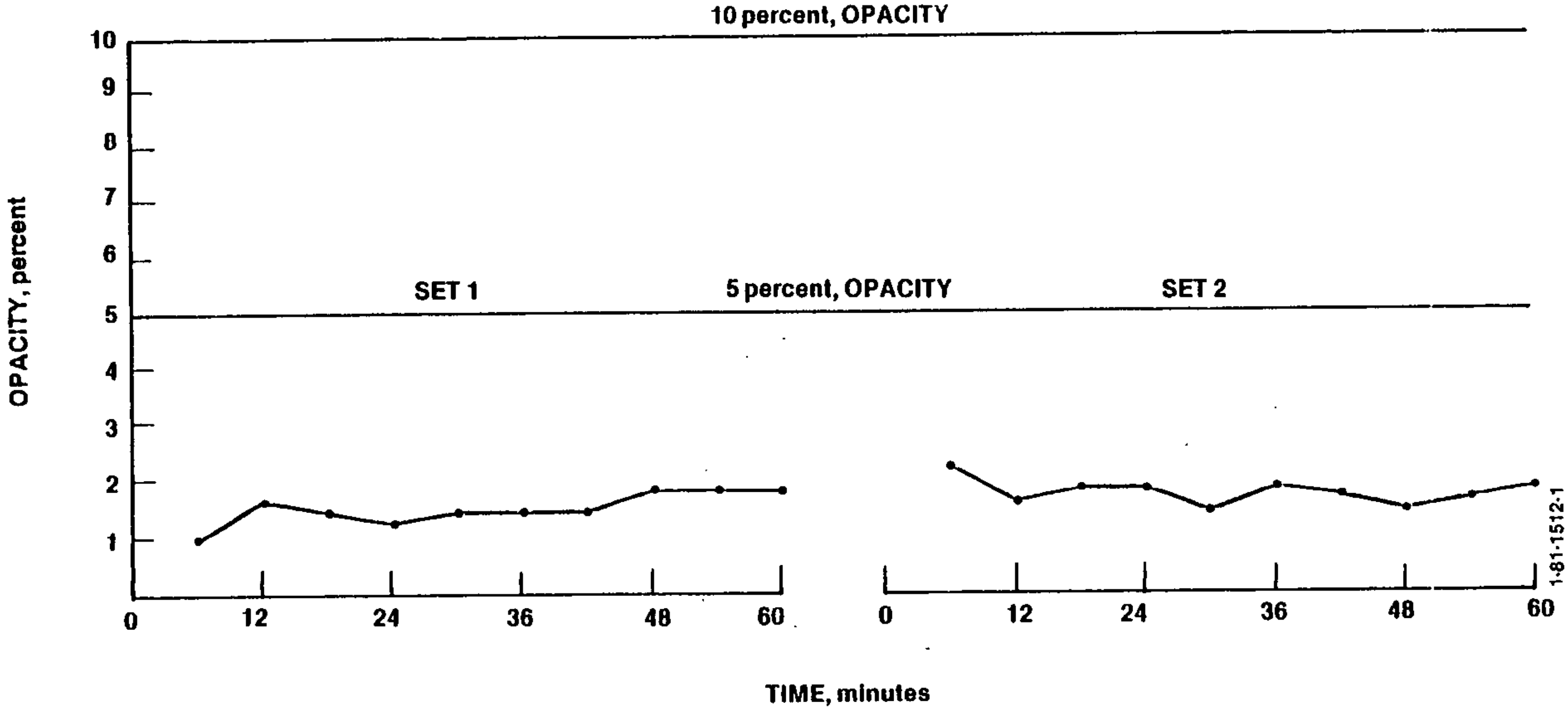


Figure 4-10. Summary of visible emissions recorded during EPA test on Calcidyne Flash calciner at Plant Y.

4.3.4 Performance Data for Fabric Filters on Board End Sawing

The results of EPA source tests on board end sawing operations controlled with fabric filters are summarized in Table 4-6 and Figure 4-11. The Plant E fabric filter controlled emissions from only a board end sawing operation and the Plant TT fabric filter controlled emissions from both board end sawing and paper scoring operations. Both fabric filters achieved overall control efficiencies of greater than 99.8 percent.

The particulate concentrations measured during the EPA source tests ranged from 0.005 g/dNm^3 (0.002 gr/dscf) to 0.032 g/dNm^3 (0.014 gr/dscf).

During the EPA source tests, the boardlines and board end sawing operations were operating under normal conditions.

4.3.4.1 Variations in the Board End Sawing Test Results. The variations in the test results presented in Table 4-6 are discussed in this section. These variations are discussed in terms of factors which affect fabric filter performance.

No significant variation is shown between the three test runs of any source test in Table 4-6. The average outlet particulate concentrations measured during the two source tests in Table 4-6 differ only slightly. The higher outlet concentration measured during the Plant TT test is expected to be due to the different air-to-cloth ratios of the two fabric filters. The higher air-to-cloth ratio at Plant TT gave a lower efficiency.

4.3.4.2 Representativeness of Board End Sawing Test Results. The degree to which the test data in Table 4-6 represent board end sawing emission control situations is discussed in this section. This representativeness is discussed in terms of factors which affect fabric filter performance, including inlet loading, air-to-cloth ratio, cleaning method, fabric type and particle size distribution.

The two boardlines tested by EPA were of medium to medium-fast speeds, ranging between 0.71 and 0.81 m/sec (140 and 160 ft/min). New boardlines are expected to operate in this same speed range.

Boardlines which operate at speeds other than those tested will have different inlet concentrations to their respective board end sawing

TABLE 4-6. PARTICULATE EMISSION PARAMETERS EXHIBITED BY BOARD END SAWING WITH FABRIC FILTERS

Plant Identification	Data Source	Emission Source	Exit Gas Temperature K	Exit Gas Temperature °F	Exit Gas Flow Rate m^3/s	Exit Gas Flow Rate acfm	Exit Gas Moisture Content Volume % H_2O	Particulate Emission Factors[a] g/Kg	Particulate Emission Factors[a] lb/ton	Particulate Concentrations g/dNm^3	Particulate Concentrations gr/dscf	Control Efficiency Percent[b]
Plant E	EPA	Board end sawing only										
Test Run 1			306	92	1.70	3,600	1.6	.001	.002	.005	.002	99.97
Test Run 2			308	95	1.65	3,500	1.7	.003	.006	.016	.007	99.90
Test Run 3			305	90	1.75	3,700	1.4	.005	.010	.023	.010	99.85
Average			306	92	1.70	3,600	1.6	.003	.006	.014	.006	99.91
Actual Air-to-Cloth Ratio = 1.5:1 ($ft^3/min:ft^2$) Filter Fabric was Dacron												
Plant TT	EPA	Board end sawing plus paper scoring										
Test Run 1			295	71	1.90	4,026	1.2	.005	.010	.021	.009	99.84
Test Run 2			297	75	1.85	3,930	1.5	.005	.009	.018	.008	99.85
Test Run 3			294	70	1.86	3,951	0.72	.008	.015	.032	.014	99.76
Average			295	72	1.87	3,969	1.1	.006	.012	.023	.010	99.81
Actual Air-to-Cloth Ratio = 4.6:1 Filter Fabric was Cotton												

[a]Based on weight of finished board product.

[b]Estimated from boardline speed.

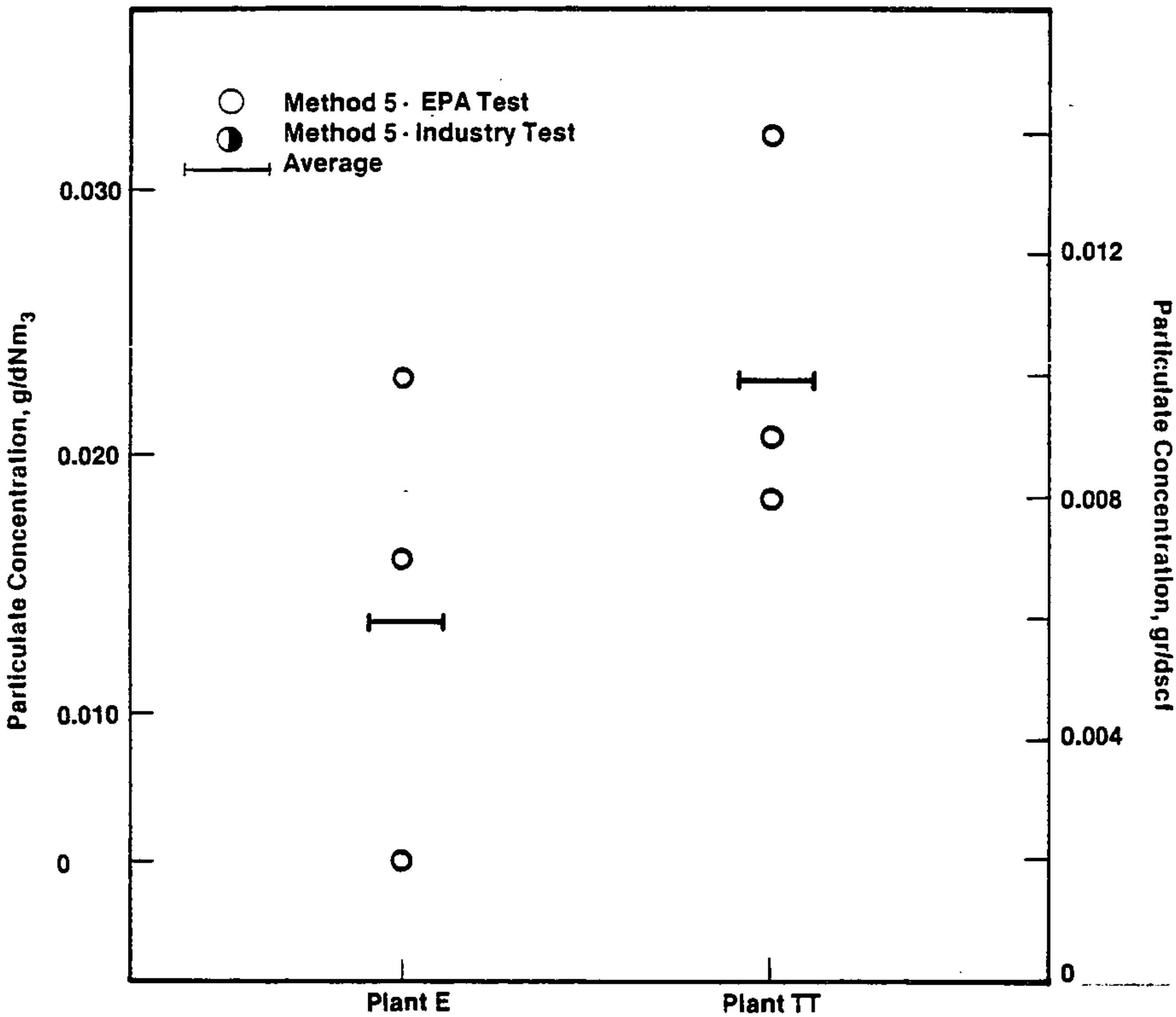


Figure 4-11. Particulate emission rates for board end sawing controlled with fabric filters.

baghouses. However, as discussed in Section 4.1.1.2, outlet concentrations for mechanical shaker baghouses are only minimally affected by large changes in inlet concentration. Emission factors from board end sawing operations will therefore vary with line speeds. For a constant outlet concentration and a given air flow rate, the emission factor would be higher for a slower boardline since the production rate in Mg/hr (ton/hr), is lower.

The recommended air-to-cloth ratio for shaker type fabric filters collecting gypsum dust is 2.5:1 (cfm:ft^2).[71] The actual air-to-cloth ratios of the plants tested were 1.5:1 and 4.6:1 (cfm:ft^2).

Filter fabrics suitable for collecting board end sawing dust are numerous because the temperature and moisture content of the gas stream to be treated is at ambient conditions. Fabrics normally used are Dacron or cotton, and both types were tested.

The distribution of particle sizes in the inlet gas to board end sawing fabric filters could not be measured using EPA Method 5 because of the large pieces of gypsum and paper in the gas stream. However, the particle size distribution resulting from board end sawing is not expected to differ from one operation to the next.

4.3.4.3 Summary of Visible Emissions from Board End Sawing. A summary of the highest visible emissions data recorded during the EPA source tests shown in Table 4-6 is given in Figure 4-12. The data show the average opacity recorded over six minute intervals during the board end sawing tests at Plant E. The highest six minute average recorded was 4.6 percent opacity.

4.3.5 Performance Data for Fabric Filters on Boardline Mixing, Scoring, Conveying, and Storage Bins

Data obtained from an industry source test on landplaster storage bins is shown in Table 4-7. The data show an average controlled particulate concentration of 0.009 g/dNm^3 (0.004 gr/dscf).

A summary of the highest visible emissions recorded during an EPA-Method 9 test on a pulse-jet fabric filter controlling the combined emissions from boardline dry mixing, scoring, conveying, and storage

TABLE 4-7. PARTICULATE EMISSION PARAMETERS FOR LANDPLASTER STORAGE BINS[a,b] CONTROLLED WITH FABRIC FILTERS

Plant Identification	Data Source	Exit Gas Temperature K	Exit Gas Temperature °F	Exit Gas Flow Rate m^3/s	Exit Gas Flow Rate acfm	Exit Gas Moisture Content Volume % H_2O	Particulate Emission Factors[a] g/Kg	Particulate Emission Factors[a] lb/ton	Particulate Concentrations g/dNm^3	Particulate Concentrations gr/dscf
Plant GG	Industry									
Test Run 1		382	109	3.53	7,487	1.2	c	c	.005	.002
Test Run 2		379	106	3.65	7,732	1.3			.005	.002
Test Run 3		383	110	3.60	7,628	0.75			.005	.002
Average		381	108	3.59	7,616	1.1			.005	.002

[a]Reference 72.

[b]Landplaster is dried, ground gypsum.

[c]Production data not yet available.

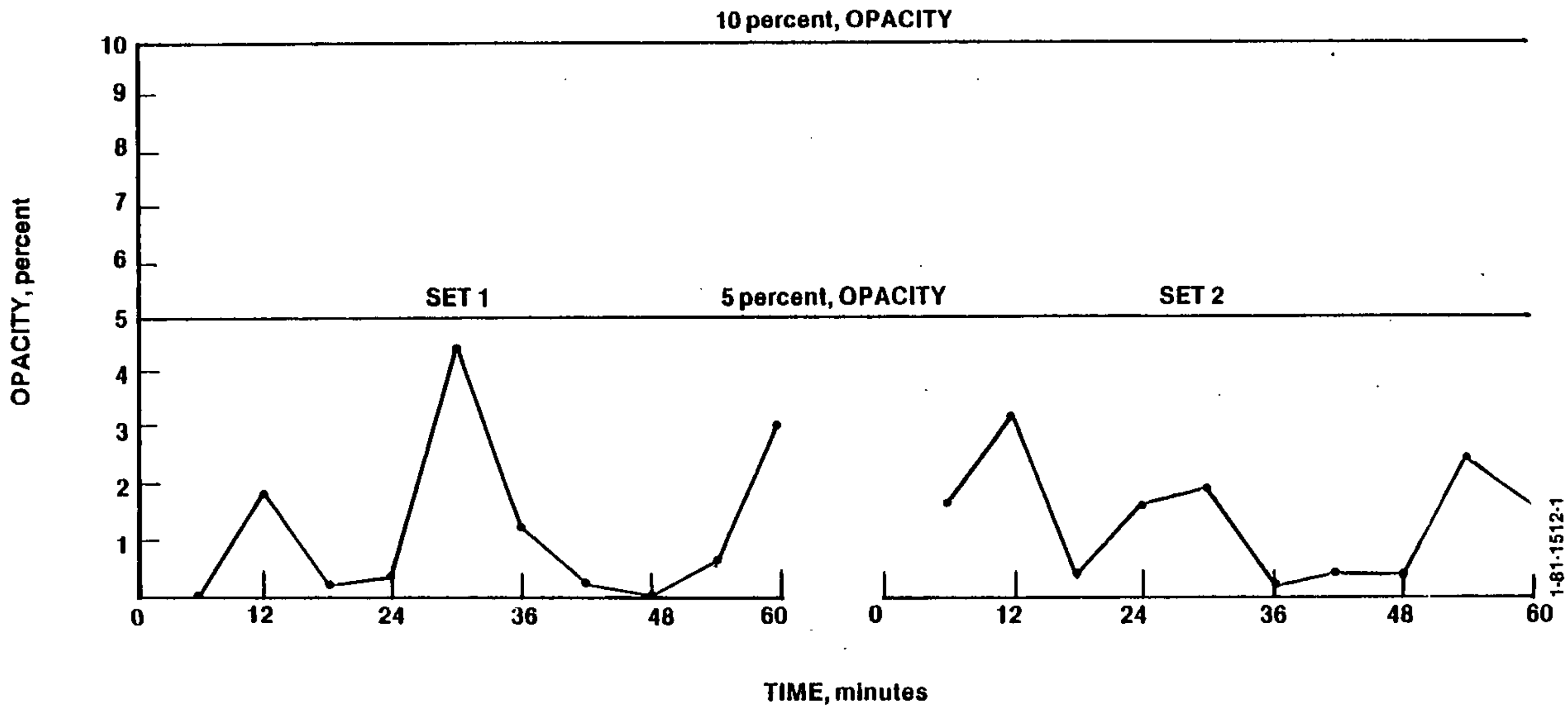


Figure 4-12. Summary of visible emissions recorded during EPA test on board end sawing at Plant E.

bins is given in Figure 4-13. The highest six minute average recorded was 2.3 percent opacity.

A summary of the highest visible emissions recorded during an EPA-Method 9 test on a fabric filter controlling the combined emissions from boardline dry mixing, pin mixing, conveying, and a storage bin is given in Figure 4-14. The highest six minute average recorded was 0.8 percent opacity.

4.3.6 Performance Data for Fabric Filters on Plaster Mixing and Bagging

Data obtained from an industry source test on a plaster mixing and bagging operation are given in Table 4-8. The data show an average controlled emission rate of 0.025 g/kg (0.05 lb/ton) of plaster bagged and an average emission concentration of 0.011 g/dNm^3 (0.005 gr/dscf).

The visible emissions recorded during two EPA-Method 9 tests on the combined emissions from plaster mixing and bagging operations was zero percent opacity.

4.3.7 Performance Data for ESP's on Continuous Batch Kettles and Grinding Mills

Data obtained from industry source tests on the combined emissions from grinding mills and kettle calciners controlled with ESP's are given in Table 4-9. The test data show controlled particulate emission factors ranging from 0.04 to 0.06 g/kg (0.07 to 0.11 lb/ton) of processed material. The average particulate concentrations corresponding to these emission factors are 0.090 g/dNm^3 (0.039 gr/dscf) and 0.081 g/dNm^3 (0.035 gr/dscf).

Estimated overall control efficiencies for the two ESP's shown in Table 4-9 (Plant W and Plant RR) are 99.5 and 99.7 percent respectively. These efficiencies were estimated using uncontrolled emission data for grinding mills and kettle calciners.[76] On the basis of these estimates, and a review of other available EPA Method 5 stack tests on ESP's, the data in Table 4-9 represent the lowest controlled emission levels currently being achieved with ESP's on the combined emissions from grinding mills and kettle calciners.

The average opacity readings recorded during the Plant W tests were less than five percent. The average opacity readings recorded during tests at Plant RR were zero percent.

TABLE 4-8. PARTICULATE EMISSION PARAMETERS FOR PLASTER MIXING AND BAGGING OPERATION CONTROLLED WITH FABRIC FILTERS[a]

Plant Identification	Data Source	Exit Gas Temperature		Exit Gas Flow Rate		Exit Gas Moisture Content Volume % H_2O	Particulate Emission Factors[a]		Particulate Concentrations	
		K	°F	m^3/s	acfm		g/Kg	lb/ton	g/dNm^3	gr/dscf
Plant GG	Industry									
Test Run 1		320	116	2.04	4,331	0.54	.014	.028	.007	.003
Test Run 2		305	90	2.42	5,135	1.30	.022	.044	.009	.004
Test Run 3		319	114	2.55	5,396	0.61	.018	.035	.009	.004
Average		315	107	2.34	4,954	0.82	.018	.036	.009	.004

[a]Reference 73.

TABLE 4-9. EMISSION PARAMETERS FOR GYPSUM FACILITIES CONTROLLED WITH ELECTROSTATIC PRECIPITATORS

Plant Identification	Data Source	Fuel Type	Emission Sources Vented to ESP	Exit Gas Flow Rate		Exit Gas Temperature		Exit Gas Moisutre Content	Particulate Emission Factors[a]		Particulate Concentrations	
				m^3/s	acfm	K	°F	% H_2O	g/Kg	lb/ton	g/dNm^3	gr/dscf
Plant W[b]	Industry test (EPA Method 5)	N/A	two grinding mills, two screw conveyors, four kettle calciners									
Test Run 1				18.9	39,986	349	168	13.3	0.08	0.16	.126	.055
Test Run 2				18.6	39,456	354	178	12.5	0.06	0.12	.095	.041
Test Run 3				18.4	39,102	351	173	16.7	0.03	0.06	.046	.020
Average				18.6	39,515	351	173	14.2	0.06	0.11	.090	.039
Plant RR[c]	Industry test (EPA Method 5)	N/A	two grinding mills, two screw conveyors, two continuous kettle calciners									
Test Run 1				10.7	22,714	355	180	13.5	0.06	0.12	.138	.060
Test Run 2				10.7	22,629	356	182	14.6	0.03	0.05	.062	.027
Test Run 3				10.7	22,714	359	187	13.8	0.02	0.04	.046	.020
Average				10.7	22,686	357	183	14.0	0.04	0.07	.081	.035

[a] Based on reported total tons of stucco produced plus total tons of rock milled per hour.

[b] Reference 74.

[c] Reference 75.

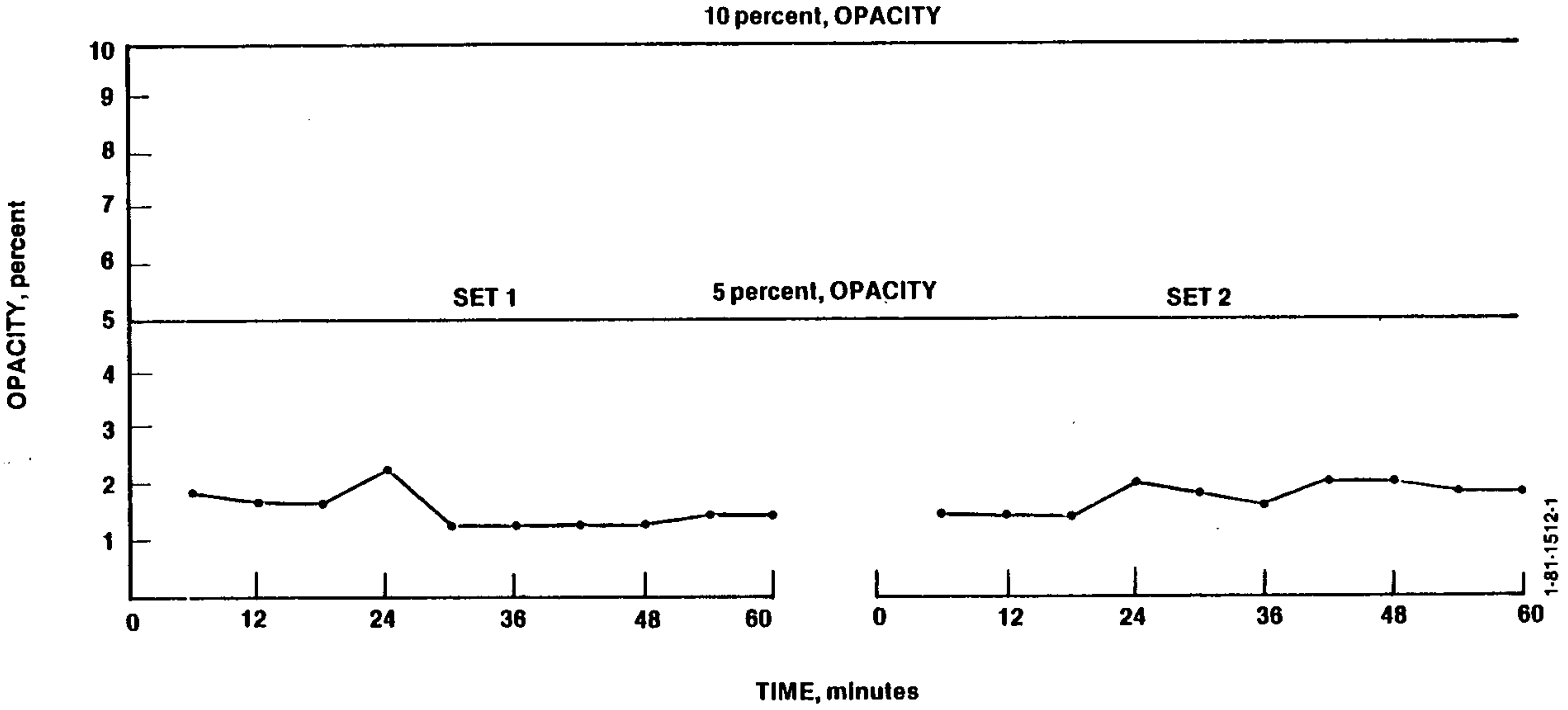


Figure 4-13. Summary of visible emissions recorded for dry mixing, scoring, conveying and storage bins controlled with a fabric filter.

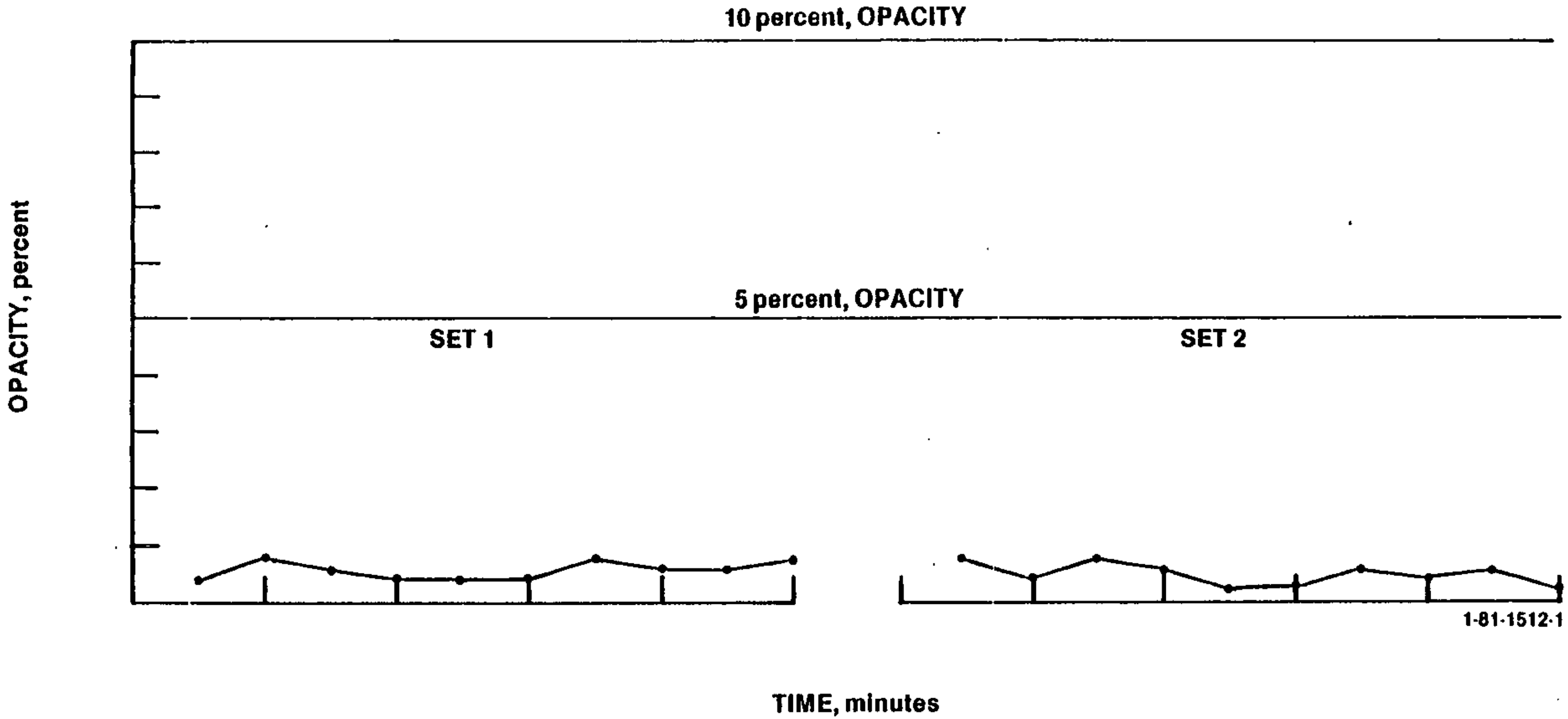


Figure 4-14. Summary of visible emissions recorded for dry mixing, pin mixing, conveying and a storage bin controlled with a fabric filter.

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5. MODIFICATION AND RECONSTRUCTION

Standards of performance are applicable to facilities whose construction, modification, or reconstruction commenced (as defined under 40 CFR 60.2(i)) after proposal of the standards. Such facilities are termed "affected facilities". Standards of performance are not applicable to "existing facilities" which are facilities whose construction, modification, or reconstruction commenced on or before proposal of the standards. However, an existing facility may become an affected facility and therefore subject to 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 Section 5.1. Section 5.2 discusses the applicability of these provisions to process facilities in gypsum manufacturing plants.

5.1 SUMMARY OF MODIFICATION AND RECONSTRUCTION PROVISIONS

5.1.1 Modification

With certain exceptions, any physical or operational change to an existing facility that would result in an increase in the emission rate to the atmosphere of any pollutant to which a standard applied, would be considered a modification within the meaning of Section 111 of the Clean Air Act. The key to a modification determination is whether total emissions to the atmosphere (expressed in kg/hr) from the facility as a whole have increased as a result of the change. For example, if the affected facility is defined as a group of pieces of equipment, then the aggregate emissions from all the equipment must increase before the facility will be considered modified.

Exceptions which allow certain changes to an existing facility without it becoming an affected facility, irrespective of an increase in emissions, are listed below.

1. Routine maintenance, repair, and replacement.

2. An increase in production rate without a capital expenditure (as defined in 40 CFR 60.2 (bb)).

3. An increase in the hours of operation.

4. Use of an alternative fuel or raw material if, prior to 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 the reduction of air pollutants, except when an emission control system is removed or is replaced by a system determined by EPA to be less environmentally beneficial.

6. Relocation or change in ownership of the existing facility.

Once an existing facility is determined to be modified, all of the emission sources of that facility are subject to the standards of performance for the pollutant whose emission rate increased and not just the emission source which displayed the increase in emissions. However, a modification to one existing facility at a plant will not cause other existing facilities at the same plant to become subject to standards.

An owner or operator of an existing facility who is planning a physical or operational change which 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 §60.7(a)(4).

5.1.2 Reconstruction

An existing facility may also become subject to new source performance standards if it is "reconstructed." As defined in 40 CFR 60.15, a reconstruction is 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 of 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 rate.

The purpose of the reconstruction provisions is to discourage the perpetuation of an existing facility (instead of replacing it at the end of its useful life) for the sole purpose of circumventing a standard which is applicable to new facilities. Without such a provision all but vestigal components (such as frames, housing, and support structures) of the existing facility could be replaced without the facility being considered a "new" facility subject to new source performance standards. If the facility is determined to be reconstructed, all of the provisions of the standards of performance applicable to that facility must be complied with.

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 shall notify the appropriate EPA regional office 60 days before the construction of the replacements commences.

5.2 APPLICATION TO GYPSUM PLANT PROCESS FACILITIES

5.2.1 Modification

The only equipment or processes within a gypsum plant which are likely to be modified as defined under 40 CFR 60.14 are ore dryers and calciners. Boardline processes such as scoring and chamfering and board end sawing are not subject to any alterations that would increase particulate emissions. Dry mixing and stucco conveying and storage also would not usually be altered in ways which would make them subject to the definitions presented in 40 CFR 60.14. However, it is possible that replacement of the conveyor screws with a different design to increase throughput could constitute a modification.

Potential ore dryer modifications might include:

- Installation of a larger fan to increase total dryer air rate in order to increase drying and hence throughput rate,
- Burner alterations or installation of a new burner to increase firing rate, or permit change from "clean" fuels to "dirtier" fuels, and

- Replacement of existing drum motor by higher horsepower motor to permit heavier ore load and hence higher throughput rate.

There is no information to indicate that such changes have actually occurred on ore dryers.

For calciners, potential modifications might include:

- Burner alterations as described for ore dryers,
- Physical enlargements of the kettle shell to increase throughput capabilities,
- Installation of additional flues in kettles to increase heat transfer and production capacity,
- Conversion of batch kettles to continuous kettles if such a conversion resulted in an increase in emissions, and
- Physical changes to permit increased recirculation of combustion gases within units, again if such a change resulted in an increase in emissions.

5.2.2 Reconstruction

It is unlikely that any reconstructions as defined under 40 CFR 60.15 would occur for gypsum processing equipment other than calciners. It is possible that physical enlargements, replacement of flues in kettles, or replacement of shells for kettles and combustion-contact chambers for direct contact units would constitute reconstructions, if the fixed capital cost of the new components exceeded 50 percent of the fixed capital cost of a comparable new calciner. Replacement of motors for the scoring operations would possibly constitute a reconstruction under 40 CFR 60.15 since the motors represent a major portion of the equipment required for this simple operation.

6. MODEL PLANTS AND REGULATORY ALTERNATIVES

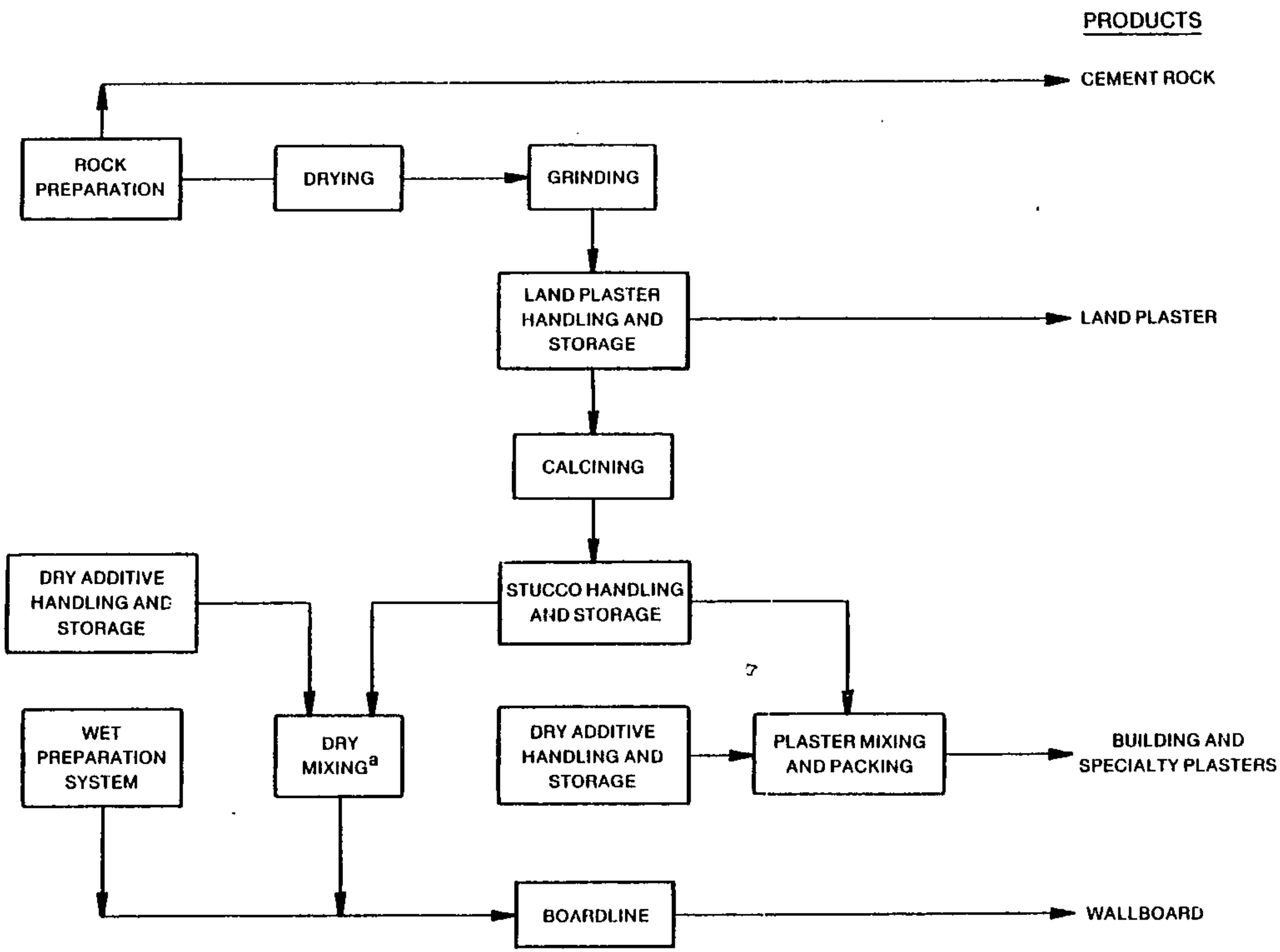
Model gypsum plants and regulatory alternatives are defined in this chapter. The model plants are chosen to be representative of new gypsum plants and of expansions which would be subject to new source performance standards. Three regulatory alternatives are defined for each model plant. These model plants and regulatory alternatives are used in subsequent chapters as the basis for analysis of the environmental and economic impacts associated with control of particulate emissions from gypsum facilities.

Section 6.1 describes the model plants in terms of the process configuration, plant capacity, operating hours, physical plant layout, raw material requirements, and utility requirements. Section 6.2 describes the control options for individual emission sources and regulatory alternatives proposed for each model plant.

6.1 MODEL PLANTS

Process operations used in gypsum product manufacture are described in Chapter 3 and control alternatives for these operations are described in both Chapter 3 and Chapter 4. A conceptual diagram of a gypsum plant is shown in Figure 6-1. The plant shown could produce the four major product categories discussed previously in Chapter 3: cement rock, land plaster, building and specialty plasters, and wallboard. All plants fundamentally follow the schematic of Figure 6-1 although product mix might differ from plant to plant. The gypsum processed in these model plants is used in wallboard manufacturing and the preparation of building and specialty plasters.

The model plants chosen do not include production of cement rock and land plaster for sales. Cement rock is generally produced by primary crushing and screening and would occur prior to the ore dryer. Land plaster produced for sales is basically a seasonal operation since land plaster can be used as a fertilizer. The additional capacity in ore



[a]This operation consists merely of mixing dry additives with stucco in a screw conveyor as it is transported to the head of the boardline.

Figure 6-1. Schematic of gypsum product manufacturing plant.

drying and grinding required for this product is already accounted for in dryer and grinder design and operating capacities. Therefore, there are no model plants considering an ore dryer alone.

Gypsum plants vary according to product mix, size, process equipment and plant layouts. The model plants considered in this study are detailed in the following subsections.

6.1.1 Plant Capacities, Process Configurations, and Equipment Design

New gypsum plants dedicated to wallboard manufacture could range in annual production capacity from 10.8 million square meters (116 million square feet) to 37.3 million square meters (401 million square feet). The three model plants chosen cover this range of capacities. In addition, two types of calciners (continuous kettle and direct contact flash) could be used to produce stucco in each model plant. Model plants 1, 2, 3, 4, 7 and 8 were chosen to represent combinations of production capacity and calciner types expected to be used in the future. Table 6-1 illustrates these combinations and presents the design production rates of the principal process units.

The major pieces of equipment used in manufacturing gypsum products are of discrete sizes. Table 6-2 presents the operating parameters for these major pieces of equipment. The equipment is combined in a modular fashion to comprise a particular model plant. The operating hours of individual pieces of equipment are varied to meet a desired overall plant production rate. For example, the same ore dryer is used in small and medium model plants. To meet the overall desired production demand, the ore dryer would operate 3123 hours/year in small plants and 6454 hours/year in medium plants.

Some new plants are expected to produce building and specialty plasters, in addition to wallboard. Model plant 5 represents a medium-sized plant that has extra calcining capacity in order to produce plasters and wallboard products. In addition, plants using stucco as the starting material, rather than gypsum ore, are also possible in the future. Model plant 6 represents a medium-sized plant of this type.

TABLE 6-1. MODEL GYPSUM PLANT CONFIGURATIONS AND CAPACITIES
(Complete Plants)

Plant Number	Plant Type	Plant Size	Dryer Operating Rate[a] (mg/hr)	Dryer Operating Rate[a] (ton/hr)	Dryer Operating Hours per day	Number of Calciners	Calciner Type	Stucco Rate (mg/hr)	Stucco Rate (ton/hr)	Design Board Rate[b] (Million m^2/yr)	Design Board Rate[b] (Million ft^2/yr)
1	Board	Small	37	40	9	1	Continuous Kettle	11	12	10.8	116
2	Board	Small	37	40	9	2	Direct Contact Flash	13	14	10.8	116
3	Board	Medium	37	40	19	2	Continuous Kettle	22	24	21.6	232
4	Board	Medium	37	40	19	4	Direct Contact Flash	25	28	21.6	232
5	Board/ Plaster	Medium	46	50	21	3	Continuous Kettles	33	36	21.6	232
6	Board/ Stucco Feed	Medium	0	0	0	0	--	22	24	21.6	232
7	Board	Large	59	64	20	4	Continuous Kettles	44	48	37.3	401
8	Baord	Large	59	64	20	6	Direct Contact Flash	38	42	37.3	401

[a]Based on dry rock produced.

[b]Boardline rate is a design value only based on one half inch board thickness. Actual rate based on calcining capacity will vary somewhat from the design value.

TABLE 6-2. MAJOR EQUIPMENT OPERATING PARAMETERS FOR MODEL PLANTS

Equipment	Plant Size	Design Capacity[a] Mg/hr	Design Capacity[a] ton/hr	Operating Capacity[a] Mg/hr	Operating Capacity[a] ton/hr	Fuel Usage KJ/g	Fuel Usage million BTU/ton
Ore dryer	small	45	50	36	40	0.17[b]	0.15[b]
	medium	45	50	36	40	0.17	0.15
	large	73	80	58	64	0.17	0.15
Grinding mill	small	15	17	15	17	N/A[c]	N/A[c]
	medium	15	17	15	17	N/A	N/A
	large	25	27	25	27	N/A	N/A
Direct contact flash calciners	all plants	6.4	7.0	6.4	7.0	0.9[d]	0.8[d]
Continuous kettle calciners	all plants	10.9	12.0	10.9	12.0	0.8[e]	0.7[e]
Stucco conveying	---	32	35	23.6	26	N/A	N/A
Stucco storage	---	---	---	23.6	26	N/A	N/A
Boardline	small	14.5	16	14.5	16	1.6[f]	1.4[f]
	medium	29	32	29	32	1.6	1.4
	large	50	55	50	55	1.6	1.4

[a] Based on process outlet

[b] Assumes 3 to 4 weight percent moisture removal.

[c] N/A = not applicable

[d] Reference 1.

[e] Reference 2.

[f] Board drying kiln fuel usage for half inch wallboard production, Reference 3.

Existing gypsum plants can expand capacity in several ways. Table 6-3 describes these expansions and notes the new equipment and the new emission sources. Plants adding calcining capacity for increased stucco production are represented by model plants 9 (continuous kettle calciner) and 10 (direct contact flash calciner). Another typical expansion is the addition of another boardline to increase wallboard production. Model plants 11 and 12 represent this type of expansion for the two types of calciners expected.

Two types of replacements are expected in the future. Model plant 10 is representative of the replacement of a kettle calciner with a direct contact flash calciner. Model plant 13 represents the replacement of obsolete plaster mixing and bagging equipment. For this model plant, only plaster mixing would be considered for regulation under a gypsum NSPS since bagging is being considered under another standards development. These replacements are listed in Table 6-3.

6.1.2 Process Requirements

When evaluating model plants with regard to product mix, size, and process equipment, various operating requirements must be considered. These include the following:

- operating labor,
- maintenance labor,
- process water,
- electricity,
- process fuel, and
- raw materials.

Process water requirements are for board production needs. Electricity is used to operate major process equipment. Process fuel consumption is for calcining, ore drying and board drying. These items are used for the base plant costs presented along with control equipment costs in Chapter 8. Estimates of these requirements for each model plant are given in Tables 6-4.

Table 6-5 presents typical raw material requirements for finished wallboard product. These include water, paper and various additives.

TABLE 6-3. MODEL GYPSUM PLANT CONFIGURATIONS AND CAPACITIES (Expansions or Replacements)

Model Plant Number	Expansion or Replacement Types	Equipment Added	New Emission Sources	Increased Stucco Capacity (Mg/hr)	Increased Stucco Capacity (tons/hr)	Remarks
9	Increase calcining capacity	Grinding mill (1) Continuous kettle (1) Stucco conveying and storage	Kettle calciner	11	12	Boardline operation increased from 5 days per week to 6 2/3 days per week to account for increased capacity
10	Increase calcining capacity, or replacement of kettle calciner with direct contact flash calciner	Direct contact flash calciner stucco conveying	Direct contact flash calciner	6.4	7	Boardline operation increased from 5 days per week to 6 2/3 days per week to account for increased capacity
11	Increase Board production	Grinding mill (1) Continuous kettle (1) Stucco conveying and Storage Small board line	Kettle calciner scoring and chamfering dry mixing board end sawing	11	12	Represents plant not needing a dryer or a general production expansion
12	Increase Board Production	Grinding mill (1) Direct contact flash calciners (2) Stucco conveying and storage Small board line	Direct contact flash calciners (2) scoring and chamfering dry mixing board end sawing	13	14	Represents plant not needing a dryer or a general production expansion
13	Replacement of plaster equipment	Plaster mixer and bagger	Plaster mixer	-	-	Represents replacement of obsolete equipment.

TABLE 6-4. MODEL PLANT PROCESS OPERATING REQUIREMENTS (Metric Units)

Model Plant No.	Gypsum Consumption Gg/yr	Operating Labor[a] (people/shift)	Maintenance Labor[b] (people/shift)	Process Water (m^3 per year)	Electricity (TJ per year)	Process Fuel (TJ per year)
Complete plants						
1	108	12	2	71,900	19.1	340
2	126	12	2	84,000	22.3	398
3	216	13	3	143,800	38.2	680
4	253	13	3	168,000	44.6	784
5	325	17	3	143,800	55.4	777
6	216	11	2	143,800	17.3	272
7	433	13	4	287,700	76.3	1362
8	378	13	4	252,000	67.0	1191
Expansions (Operating requirements are those directly associated with equipment in the expansion only. The additional capacity will increase the overall plant requirements shown above proportional to the additional tons per year processed.)						
9	108	no change	no change	no change	9.4 increase	159 increase
10	63	no change	no change	no change	9.4 increase	92 increase
11	108	8	1	71,900 increase	16.9 increase	295 increase
12	126	8	1	84,000 increase	19.8 increase	345 increase
13	no change - replacement of obsolete equipment					

[a]Direct operating labor per shift including one foreman. Does not include administrative or out-door staff.

[b]Direct maintenance labor per shift. Materials not included but will be taken as percentage of labor cost.

TABLE 6-4. MODEL PLANT PROCESS OPERATING REQUIREMENTS
(English Units)

Model Plant No.	Gypsum Consumption (thousands tpy)	Operating Labor[a] (people/shift)	Maintenance Labor[b] (people/shift)	Process Water (million gal/year)	Electricity (million kwh/year)	Process Fuel (billion Btu/year)
Complete plants						
1	119	12	2	19.0	5.3	321
2	139	12	2	22.2	6.2	375
3	238	13	3	38.0	10.6	642
4	278	13	3	44.4	12.4	740
5	357	17	3	38.0	15.4	733
6	238	11	2	38.0	4.8	257
7	476	13	4	76.0	21.2	1,285
8	416	13	4	66.6	18.6	1,124
Expansions (Operating requirements are those directly associated with equipment in the expansion only. The additional capacity will increase the overall plant requirements shown above proportional to the additional tons per year processed.)						
9	119	no change	no change	no change	2.6 increase	150 increase
10	69	no change	no change	no change	2.6 increase	87 increase
11	119	8	1	19.0 increase	4.7 increase	278 increase
12	139	8	1	22.2 increase	5.5 increase	325 increase
13		2	no change - replacement of obsolete equipment			

[a]Direct operating labor per shift including one foreman. Does not include administrative or out-door staff.

[b]Direct maintenance labor per shift. Materials not included but will be taken as percentage of labor cost.

TABLE 6-5. RAW MATERIAL REQUIREMENTS[6] FOR WALLBOARD PRODUCT

	Per megagram of wallboard	Per short ton of wallboard
Process water, to slurry the stucco	0.6 m^3	144 gal
Lignin	1 kg	2 lb
Raw gypsum (accelerator)	5 kg	10 lb
Starch	5 kg	10 lb
Fiber glass	2 kg	4 lb
Paper pulp	4-8 kg	12 lb
Soap (to produce foam)	1 kg	2 lb
Sawdust (may replace paper pulp)	4-8 kg	12 lb
Potassium sulfate	0.5 kg	1 lb
Perlite	4-6 kg	10 lb
Paper	70-95 kg	140-190 lb
Stucco (appx.)	760 kg	1520 lb

Note: Additives and relative amounts of additives will vary for the particulate type of wallboard produced.

6.1.3 Emission Parameters

Two levels of emission control are considered in this study. These are baseline and more stringent (or best demonstrated) levels. Baseline emission levels are presented in Chapter 3. The more stringent emission levels are based on EPA and EPA-approved test results presented in Chapter 4. Uncontrolled and controlled emission parameters for emission sources from model gypsum plants are given in Table 6-6.

6.1.4 Plant Layouts

Stack layout configurations and plot plans vary according to plant, site, and other factors including product mix produced. An example of a plot plan showing stack locations for Model Plant Number 1 is shown in Figure 6-2. This layout is representative of a typical plant layout and does not necessarily reflect the exact layout of any actual plant.

6.2 REGULATORY ALTERNATIVES

6.2.1 Approach

Regulatory alternatives considered for the model gypsum plants are summarized in Table 6-7. For each source within a plant, two emission levels were considered:

1. Controlling emissions to the baseline level, which would be required under the majority of existing State regulations as described in Chapter 3, and

2. Controlling emissions to the level of emission reduction achievable in the gypsum industry as demonstrated in EPA and EPA-approved tests. For all sources, particulate control equipment would be required to meet the baseline level. The more stringent control levels for each source would be met by requiring more frequent inspections and better maintenance practices for control devices of the same type that would be installed to meet existing State regulations.

Two monitoring options were considered for Regulatory Alternatives 2 and 3. Monitoring option A represents opacity measurements of emissions from each source conducted on a weekly basis by a certified observer using EPA Reference Method 9. Monitoring option B represents continuous opacity monitoring using transmissometers on each source. The increased maintenance and more frequent bag replacement necessary to achieve the

TABLE 6-6. EMISSION PARAMETERS FOR SOURCES IN MODEL GYPSUM PLANTS (Metric Units)[a]

Emission Source	Gas Flow (m^3/s)	Gas Temperature (K)	Process Rate[b] Mg/hr	Uncontrolled Emissions Mg/yr	Uncontrolled Emissions g/kg	Uncontrolled Emissions g/m^3	Baseline Emissions Mg/yr	Baseline Emissions g/kg	Baseline Emissions g/m^3	Best Demonstrated Level of Emissions Mg/yr	Best Demonstrated Level of Emissions g/kg	Best Demonstrated Level of Emissions g/m^3	H_2O conc. (Vol. %)
Ore dryer													
small plant	6.6	366	36	5337	47	71.6[d]	32.4	1.30	0.43[d]	4.0	.035	.053[d]	8.0
medium plant	6.6	366	36	11031	47	71.6	66.9	1.30	0.43	8.2	.035	.053	8.0
large plant	7.5	366	58	18860	47	100.5	82.3	0.94	0.43	14.0	.035	.076	8.0
Calciners (all plants - each unit)													
Direct contact continuous	1.9	450	6.4	1059	20	18.8	24.6	2.13	0.43	1.5	.003	.027	40
Continuous kettle	1.9	392	10.9	1950	22	34.3	24.6	1.24	0.43	0.45	.005	.009	60
Board end sawing[e]													
small plant	1.4	305	14.5	381	3.2	8.9	18.5	0.71	0.43	0.36	.003	.009	ambient
medium plant	1.9	305	29	762	3.2	13.5	24.6	0.46	0.43	0.73	.003	.014	ambient
large plant	2.8	305	50	1310	3.2	15.3	37.0	0.41	0.43	1.3	.003	.016	ambient
Scoring and chamfering[e]													
small plant	0.71	305	14.5	28	0.24	1.4	9.3	0.34	0.43	0.18	0.002[f]	.009	ambient
medium plant	0.94	305	29	57	0.24	2.0	12.4	0.23	0.43	0.36	0.002[f]	.014	ambient
large plant	1.4	305	50	98	0.24	2.3	18.5	0.21	0.43	0.63	0.002[f]	.016	ambient
Stucco continuous dry mixing													
small plant	0.19	305	12	35	0.35[g]	6.2	2.5	0.11	0.43	0.05	0.001[g]	.009	ambient
medium plant	0.24	305	23.6	69	0.35	9.6	3.1	0.07	0.43	0.10	0.001[g]	.014	ambient
large plant	0.38	305	41	119	0.35	10.5	4.9	0.07	0.43	0.17	0.001[g]	.016	ambient
Stucco plaster mixing and bagging	1.4	308	3.6	302	10	7.1	18.5	2.8	0.43	0.75	.025	.018	ambient
Stucco Conveying	2.6	322	23.6	69	0.35[g]	0.8	34.5	0.80	0.43	0.10	.001[g]	.002	ambient
Stucco Storage	0.47	322	23.6	294	1.5	20.8	6.2	0.14	0.43	0.79	.004	.055	ambient

[a]All emissions given in this table are based on actual test data presented in Chapters 3 and 4 unless otherwise noted.

[b]Average hourly process rate required for plant boardline capacity, process outlet basis.

[c]Based on 8328 operating hours per year.

[d]Ore dryer grain loadings calculated on the basis of 80% utilization of dryer design capacity.

[e]Calculations based on dry board production weight using 1.7 lb/ft^2 of board.

TABLE 6-6. EMISSION PARAMETERS FOR SOURCES IN MODEL GYPSUM PLANTS (English Units)[a]

Emission Source	Gas Flow (acfm)	Gas Temp. (°F)	Process Rate[b] (ton/hr)	Uncontrolled Emissions (ton/yr)[c]	Uncontrolled Emissions (lb/ton)	Uncontrolled Emissions (gr/acf)	Baseline Emissions (ton/yr)[c]	Baseline Emissions (lb/ton)	Baseline Emissions (gr/acf)	Best Demonstrated Level of Emissions (ton/yr)[c]	Best Demonstrated Level of Emissions (lb/ton)	Best Demonstrated Level of Emissions (gr/acf)	H_2O Conc. (Vol.%)
Ore dryer													
small plant	14,000	200	40	5871	94	31.3[d]	35.6	0.57	0.19[d]	4.4	0.070	0.023[d]	8.0
medium plant	14,000	200	40	12134	94	31.3	73.6	0.57	0.19	9.0	0.070	0.023	8.0
large plant	16,000	200	64	20746	94	43.9	90.5	0.41	0.19	15.4	0.070	0.033	8.0
Calciners (all plants - each unit)													
Direct contact continuous	4,000	350	7.0	1166	40	8.2	27.1	0.93	0.19	1.7	0.060	0.012	40
Continuous kettle	4,000	245	12.0	2148	43	15	27.1	0.54	0.19	0.50	0.010	0.004	60
Board end sawing[e]													
small plant	3,000	90	16	420	6.3	3.9	20.3	0.31	0.19	0.40	0.006	0.004	ambient
medium plant	4,000	90	32	839	6.3	5.9	27.1	0.20	0.19	0.80	0.006	0.006	ambient
large plant	6,000	90	55	1443	6.3	6.7	40.7	0.18	0.19	1.4	0.006	0.007	ambient
Scoring and chamfering[e]													
small plant	1,500	90	16	31	0.47	0.59	10.2	0.15	0.19	0.20	0.003[f]	0.004	ambient
medium plant	2,000	90	32	63	0.47	0.88	13.6	0.10	0.19	0.40	0.003[f]	0.006	ambient
large plant	3,000	90	55	108	0.47	1.0	20.3	0.09	0.19	0.69	0.003[f]	0.007	ambient
Stucco continuous dry mixing													
small plant	400	90	13	38	0.7[g]	2.7	2.7	0.05	0.19	0.05	0.001[g]	0.004	ambient
medium plant	500	90	26	76	0.7	4.2	3.4	0.03	0.19	0.11	0.001[g]	0.006	ambient
large plant	800	90	45	131	0.7	4.6	5.4	0.03	0.19	0.19	0.001[g]	0.007	ambient
Stucco plaster mixing and bagging	3,000	95	4	333	20	3.1	20.3	1.22	0.19	0.83	0.05	0.008	ambient
Stucco conveying	5,600	120	26	76	0.7[g]	0.34	38.0	0.35	0.19	0.11	0.001[g]	0.001	ambient
Stucco storage	1,000	120	26	324	3	9.1	6.8	0.06	0.19	0.87	0.008	0.024	ambient

[a]All emission given in this table are based on actual test data presented in Chapters 3 and 4 unless otherwise noted.

[b]Average hourly process rate required for plant boardline capacity, process outlet basis.

[c]Based on 8328 operating hours per year.

[d]Ore dryer grain loadings calculated on the basis of 80% utilization of dryer design capacity.

[e]Calculations based on dry board production weight using 1.7 lb/ft^2 of board.

[f]From plant permit application, Reference 4.

[g]Reference 5.

TABLE 6-7. REGULATORY ALTERNATIVES FOR GYPSUM PLANTS

	Regulatory Alternative		
Emission Source	1	2A, 2B	3A, 3B
Ore dryer	0	X	X
Calciners	0	X	X
Board end sawing	0	X	X
Dry mixing	0	0	X
Scoring and chamfering	0	0	X
Stucco continuous mixing, conveyors, bucket elevators, and storage bins[b]	0	0	X
Stucco plaster mixing[c]	0	0	X

Key: 0 = Baseline control level.
X = More stringent control level based on best demonstrated technology.

[a]For Regulatory Alternatives 2 and 3, both monitoring option A (monitoring of visible emissions weekly by a certified observer using EPA Reference Method 9) and monitoring option B (continuous opacity monitoring by means of transmissometers) are considered in the cost analysis presented in Chapter 8. Monitoring options are assumed to have an equal effect on emissions levels.

[b]For plants that use stucco rather than raw gypsum as a starting material.

[c]Only for plants with plaster production.

TABLE 6-8. EMISSION LEVELS FOR REGULATORY ALTERNATIVES BY SOURCE
g/kg (lb/ton)

Emission Source	Regulatory Alternatives		
	1	2A, 2B	3A, 3B
Ore dryer - small	.29 (.57)	.04 (.07)	.04 (.07)
Ore dryer - medium	.29 (.57)	.04 (.07)	.04 (.07)
Ore dryer - large	.21 (.41)	.04 (.07)	.04 (.07)
Direct contact flash calciner	.47 (.93)	.03 (.06)	.03 (.06)
Kettle calciner	.27 (.54)	.005 (.01)	.005 (.01)
Board end sawing - small	.16 (.31)	.003 (.006)	.003 (.006)
Board end sawing - medium	.10 (.20)	.003 (.006)	.003 (.006)
Board end sawing - large	.09 (.18)	.003 (.006)	.003 (.006)
Dry mixing - small	.03 (.05)	.03 (.05)	.0005 (.001)
Dry mixing - medium	.02 (.03)	.02 (.03)	.0005 (.001)
Dry mixing - large	.02 (.03)	.02 (.03)	.0005 (.001)
Scoring and chamfering - small	.08 (.15)	.08 (.15)	.002 (.003)
Scoring and chamfering - medium	.05 (.10)	.05 (.10)	.002 (.003)
Scoring and chamfering - large	.05 (.09)	.05 (.09)	.002 (.003)
Stucco continuous mixing, conveyors, bucket elevators, and storage bins[a]	.04 (.41)	.94 (.41)	.02 (.009)
Stucco plaster mixing[b]	.61 (1.22)	.61 (1.22)	.025 (.05)

[a]For plants that use stucco rather than raw gypsum as a starting material.
[b]Only for plants with plaster production.

TABLE 6-8. EMISSION LEVELS FOR REGULATORY ALTERNATIVES BY SOURCE
g/dNm^3 (gr/dscf)

Emission Source	Regulatory Alternatives 1	2A, 2B	3A, 3B
Ore dryer - small	0.59 (0.26)	0.072 (0.031)	0.072 (0.031)
Ore dryer - medium	0.59 (0.26)	0.072 (0.031)	0.072 (0.031)
Ore dryer - large	0.59 (0.26)	0.103 (0.045)	0.103 (0.045)
Direct contact flash calciner	1.11 (0.49)	0.070 (0.031)	0.070 (0.031)
Kettle calciner	1.45 (0.63)	0.031 (0.013)	0.031 (0.013)
Board end sawing - small	0.46 (0.20)	0.010 (0.004)	0.010 (0.004)
Board end sawing - medium	0.46 (0.20)	0.015 (0.006)	0.015 (0.006)
Board end sawing - large	0.46 (0.20)	0.017 (0.007)	0.017 (0.007)
Dry mixing - small	0.46 (0.20)	0.46 (0.20)	0.010 (0.004)
Dry mixing - medium	0.46 (0.20)	0.46 (0.20)	0.015 (0.006)
Dry mixing - large	0.46 (0.20)	0.46 (0.20)	0.017 (0.007)
Scoring and chamfering - small	0.46 (0.20)	0.46 (0.20)	0.010 (0.004)
Scoring and chamfering - medium	0.46 (0.20)	0.46 (0.20)	0.015 (0.006)
Scoring and chamfering - large	0.46 (0.20)	0.46 (0.20)	0.017 (0.007)
Stucco continuous mixing, conveyors, bucket elevators, and storage bins[a]	0.49 (0.21)	0.49 (0.21)	0.011 (.005)
Stucco plaster mixing[b]	0.47 (0.20)	0.47 (0.20)	0.020 (.009)

[a]For plants that use stucco rather than raw gypsum as a starting material.
[b]Only for plants with plaster production.

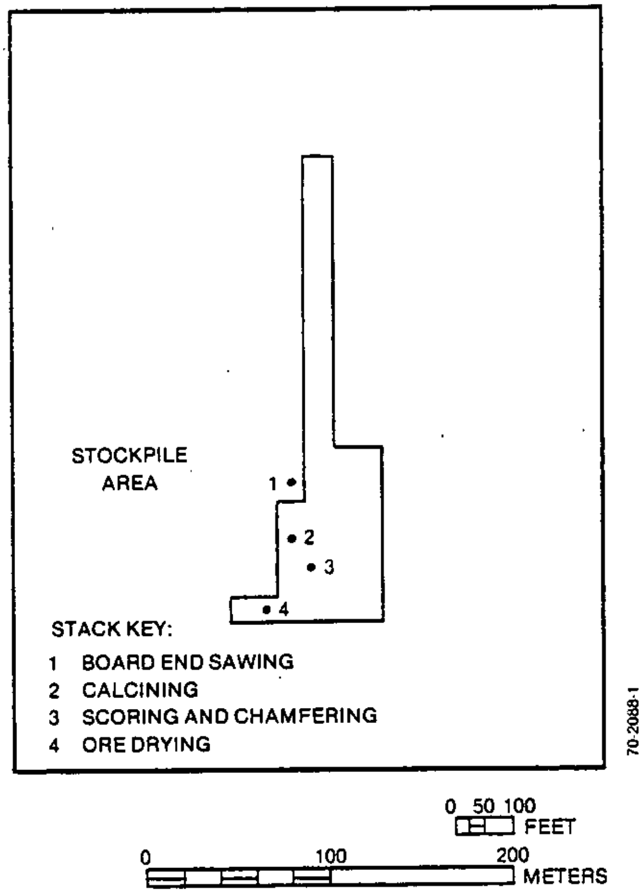


Figure 6-2. Plot plant and stack layout for model plant no. 1.

desired increased emissions reductions is ensured by monitoring the visible emissions from each source. Both monitoring options are assumed to result in the same emissions reduction and environmental impacts. But, the choice of monitoring option does impact costs associated with the regulatory alternatives. Therefore, the cost analysis presented in Chapter 8 addresses Regulatory Alternatives 1, 2A, 2B, 3A, and 3B.

The two control options for each source could be combined in various ways to provide many regulatory alternatives for each model gypsum plant. The sources considered in this study fall into basically two groups, considering the amount of emissions and the cost effectiveness of emissions control. The three principal sources in typical gypsum plants (ore dryers, calciners, and board end sawing) have similar cost effectiveness for particulate emissions control. In addition, the other sources in typical gypsum plants (scoring and chamfering and continuous or boardline dry mixing) are both smaller sources with higher cost effectiveness values. Therefore, only three regulatory alternatives were considered for each model plant. Emissions levels for each source and regulatory alternative are given in Table 6-8.

Alternative 1 was chosen to represent control of all particulate emission sources considered to the baseline level of emissions described in Chapter 3. Alternative 3 represents control of all particulate emission sources considered to the best demonstrated level of emissions reduction for each source.

Alternative 2 represents control of the three principal emission sources (ore dryers, calciners, board end sawing) to the best demonstrated emission level. The remaining minor sources are considered to be controlled to the baseline emissions level for Alternative 2. This alternative was chosen to illustrate the relative benefits of controlling the minor particulate emission sources as compared with controlling the principal gypsum emission sources. As an example, for a medium-size gypsum plant, the incremental particulate collection due to improved control of the principal emissions sources ranges from 131 Mg/yr (144 TPY) to 175 Mg/yr (193 TPY), whereas the incremental collection due to improved control of the minor sources is only 15 Mg/yr (18 TPY). The emissions reductions associated with the regulatory alternatives for the model gypsum plants are detailed in Chapter 7.

Stucco conveying and storage and plaster mixing and bagging are considered in Model Plants 6 and 5, respectively. Control of these sources to the more stringent emissions levels was considered only in Alternative 3 to show the relative impact of these sources compared to the principal sources. For example, the minor sources considered from Alternative 2 to Alternative 3 for model plant 5 include scoring and chamfering, boardline cry mixing, and plaster mixing and bagging. The incremental change due to control of the plaster operation (35 Mg/yr (39 TPY) collected) can be determined by comparing the incremental changes for model plants 5 and 3. Similarly, the only principal source considered for model plant 6 is board end sawing, but the minor sources include scoring and chamfering, boardline dry mixing, and stucco conveying and storage. With this last source being considered only for Alternative 3, the impact of control of stucco conveying and storage (approximately 30 Mg/yr (44 TPY)) may be determined by comparison to the other model plants of the same size.

6.2.2 Control Technologies

Emission control systems that can be used to control emissions from each source were discussed in detail in Chapter 4. The choice of the baseline control device used for sources in this industry was discussed in the baseline section of Chapter 3. The control systems selected for analysis of environmental and economic impacts were chosen on the basis of best level of particulate emissions reductions demonstrated in EPA and EPA-approved tests.

Fabric filters on emission sources tested in this study exhibited greater than 99 percent removal of particulate emissions. No other types of control systems are used in the gypsum that would be likely to achieve greater control. Therefore, the fabric filter was chosen as the control device demonstrating the best level of emissions reduction. Since fabric filters are also currently in wide use in the gypsum industry for emissions control, control options other than fabric filters were not chosen. For the emission sources considered, the fabric filters representative of best demonstrated are the same type as those used to meet the baseline level, but they are maintained and operated for a higher degree of performance.

In some cases, exhaust streams from ore dryers, grinding mills, and calciners are vented through a common control device. For this situation, the combined air flow rate may be high enough to make emissions control of the combined streams using an ESP economically feasible.[7] However, the recommended CTG which is being developed for the non-metallic minerals industry would be based on the use of fabric filters on some sources in the gypsum industry, such as grinding mills and bucket elevators. This would preclude combining these sources with ore dryers and calciners and ducting them to a common ESP if ESPs, as reported, do not attain collection efficiencies as high as demonstrated by fabric filters. Without the additional air flow from these other sources, control of emissions associated with the lower air flow rates of ore dryers and calciners could be accomplished at a lower cost by using fabric filters.[7,8]

6.3 REFERENCES

1. Letter and attachments from McPeck, M., New York State Department of Environmental Conservation, to DeWolf, G., Radian Corporation. June 2, 1980. 14 p. Operation permits for Gold Bond Building Products.

2. Trip report. Murin, P. J., Radian Corporation, to file. November 28, 1979. p. 7. Report of visit to U.S. Gypsum in Shoals, Indiana.

3. Reference 2, p. 9.

4. Letter and attachments from Burnop, W., Texas Air Control Board, to Kelly, M. E., Radian Corporation. March 10, 1980. p. . Permit application for the Flintkote Company in Dallas, Texas.

5. U. S. Environmental Protection Agency. Compilation of Air Pollutant Emission Factors, Third Edition. Research Triangle Park, N.C. Publication No. AP-42. August 1977. p. 18.14-1.

6. Muelberg, P. E. and B. P. Shepherd. (Dow Chemical.) Industrial Process Profiles for Environmental Use, Chapter 17: The Gypsum and Wallboard Industry. (Prepared for U.S. Environmental Protection Agency.) Cincinnati, Ohio. Publication No. EPA-600/2-77-023q. February 1977.

7. Letter and attachments from Tretter, V. J., Georgia-Pacific Corporation, to DeWolf, G. B., Radian Corporation. August 22, 1980. 5 p. Questionnaire for Georgia-Pacific Corporation.

8. Memo from Stelling, J., Radian Corporation, to file. October 12, 1980. 51 p. Cost analysis computations for regulatory alternatives.

7. ENVIRONMENTAL IMPACTS

The purpose of this chapter is to present the environmental impacts of the regulatory alternatives specified in Chapter 6 for control of particulate emission sources in the gypsum industry. The emission sources to be considered include:

- ore dryers,
- calciners,
- board end sawing,
- boardline dry mixing, and
- scoring and chamfering.

Emissions from plaster mixing and bagging and stucco conveying and storage are also considered. However, environmental impacts of emissions from these sources were only considered in three model plants.

The air pollution, water pollution, solid waste, and energy impacts associated with the application of the regulatory alternatives are identified and discussed in Sections 7.1 to 7.4, respectively. Additional impacts are described in Section 7.5. Although two monitoring options are considered for Regulatory Alternatives 2 and 3, these options are assumed to have an equal effect on the environmental impacts associated with these alternatives. Therefore, the impacts discussed in this chapter will be presented in terms of Regulatory Alternatives 2 an 3 with no specific reference to monitoring option. These impacts on the environment are also projected over a five year period to determine the long range national impacts. All impacts are based on the model plant parameters presented in Chapter 6 and industry growth projections presented in Chapter 9.

7.1 AIR POLLUTION IMPACTS

In this section, the impact of each regulatory alternative on air pollution is considered. Two impacts were addressed in this analysis: primary impacts, or the reduction of particulate emissions due to implementation of the regulatory alternative, and secondary impacts, or those due to pollutants generated as a result of implementing the regulatory alternative. The impact of the regulatory alternatives on nationwide emissions is assessed on the basis of projected industry growth (see Chapter 9). The impact on ambient air quality in the vicinity of the sources is evaluated by means of dispersion modeling for each model plant. Dispersion modeling is discussed in Subsection 7.1.2.

7.1.1 Primary Air Pollution Impacts

Table 7-1 presents annual particulate emissions for each emission source considered under the regulatory alternatives. The table also presents the amount of emissions collected beyond baseline levels for each source and regulatory alternative. In each case, Alternative 1 represents no NSPS regulatory action and, therefore, represents the baseline control level. Alternative 2 represents best demonstrated control of the three principal emission sources, ore dryers, calciners and board end sawing. Alternative 3 represents best demonstrated control of all particulate emission sources.

As can be determined from Table 7-1, the best demonstrated levels of emissions reductions represent from 87 to 98 percent improvement over baseline emissions levels for the various sources in the gypsum industry. Particulate emission reductions over baseline range from 2.41 Mg/yr (2.65 TPY) for a small dry mixing operation to 68.2 Mg/yr (75.1 TPY) for a large ore dryer.

Table 7-2 presents the total annual particulate reductions over baseline anticipated for each model plant configuration presented in Chapter 6 and each regulatory alternative considered. The reduction in plant-wide particulate emissions range from 17.1 Mg/yr (19.5 TPY) to 265 Mg/yr (292 TPY) depending upon the model plant under consideration.

Emissions are expected to increase as the gypsum industry grows. Chapter 9 presents the projected growth in the domestic gypsum industry by 1986. The United States Bureau of Mines indicates that to meet expected gypsum demand, the industry will need to build five new plants in the medium size range by 1986.[2] The five new plants will all have

TABLE 7-1. PARTICULATE EMISSIONS AND EMISSION REDUCTIONS FOR REGULATORY ALTERNATIVES BY SOURCE.

		Particulate Emissions Mg/yr (ton/yr)			Absolute Reduction Over Baseline Mg/yr (ton/yr)		
		Regulatory Alternative			Regulatory Alternative		
Source	Plant Size[a]	1	2	3	1	2	3
Ore dryer	S	32.3 (35.6)	4.0 (4.4)	4.0 (4.4)	0	28.3 (31.2)	28.3 (31.2)
	M	66.8 (73.6)	8.2 (9.0)	8.2 (9.0)	0	58.7 (64.6)	58.7 (64.6)
	L	82.2 (90.5)	14.0 (15.4)	14.0 (15.4)	0	68.2 (75.1)	68.2 (75.1)
Calciners							
Continuous Kettle	---	24.6 (27.1)	0.45 (0.5)	0.45 (0.5)	0	24.2 (26.6)	24.2 (26.6)
Direct Contact	---	24.6 (27.1)	1.5 (1.7)	1.5 (1.7)	0	23.1 (25.4)	23.1 (25.4)
Board end sawing	S	18.4 (20.3)	0.36 (0.4)	0.36 (0.4)	0	17.5 (19.3)	17.5 (19.3)
	M	24.6 (27.1)	0.73 (0.8)	0.73 (0.8)	0	23.9 (26.3)	23.9 (26.3)
	L	37.0 (40.7)	1.3 (1.4)	1.3 (1.4)	0	35.7 (39.3)	35.7 (39.3)
Dry mixing	S	2.5 (2.7)	2.5 (2.7)	0.045 (0.05)	0	0	2.41 (2.65)
	M	3.1 (3.4)	3.1 (3.4)	0.10 (0.11)	0	0	2.99 (3.29)
	L	4.9 (5.4)	4.9 (5.4)	0.17 (0.19)	0	0	4.73 (5.21)
Scoring and chamfering	S	9.3 (10.2)	9.3 (10.2)	0.18 (0.20)	0	0	9.08 (10.0)
	M	12.3 (13.6)	12.3 (13.6)	0.36 (0.40)	0	0	12.0 (13.2)
	L	18.4 (20.3)	18.4 (20.3)	0.63 (0.69)	0	0	17.8 (19.6)
Plaster mixing and bagging	---	18.4 (20.3)	18.4 (20.3)	0.75 (0.83)	0	0	17.7 (19.5)
Stucco conveying and storage	---	40.7 (44.8)	40.7 (44.8)	0.89 (0.98)	0	0	39.8 (43.8)

[a] S = small, M = medium, L = large

TABLE 7-2. PARTICULATE EMISSION REDUCTIONS FOR REGULATORY ALTERNATIVES BY MODEL PLANT[a]

Model Plant Number	Plant Configuration	Absolute Reduction Over Baseline, Mg/yr (ton/yr)		
		Regulatory Alternative		
		1	2	3
1	Small plant with kettle calciners	0	70.6 (77.7)	82.1 (90.4)
2	Small plant with direct contact flash calciners	0	92.5 (101.9)	104.1 (114.6)
3	Medium plant with kettle calciners	0	130.8 (144.1)	145.8 (160.6)
4	Medium plant with direct contact flash calciners	0	174.8 (192.5)	189.8 (209.0)
5	Medium plant with kettle calciners and plaster production	0	155.0 (170.7)	205.4 (226.2)
6	Medium plant purchasing calcined gypsum	0	23.9 (26.3)	78.6 (86.6)
7	Large plant with kettle calciners	0	200.5 (220.8)	223.0 (245.6)
8	Large plant with direct contact flash calciners	0	242.3 (266.8)	264.8 (291.6)
9	Increase of calcining capacity (kettle calciner)	0	24.2 (26.6)	24.2 (26.6)
10	Increase of calcining capacity (direct contact flash calciner)	0	23.1 (25.4)	23.1 (25.4)
11	Increase board production (kettle calciner)	0	42.2 (46.5)	53.8 (59.2)
12	Increase board production (direct contact flash calciners)	0	64.2 (70.7)	75.7 (83.4)
13	Replacement of plaster equipment	0	0	17.7 (19.5)

[a]Reference 1.

TABLE 7-3. 1986 NATIONAL ANNUAL EMISSIONS AND REDUCTIONS FOR PROJECTED[a] GYPSUM PLANTS

Regulatory Alternative	Total Emissions (Mg/yr)	(ton/yr)	Incremental Reduction of Emissions Over Baseline (Mg/yr)	(ton/yr)
1	829	912	--[b]	--[b]
2	131	143	698	769
3	56	61	773	851

[a]Reference 3.

[b]Alternative 1 is baseline level.

capacities of about 21.6 million square meters (232 million square feet) of wallboard per year. A summary of the national annual emissions in 1986 from these projected new plants is given in Table 7-3 for each regulatory alternative.

Implementation of Alternative 2 would result in a nationwide reduction of particulate emissions over baseline of 698 Mg/yr (769 TPY). The nationwide reduction of particulate emissions with implementation of Alternative 3 would be 773 Mg/yr (851 TPY). Approximately 12.5 percent of the increment from Alternative 1 to Alternative 3 is attributable to regulation of boardline dry mixing, scoring and chamfering.

7.1.2 Ambient Air Quality Impacts

This section presents a discussion of the air quality impacts of the regulatory alternatives based on dispersion modeling. Characteristics of the emission sources, details of the meteorological data and results of the dispersion analysis are discussed separately in the following sections.

7.1.2.1 Emission Source Characteristics. Stack parameters, mass emission rates, gas flow rates and gas temperatures for model plant emission sources are presented in Tables 7-4 and 7-5 for the regulatory alternatives considered. These model plant stack parameters, in conjunction with the stack coordinates of the model plants in Table 7-6, were used to perform the dispersion analysis.

7.1.2.2 Meteorological Data. Wind speeds and stability data considered in the dispersion modeling reflect the meteorological conditions of Abilene, Texas. This site was chosen as representative of an inland location of gypsum plants in urban areas on flat terrain. A site with flat terrain and relatively stagnant atmospheric conditions would represent a worst case analysis of ground level particulate concentrations due to emissions from sources in gypsum plants.

7.1.2.3 Results of Dispersion Analysis. All maximum concentrations for the regulatory alternatives considered in the dispersion modeling analysis occurred at the plant boundary. The calciners were oriented so as to maximize the effect of their emissions on the ambient concentration

TABLE 7-4. BASELINE STACK PARAMETERS FOR SOURCES IN MODEL GYPSUM PLANTS

Emission Source	Control Method	Particulate Emission Rate (kg/hr)	(lb/hr)	Particulate Concentration (g/dNm^3)	(gr/dscf)	Gas Flow Rate (m^3/sec)	(acfm)	Gas Temp. (K)	(°F)	H_2O Conc. (Vol.%)	Stack Diameter (m)	(ft)	Stack Height (m)	(ft)	Stack Velocity (m/s)	(ft/s)
Ore dryer[a]																
small plant	Fabric	10	23	0.59	0.26	6.6	14,000	366	200	8.0	0.67	2.2	21.3	70	18.7	61.4
medium plant	filter	10	23	0.59	0.26	6.6	14,000	366	200	8.0	0.67	2.2	21.3	70	18.7	61.4
large plant		12	26	0.59	0.26	7.5	16,000	366	200	8.0	0.73	2.4	21.3	70	18.0	58.9
Calciners (all plants - each unit)																
Direct contact continuous	Fabric filter	3.0	6.5	1.11	0.49	1.9	4,000	450	350	40	0.30	1.0	21.3	70	25.9	84.9
Continuous kettle		3.0	6.5	1.45	0.63	1.9	4,000	366	200	60	0.30	1.0	21.3	70	25.9	84.9
Board end sawing																
small plant	Fabric	2.2	4.9	0.46	0.20	1.4	3,000	305	90	1.8	0.30	1.0	15.2	50	19.4	63.7
medium plant	filter	3.0	6.5	0.46	0.20	1.9	4,000	305	90	1.8	0.34	1.1	15.2	50	21.4	70.2
large plant		4.4	9.8	0.46	0.20	2.8	6,000	305	90	1.8	0.43	1.4	15.2	50	19.8	65.0
Scoring and chamfering																
small plant	Fabric	1.1	2.4	0.46	0.20	0.71	1,500	305	90	1.8	0.21	0.67	15.2	50	21.6	70.9
medium plant	filter	1.5	3.3	0.46	0.20	0.94	2,000	305	90	1.8	0.26	0.84	15.2	50	18.3	60.1
large plant		2.2	4.9	0.46	0.20	1.4	3,000	305	90	1.8	0.30	1.0	15.2	50	19.4	63.7
Stucco continuous dry mixing																
small plant	Fabric	0.30	0.65	0.46	0.20	0.19	400	305	90	1.8	0.10	0.33	21.3	70	23.8	77.9
medium plant	filter	0.37	0.81	0.46	0.20	0.24	500	305	90	1.8	0.12	0.38	21.3	70	22.4	73.5
large plant		0.60	1.3	0.46	0.20	0.38	800	305	90	1.8	0.15	0.48	21.3	70	22.5	73.7
Stucco plaster mixing	Fabric filter	2.2	4.9	0.46	0.20	1.4	3,000	308	95	1.8	0.30	1.0	21.3	70	19.4	63.7
Stucco conveying	Fabric filter	4.1	9.1	0.46	0.20	2.6	5,600	322	120	1.8	0.43	1.4	21.3	70	18.5	60.6
Stucco storage	Fabric filter	0.74	1.6	0.46	0.20	0.47	1,000	322	120	1.8	0.18	0.60	21.3	70	18.0	58.9

[a]Operating hours for ore dryers vary for each model plant: small plant = 9 hr/day; medium plant = 18.6 hr/day; large plant = 20 hr/day. Emission rate is rate during the hours of ore dryer operation.

TABLE 7-5. MORE STRINGENT CONTROL STACK PARAMETERS FOR SOURCES IN MODEL GYPSUM PLANTS

Emission Source	Control Method	Particulate Emission Rate (kg/hr)	(lb/hr)	Particulate Concentration (g/dNm^3)	(gr/dscf)	Gas Flow Rate (m^3/sec)	(acfm)	Gas Temp. (K)	(°F)	H_2O Conc. (Vol.%)	Stack Diameter (m)	(ft)	Stack Height (m)	(ft)	Stack Velocity (m/s)	(ft/s)
Ore dryer[a]																
small plant	Fabric	1.3	2.8	0.072	0.031	6.6	14,000	366	200	8.0	0.67	2.2	21.3	70	18.7	61.4
medium plant	filter	1.3	2.8	0.072	0.031	6.6	14,000	366	200	8.0	0.67	2.2	21.3	70	18.7	61.4
large plant		2.1	4.5	0.103	0.045	7.5	16,000	366	200	8.0	0.73	2.4	21.3	70	18.0	58.9
Calciners (all plants - each unit)																
Direct contact continuous	Fabric filter	0.19	0.41	0.070	0.031	1.9	4,000	450	340	40	0.30	1.0	21.3	70	25.9	84.9
Continuous kettle		0.06	0.14	0.031	0.013	1.9	4,000	366	200	60	0.30	1.0	21.3	70	25.9	84.9
Board end sawing																
small plant	Fabric	0.047	0.10	0.010	0.004	1.4	3,000	305	90	1.8	0.30	1.0	15.2	50	19.4	63.7
medium plant	filter	0.086	0.19	0.015	0.006	1.9	4,000	305	90	1.8	0.34	1.1	15.2	50	21.4	70.2
large plant		0.16	0.36	0.017	0.007	2.8	6,000	305	90	1.8	0.43	1.4	15.2	50	19.8	65.0
Scoring and chamfering																
small plant	Fabric	0.023	0.051	0.010	0.004	0.71	1,500	305	90	1.8	0.21	0.67	15.2	50	21.6	70.9
medium plant	filter	0.044	0.096	0.015	0.006	0.94	2,000	305	90	1.8	0.26	0.84	15.2	50	18.3	60.1
large plant		0.082	0.18	0.017	0.007	1.4	3,000	305	90	1.8	0.30	1.0	15.2	50	19.4	63.7
Stucco continuous dry mixing																
small plant	Fabric	0.006	0.013	0.010	0.004	0.19	400	305	90	1.8	0.10	0.33	15.2	50	23.8	77.9
medium plant	filter	0.012	0.026	0.015	0.006	0.24	500	305	90	1.8	0.12	0.38	15.2	50	22.4	73.5
large plant		0.020	0.045	0.017	0.007	0.38	800	305	90	1.8	0.15	0.48	15.2	50	22.5	73.7
Stucco plaster mixing	Fabric filter	0.09	0.2	0.020	0.009	1.4	3,000	308	95	1.8	0.30	1.0	21.3	70	19.4	63.7
Stucco conveying	Fabric filter	0.012	0.026	0.002	0.001	2.6	5,600	322	120	1.8	0.43	1.4	21.3	70	18.5	60.6
Stucco storage	Fabric filter	0.095	0.21	0.051	0.022	0.47	1,000	322	120	1.8	0.18	0.60	21.3	70	18.0	58.9

[a]Operating hours for ore dryers vary for each model plant: small plant = 9 hr/day; medium plant = 18.6 hr/day; large plant = 20 hr/day. Emission rate is rate during the hours of ore dryer operation.

TABLE 7-6. COORDINATES FOR STACK IN MODEL GYPSUM PLANTS[a]

Units: meters (ft)

Model Plant No.	Stack Number 1 X	1 Y	1 Z	2[b] X	2[b] Y	2[b] Z	3 X	3 Y	3 Z	4 X	4 Y	4 Z	5 X	5 Y	5 Z
1,3,7,9,11[c]	152 (500)	168 (550)	15 (50)	152 (500)	137 (450)	21 (70)	160 (525)	107 (350)	15 (50)	137 (450)	91 (300)	21 (70)	- -	- -	- -
2,4,8,10,12[c]	152 (500)	168 (550)	15 (50)	154 (505)	137 (450)	21 (70)	160 (525)	107 (350)	15 (50)	137 (450)	91 (300)	21 (70)	- -	- -	- -
5, 13[c]	152 (500)	168 (550)	15 (50)	152 (500)	137 (450)	21 (70)	160 (525)	107 (350)	15 (50)	137 (450)	91 (300)	21 (70)	183 (600)	137 (450)	21 (70)
6	152 (500)	168 (550)	15 (50)	130 (425)	130 (425)	21 (70)	160 (525)	107 (350)	15 (50)	137 (450)	130 (425)	21 (70)	137 (450)	122 (400)	21 (70)

[a]The origin is the lower-left hand corner of the property boundary for each model plant. X-coordinate is positive to the right, Y-coordinate is positive toward the top of the page, and Z-coordinate positive upward perpendicular to the page. An example plot plan is given in Figure 6-2.

[b]Only the coordinates of the right-hand most stack are given where several stacks are in a row. Spacing between stacks for model plants No. 2, No. 4, No. 8, No. 10, and No. 12 is 3m (10 ft.) and for model plants No. 3, No. 5, No. 6, No. 7, No. 9, and No. 11 is 6m (20 ft.).

[c]For expansions (model plants No. 9 to No. 12) and replacements (model plant No. 13), only those stacks from affected sources should be considered.

for the baseline cases. Under Regulatory Alternative 1, the maximum ambient air concentrations for all model plants, except model plants 8 and 12, were below the National Ambient Air Quality Standards (NAAQS) for particulate matter (primary standards: annual geometric mean = 75 g/m^3, maximum 24-hour concentration = 260 g/m^3; secondary standards: annual geometric mean = 60 g/m^3, maximum 24-hour concentration = 150 g/m^3). Model plants 8 and 12 exceeded the secondary or welfare standard of 60 g/m^3, but were below the primary standard of 75 g/m^3. The higher concentrations resulted from the large contribution to emissions of six direct contact flash calciners.

All maximum concentrations for model plants (1-8) representing new installations using Regulatory Alternatives 2 and 3 were well below the NAAQS, representing reductions in ambient air particulate concentrations between 77 and 97 percent below baseline levels. The reductions in particulate concentrations for model plant expansions and replacements (9-13) were less evident (9 to 33 percent) since some sources (those in the base gypsum plant) were maintained at the baseline level and only those new sources were considered at the lower emission levels.

The primary contributors to the maximum concentration estimates under Regulatory Alternative 1 were board end sawing operations in small model plants (1 and 2) and calciners in the remaining model plants. Under Regulatory Alternatives 2 and 3, however, the main contribution to the ambient air particulate concentrations was due to emissions from the ore dryer.

7.1.3 Secondary Air Pollution Impacts

Secondary air pollutants are pollutants generated as a result of applying the control equipment. There are no air pollutants generated directly by fabric filter control equipment. While the need for electrical power to support the fabric filter control systems causes utility power plant emissions, no increase in electrical power will result from implementation of Alternative 2 or Alternative 3 because the emission control equipment is identical to baseline control equipment (Alternative 1). The reduction in particulate emissions results from improved fabric filter maintenance and operation.

7.1.4 Summary of Air Pollution Impacts

The primary air pollutant emitted from the gypsum industry is particulate matter. The major benefit of implementing the regulatory alternatives is the reduction of these particulate emissions. Implementation of Alternative 3 and Alternative 2 will reduce particulate emissions over Alternative 1 by a maximum of 773 Mg/yr (851 TPY) and 698 Mg/yr (769 TPY), respectively, by 1986. There will also be a decrease in visible emissions from all emission sources with implementation of Alternatives 2 and 3. No incremental secondary air pollution impacts would result from the regulatory alternatives considered.

7.2 WATER POLLUTION IMPACT

There would be no adverse water pollution impact due to implementation of any of the regulatory alternatives since fabric filters do not use water to control particulate emissions.

7.3 SOLID WASTE IMPACT

There would be no significant solid waste impact due to implementation of the regulatory alternatives. Gypsum dust collected in fabric filters is recycled to the process in all cases except for board end sawing. In plants located at mines, the board end sawing dust is typically landfilled on site.[4,5] For plants not located near a mine, the end sawing dust is usually recycled to the beginning of the process.[6] However, in a few installations, the dust is landfilled at offsite locations. Assuming one new plant landfills offsite, the incremental increase in solid waste from implementation of either Alternative 2 or Alternative 3 would be 23.9 Mg/year (23.3 TPY).

7.4 ENERGY IMPACT

The primary electrical demand for fabric filters is from the fans used to generate sufficient air flow rates and draft to overcome pressure drops across the filter bags and from compressors used to supply compressed air for fabric filter cleaning. Less than one-half of one percent of the energy used by gypsum plants is attributable to the control equipment.

Table 7-7 presents the total annual energy requirements of the model plants presented in Chapter 6. Also presented in Table 7-7 are the total control equipment energy requirements for these plants. No incremental energy impact will result from implementation of the regulatory alternatives since the control equipment used for each alternative is identical.

7.5 OTHER IMPACTS

There would be no incremental noise impact due to implementation of any of the regulatory alternatives since the control equipment for each of the regulatory alternatives is identical.

TABLE 7-7. ANNUAL ENERGY REQUIREMENTS FOR GYPSUM MODEL PLANTS[a,b]

Model Plant Number	Total Model Plant Energy Usage TJ	Total Model Plant Energy Usage 10^9 BTU	Control Equipment Energy Usage TJ	Control Equipment Energy Usage 10^9 BTU
1	359	340	1.53	1.45
2	420	398	1.92	1.82
3	718	681	2.48	2.35
4	829	786	3.26	3.09
5	832	789	3.17	3.00
6	289	274	1.28	1.21
7	1440	1360	3.52	3.34
8	1260	1190	4.30	4.08
9[c]	168	160	0.39	0.37
10	101	96	0.39	0.37
11	312	296	1.01	0.96
12	365	346	1.41	1.34
13	Not Available		0.40	0.38

[a]Energy usage for all model plants is the same under Alternatives 1, 2, and 3.

[b]Reference 7.

[c]Model Plants 9-13 represent plant expansions or equipment replacements. The energy values given for these plants represent the increased energy usage resulting from the expansion.

7.6 REFERENCES

1. Memo from Palazzolo, M., Radian Corporation, to file. November 6, 1980. 1 p. Calculation of emission reductions for regulatory alternatives by model plant.

2. Telecon. Stelling, J., Radian Corporation, with Pressler, J., U. S. Bureau of Mines. October 9, 1980. Conversation about gypsum industry growth.

3. Memo from Palazzolo, M., Radian Corporation, to file. November 6, 1980. 2 p. Calculation of 1986 national emissions based on projected plants.

4. Trip report. Kelly, M. E., Radian Corporation, to file. November 29, 1979. 5 p. Report of visit to Flintkote Company in Sweetwater, Texas. p. 3.

5. Trip report. Murin, P. J., Radian Corporation, to file. November 28, 1979. 40 p. Report of visit to U.S. Gypsum Company in Shoals, Indiana. p. 6.

6. Trip report. Palazzolo, M. A., Radian Corporation, to file. March 12, 1980. 5 p. Report of visit to Gold Bond Building Products in Wilmington, North Carolina, p. 4.

7. Memo from Palazzolo, M., Radian Corporation, to file. November 6, 1980. 4 p. Calculation of model plant control equipment energy usage.

8. COSTS

This chapter presents a cost analysis of the regulatory alternatives for model plants described in Chapter 6. In Chapter 9 the results of this cost analysis are used in conjunction with the gypsum industry growth projection to determine the economic impact of regulatory alternatives. Costs associated with regulatory alternatives on new sources are presented in Section 8.1.1, while costs for modified and reconstructed sources are discussed in Section 8.1.2. Section 8.2 presents other cost considerations.

8.1 COST ANALYSIS OF REGULATORY ALTERNATIVES

8.1.1 New Facilities

This section presents the costs associated with the regulatory alternatives for new sources. Seven sources were considered in the model plant matrix. These were ore dryers, calciners, board end sawing, scoring and chamfering, boardline dry mixing, plaster mixing and bagging, and stucco conveying and storage. Two control options and two monitoring options were identified for each source and these were used as the basis for the formulation of the regulatory alternatives.

The regulatory alternatives are summarized in Table 8-1. Exhaust stream characteristics are presented in Table 6-6. Table 8-2 presents the specifications of the fabric filters used as the control equipment associated with the control options.

The following section describes the major equipment considered in the cost estimates for control of each source. Capital costs for each source were developed from the major equipment lists and factored cost estimates (Section 8.1.1.2). Total capital costs for each regulatory alternative were then obtained by summing the costs of control for the individual sources within a given model plant. Annualized costs and cost effectiveness of each regulatory alternative are similarly developed in later sections.

TABLE 8-1. REGULATORY ALTERNATIVES EXAMINED IN COST ANALYSIS FOR ALL MODEL PLANTS[a]

	Regulatory Alternative[b]				
Emission Source	1	2A	2B	3A	3B
Ore dryer	0	x	x	x	x
Calciners	0	x	x	x	x
Board end sawing	0	x	x	x	x
All other sources[c]	0	0	0	x	x

[a]Model plants are detailed in Chapter 6.

[b]0 = Baseline control level; x = more stringent level of control. For Regulatory Alternatives 2 and 3, both monitoring option A (monitoring of visible emissions weekly by a certified observer using EPA Reference Method 9) and monitoring option B (continuous opacity monitoring by means of transmissometers) were considered in the cost analysis.

[c]All other sources include scoring and chamfering, dry mixing, plaster mixing, and stucco conveying and storage.

TABLE 8-2. SPECIFICATIONS FOR FABRIC FILTER SYSTEMS

Emission Source	Bag Medium	Air-to-Cloth Ratio ($cfm:ft^2$)	Cleaning Method	Pressure Drop kPa (in.W.G.)
Ore dryer	Nomex	4:1	pulse jet	0.51-0.77 (2-3)
Calciners:				
Direct contact flash	Nomex	4:1	pulse jet	0.77-1.02 (3-4)
Continuous kettle	Nomex	4:1	pulse jet	0.51-0.77 (2-3)
Board end sawing	Cotton	1:1	mechanical shaking	1.02 (4)
Scoring and chamfering	Cotton	5:1	pulse jet	0.77 (3)[a]
Dry mixing	Cotton	5:1	pulse jet	1.02 (4)
Plaster mixing	Cotton	2:1	pulse jet	0.77 (3)[a]
Stucco conveying and storage	Cotton	5:1	pulse jet	0.77 (3)[a]

[a]These values are estimates based on published reports and industry responses.

8.1.1.1 Description of Control Equipment Used. Fabric filters are used for the baseline and more stringent control options for all sources considered in each model plant. Table 8-3 presents a description of the major equipment associated with a fabric filter control system. This description is representative of the major equipment needs for sources using a fabric filter system. The sample presented in Table 8-3 is for a direct contact flash calciner capable of processing 7.7 Mg/hour (7 TPH) of calcined gypsum. The major equipment required includes the baghouse, nomex bags (for elevated temperature operation), ducting (including damper), fan, motor, starter, and insulation. A transmissometer system is included for the more stringent control option only when monitoring option B is considered. Only baghouses and associated ducting on ore dryers and calciners require insulation.

8.1.1.2 Capital Cost of Control Systems. The total installed cost of emission control systems was determined using basically a modified "Lang Method" of cost estimating. Cost factors for direct capital costs (cost of materials and labor directly associated with installation), indirect capital costs (cost of engineering, contracting, freight, taxes, etc.), and contingencies are applied to the cost of the major equipment to yield the total installed cost of the control system. Factors used in this study for fabric filter systems are presented in Table 8-4.

For fabric filters on ore dryers and calciners, insulation was considered an additional cost above the basic installation cost. Therefore, for these systems, the cost of insulation was added to the total installed cost of the basic fabric filter system. Insulation was considered in these cases for ducting also.

Control device costs were based on manufacturer's quotations.[1] Costs of auxiliary equipment such as fans, starters, motors, etc., were determined from standard cost estimating references.[1-7] All costs are reported in first quarter 1980 dollars. Costs were updated to first quarter 1980 dollars using Chemical Engineering Plant Cost Indices.[8] The reliability of the resulting cost estimates is taken to be within 30 percent of the actual value.

TABLE 8-3. EXAMPLE OF MAJOR EQUIPMENT REQUIREMENTS FOR A FABRIC FILTER CONTROL SYSTEM (Direct Contact Flash Calciner) (Metric Units)

	Baseline requirements
Control Device	Baghouse, continuous operation, suction type, pulse jet, carbon steel construction, air-to-cloth ratio 4:1, Δp = 0.77 - 1.02 kPa, insulated.
Bags	640 Nomex bags, 152 mm diameter x 2.44 m long
Fan	1.89 m^3/s @ 450 K, 3500 rpm, 11.7 kW
Ducting	24.4 m, 0.31 m diameter, carbon steel with circular manual damper.
	More stringent requirements
Control Device Bags Fan Ducting	As above
Monitoring	Transmissometer, recorder, associated cable (Required for monitoring option B only)

TABLE 8-3. EXAMPLE OF MAJOR EQUIPMENT REQUIREMENTS FOR A FABRIC FILTER CONTROL SYSTEM (Direct Contact Flash Calciner) (English Units)

	Baseline requirements
Control Device	Baghouse, continuous operation, suction type, pulse jet, carbon steel construction, air-to-cloth ratio 4:1, Δp = 3-4 inches WG, insulated.
Bags	640 Nomex bags, 6 inches diameter x 8 feet long
Fan	4000 ACFM @ 350°F, 3500 rpm, 15.7 bhp
Ducting	80 feet, 1 foot diameter, carbon steel with circular manual damper.
	More stringent requirements
Control Device Bags Fan Ducting	As above
Monitoring	Transmissometer, recorder, associated cable (Required for monitoring option B only)

TABLE 8-4. COMPONENT CAPITAL COST FACTORS FOR A FABRIC FILTER AS A FUNCTION OF EQUIPMENT COST, Q

Component	Direct Costs	
	Material Factor	Labor Factor
Equipment	1.00 Q	0.20 Q
Instrumentation	0.12 Q	0.10 Q
Foundations and subparts	0.05 Q	0.10 Q
Electrical	0.10 Q	0.10 Q
Ducting (miscellaneous)	0.03 Q	0.08 Q
Painting	0.01 Q	0.02 Q
Total direct cost factor	1.31 Q	0.60 Q

Component	Indirect Costs	
	Measure of cost	Factor
Engineering and supervision	3% material and labor	0.06 Q
Construction and field expenses	12.5% material and labor	0.24 Q
Construction fee	6.25% material and labor	0.12 Q
Taxes and freight	7.5% material	0.10 Q
Total indirect cost factor		0.52 Q
Contingencies		0.18 Q
Total installed cost[a] factor without insulation		2.61 Q[b]

[a]This factor represents the system cost factor derived from a modified "Lang Method" of cost estimating described in Reference 1.

[b]Insulation cost is calculated separately without the use of factors.

Table 8-5 presents the major equipment costs for a fabric filter system for a direct contact flash calciner. This table also includes the total equipment cost and total installed cost for this emission control system. The capital cost of the control system under monitoring option A is equal to the capital cost of the baseline control system. The example given in Table 8-5 is representative of the procedure used in determining the total installed cost of all fabric filter systems considered.

Table 8-6 presents the control device costs, total equipment costs, (fabric filters, fans, ducting, etc.) and total installed costs of control systems for sources considered in the gypsum model plants. The costs presented in this table were used in determining the total installed costs of regulatory alternatives for the gypsum model plants.

Table 8-7 presents an example of a total installed cost computation for model plant 7 and Regulatory Alternative 3B. This cost is determined by summing the total installed costs of control systems for each source included in the model plant. The same procedure shown in this example was used to derive the total installed costs of the regulatory alternatives for all model plants.

The total installed costs of the regulatory alternatives for all model plants are summarized in Table 8-8. The total installed cost of a control system under monitoring option A is equal to the total installed cost of the corresponding baseline control system. These costs vary by model plants depending upon the number of sources controlled and the type and number of fabric filters used. The largest capital investment is $1.12 million for model plant 8, Regulatory Alternative 3B (a large gypsum plant with 6 direct contact flash calciners). This investment represents about $200 thousand more than that required to meet baseline emission levels and is due to the cost of continuous opacity monitoring systems. Each continuous opacity monitoring system, equipment and installation, is estimated to be about $20,000 per device.

For batch kettle calciners, an additional preheater may be required to raise the dew point of the kettle exhaust gases prior to the fabric

TABLE 8-5. EXAMPLE EQUIPMENT COST BREAKDOWN OF MAJOR EQUIPMENT FOR DIRECT CONTACT FLASH CALCINER FABRIC FILTER SYSTEM

Item	Cost, $1,000 (March 1980)
Control device	$14.36
Bags	$4.80
Fan, motor, starter	$2.54
Ducting (including damper)	$2.98
Major equipment cost	$24.68
Installed cost factor[a]	x2.61
Installed equipment cost	$64.41
Insulation	$8.15
Total installed cost -	
for baseline control system	$72.60
Continuous opacity monitoring system	$20.00
Total installed cost -	
for more stringent control system (monitoring option B)	$92.60

[a]This factor represents the system cost factor derived from a modified "Lang Method" of cost estimating described in Reference 1.

TABLE 8-6. TOTAL INSTALLED CAPITAL COSTS FOR EMISSION CONTROL SYSTEMS IN GYPSUM MODEL PLANTS $1000 (March 1980)

Emission Source	Control Device Cost	Total Equipment Cost	Total Installed Cost
Ore dryer - small	35.9	81.7	189.0
Ore dryer - medium	35.9	81.7	189.0
Ore dryer - large	40.2	90.8	211.0
Direct contact flash calciner	14.4	24.7	72.6
Continuous kettle calciner	15.0	25.7	75.5
Board end sawing[a]			
small	31.7	43.6	114.0
medium	40.2	54.8	143.0
large	57.3	74.0	193.0
Scoring and chamfering			
small	8.40	13.6	35.6
medium	9.19	14.7	38.9
large	10.8	17.2	44.9
Dry mixing - small	6.66	11.0	28.7
Dry mixing - medium	6.82	11.6	30.2
Dry mixing - large	7.30	12.5	32.7
Plaster mixing and bagging	18.8	27.5	71.7
Stucco conveying and storage	16.5	27.6	71.9

[a]An air-to-cloth ratio of 1:1 was used for this source. See Table 8-2.

TABLE 8-7. EXAMPLE OF TOTAL INSTALLED COST COMPUTATION FOR MODEL PLANT 7, REGULATORY ALTERNATIVE 3B (MORE STRINGENT CONTROL OF ALL SOURCES), $1000 - March 1980

Source	Control System	Monitors
Ore dryer (1)	211	20
Kettle calciners (4)	301	80
Board end sawing (1)	193	20
Scoring and chamfering (1)	44	20
Dry mixing (1)	33	20
Total Installed Cost	783	160
Total Installed Cost for Entire Model Plant - Regulatory Alternative 3B		943

TABLE 8-8. TOTAL INSTALLED COSTS OF CONTROL SYSTEMS FOR MODEL PLANTS AND REGULATORY ALTERNATIVES, $1000 (March 1980)

Model Plant	Regulatory Alternative		
	1	2B	3B
1	443.	503.	543.
2	512.	592.	632.
3	552.	632.	672.
4	691.	811.	851.
5	771.	871.	931.
6	284.	304.	364.
7	783.	903.	943.
8	917.	1077.	1117.
9	75.5	95.5	95.5
10	72.6	92.6	92.6
11	254.	294.	334.
12	323.	383.	423.
13	143.	143.	163.

filter. The addition of this preheater, which could operate using steam or excess process heat from the flue gases of the same kettle, would cost less than $5,000. This cost represents about five percent of the estimated total installed cost for the control system for a continuous kettle calciner.

8.1.1.3 Annualized Costs. The total annualized cost for a control option or regulatory alternative includes direct operating costs, annualized capital costs, and any credit taken for product recovered through the use of the control device(s). The factors used in determining annualized costs for control systems for gypsum emission sources are given in Table 8-9.

Direct operating costs include labor, electricity, maintenance, administration, overhead, and taxes and insurance. Taxes, insurance, and administration costs were estimated as a factor of the total installed cost of each regulatory option. Operating and maintenance labor was estimated based on industry responses and typical reported values.[9] Maintenance costs also included replacement of bags in fabric filters. The frequency of replacements is given in Table 8-9. All bags were assumed to be replaced at one time. No allowances were made for initial bag failures after installation since these are expected to be small. Electricity consumption was based on fan and shaker power requirements. The energy requirements of solids removal from the fabric filter are assumed to be part of the normal conveying system requirements and are small in comparison to fan requirements.

Annualized costs were considered with and without product recovery credits. Gypsum recovery credits were estimated at $8.25 per megagram ($7.50 per ton) for land plaster (uncalcined gypsum) and at $36.63 per megagram ($33.30 per ton) for calcined gypsum based on historical product values reported by the U.S. Bureau of Mines.[10,11] No credit was taken for emissions collected from scoring and chamfering operations. Credit for recovered gypsum and land plaster from other sources was taken since these products were assumed to be recyclable to the process.

TABLE 8-9. BASES FOR BAGHOUSE ANNUALIZED COST ESTIMATES (1980)

Direct Operating Costs	
Utilities	
Electricity	$0.045/kWh[a]
Labor	
Operation	$17.45/hour[b]
	1041 man-hours[c]
Maintenance	$19.20/hour[d]
Baseline control	220 hours[e]
More stringent control	440 hours[e]
Operating hours	8328 hours[f]
Bag replacements[g]	
Baseline: Ore dryer	every 9 months
kettle calciners	every 6 months
other sources	every 12 months
More stringent: Ore dryer	every 4 months
kettle calciners	every 3 months
other sources	every 6 months
Capital charges	
Capital recovery factor	.1175[h]
Taxes and insurance	2% of capital investment[i]
Administration	2% of capital investment[i]
Overhead	80% of operation and maintenance labor[i]
Recovery credit[j]	
Land plaster	$7.50/ton
Calcined material	$33.30/ton

[a]Reference 1.

[b]Includes wages plus 40% for labor-related administrative and supervision costs. Costs (4077) updated using Hourly Wage Index: 260.4 ÷ 212.8.

[c]Operating labor is based on 1 man-hour per shift during operations.

[d]Maintenance labor considered as operating labor rate plus a 10% premium.

[e]Based on industry survey and Reference 1. More stringent control is based on more frequent, improved maintenance.

[f]Operating hours are based on 95% utilization.

[g]Based on industry survey.

[h]Capital recovery factor is based on 10% interest rate and 20 year life.[1]

[i]Reference 1.

[j]Reference 10.

TABLE 8-10. COMPONENT ANNUALIZED COSTS FOR A FABRIC FILTER CONTROL SYSTEM (DIRECT CONTACT FLASH CALCINER - REGULATORY ALTERNATIVE 1)

Component	Annualized cost, $1000 (March 1980)
Operating labor and supervision	18.2
Maintenance labor and materials	9.0
Utilities	
Electricity	4.9
Total Direct Costs	32.1
Administration	2.9
Taxes and insurance	2.9
Overhead	17.9
Capital recovery charges	8.5
Total Capital Charges and Overhead	29.3
Total Annualized Costs (without product recovery)	61.4
Recovery credit (@ $33.30/ton for calcined material)	37.9
Net Annualized Costs	23.5

An example of an annualized cost breakdown is given in Table 8-10. This example is for the baseline fabric filter system on a direct contact flash calciner. The same procedure shown in this example was used to determine the total annualized costs of the two control options for each source considered in this study. Table 8-11 presents an example of the annualized cost computation for a regulatory alternative for a model plant. The annualized cost for a regulatory alternative is the sum of annualized costs for each source considered in the model plants. This summation procedure was used in determining the annualized costs for all model plants and regulatory alternatives. The annualized costs for regulatory alternatives 2B and 3B include the annualized costs for maintaining and operating the continuous opacity monitoring systems, which are estimated to be $11,000 per year per source.

The annualized costs for regulatory alternatives are reported with and without gypsum recovery credit. Annual operating costs of regulatory alternatives where no recovery credit is taken are presented in Table 8-12. Annual operating costs of regulatory alternatives where recovery credits are taken are given in Table 8-13. On an average, there is a 46 percent decrease in the annualized operating costs of the regulatory alternatives when credits are taken for recovered gypsum and land plaster. This high percentage results from the large amount of land plaster recovered from ore dryer emissions.

When preheaters are included on batch kettle calciners, the annualized operating cost would increase about $500 over the annualized cost of kettle calciners without preheaters. Waste heat from indirect-fired process equipment is assumed to be used. The flue gases from the same kettle is an example of a waste heat source that could be used.

8.1.1.4 Cost Comparison of Regulatory Alternatives. The cost of the regulatory alternatives for the model plants are compared in several ways. The overall cost effectiveness and the cost effectiveness compared to baseline of each alternative can be considered. In addition, the effects of cost of control on the product cost can be examined. And a comparision of the capital cost of a regulatory alternative with the capital cost of a new plant or plant expansion can be made.

TABLE 8-11. EXAMPLE OF ANNUALIZED COST COMPUTATION FOR MODEL PLANT 7, REGULATORY ALTERNATIVE 3B (More Stringent Control of All Sources), $1000 (March 1980)

Total Annualized Costs			
Ore dryer			161
Kettle calciners			344
Board end sawing			117
Scoring and chamfering			72
Dry mixing			66
	TOTAL - Annualized Costs		760
Recovery Credits			
Ore dryer	20731 TPY @ $7.50/ton	=	156
Kettle calciners	4 x 2148 TPY @ $33.30/ton	=	286
Board end sawing	1442 TPY @ $33.30/ton	=	48
Scoring and chamfering	107 TPY @ $0.00/ton	=	0
Dry mixing	131 TPY @ $33.30/ton	=	4
	TOTAL - Credits		494
Net Annualized Costs			266

TABLE 8-12. ANNUALIZED COSTS AND COST EFFECTIVENESS OF REGULATORY ALTERNATIVES FOR MODEL GYPSUM PLANTS WITHOUT RECOVERY CREDITS (March 1980)

Model Plant	Regulatory Alternative														
	1			2A			2B			3A			3B		
	Annualized Cost $1000	Cost Effectiveness $/Mg	Cost Effectiveness $/ton	Annualized Cost $1000	Cost Effectiveness $/Mg	Cost Effectiveness $/ton	Annualized Cost $1000	Cost Effectiveness $/Mg	Cost Effectiveness $/ton	Annualized Cost $1000	Cost Effectiveness $/Mg	Cost Effectiveness $/ton	Annualized Cost $1000	Cost Effectiveness $/Mg	Cost Effectiveness $/ton
1	324.	42	36	389.	50	46	414.	54	49	408.	53	48	452.	58	53
2	385.	49	45	463.	59	53	497.	63	57	482.	61	56	535.	68	62
3	403.	26	23	484.	31	28	518.	33	30	504.	32	29	557.	35	32
4	524.	33	30	633.	39	36	686.	42	39	652.	40	37	724.	45	41
5	583.	32	29	678.	37	34	722.	39	36	721.	39	36	793.	43	39
6	235.	200	182	256.	214	195	262.	219	199	297.	238	216	322.	257	234
7	552.	20	18	668.	24	22	721.	26	23	688.	24	22	760.	27	25
8	672.	25	23	813.	30	28	886.	33	30	834.	31	28	925.	35	31
9	62.	32	29	80.	41	37	86.	44	40	80.	41	37	86.	44	40
10	61.	59	54	79.	74	68	85.	80	73	79.	74	68	85.	80	73
11	225.	96	87	259.	108	99	274.	114	104	278.	116	105	312.	130	118
12	265.	114	104	333.	131	119	358.	141	128	352.	137	125	396.	154	140
13	117.	207	188	117.	206	188	117.	207	188	144.	246	224	150.	256	233

TABLE 8-13. ANNUALIZED COSTS AND COST EFFECTIVENESS OF REGULATORY ALTERNATIVES FOR MODEL GYPSUM PLANTS WITH RECOVERY CREDIT (March 1980)

Model Plant	Regulatory Alternative 1			2A			2B			3A			3B		
	Annualized Cost $1000	Cost Effectiveness $/Mg	Cost Effectiveness $/ton	Annualized Cost $1000	Cost Effectiveness $/Mg	Cost Effectiveness $/ton	Annualized Cost $1000	Cost Effectiveness $/Mg	Cost Effectiveness $/ton	Annualized Cost $1000	Cost Effectiveness $/Mg	Cost Effectiveness $/ton	Annualized Cost $1000	Cost Effectiveness $/Mg	Cost Effectiveness $/ton
1	195.	26	23	258.	33	30	283.	37	33	277.	36	33	321.	41	38
2	251.	32	29	326.	41	38	360.	46	42	345.	44	40	398.	50	46
3	142.	9	8	220.	14	13	254.	16	15	239.	15	14	292.	18	17
4	253.	16	14	356.	22	20	409.	25	23	376.	23	21	447.	28	25
5	230.	13	12	321.	18	16	365.	20	18	363.	20	18	435.	24	22
6	194.	165	150	214.	179	163	220.	184	167	254.	203	184	278.	222	202
7	64.	2	2	174.	6	6	227.	8	7	194.	7	6	266.	9	9
8	238.	9	8	373.	14	13	446.	17	15	394.	15	13	484.	18	16
9	(8.)[a]	(4)	(4)	8.	4	4	15.	8	7	8.	4	4	15.	8	7
10	24.	23	21	40.	38	34	46.	44	40	40.	38	34	46.	44	40
11	140.	59	54	172.	72	65	187.	78	71	191.	80	72	225.	94	85
12	195.	78	71	240.	94	86	265.	103	94	259.	101	92	303.	118	107
13	97.	169	154	97.	170	154	97.	169	154	123.	209	190	129.	220	200

[a]Parentheses indicate credits due to recovered product.

The cost effectiveness of a regulatory alternative is defined as the total annualized cost of the regulatory alternative divided by the amount of pollutant removed by the control system in the same period. The cost effectiveness for each of the regulatory alternatives and model plants is given in Table 8-12 and Table 8-13 and is reported in $/Mg and $/ton of particulate removed.

The cost effectiveness compared to baseline is computed as the incremental annualized cost of the regulatory alternative above the baseline annualized cost divided by the incremental pollutant reduction achieved by the regulatory alternative over the baseline level. The cost effectiveness of Alternative 3B compared to baseline ranges from $1408/Mg ($1280/ton) for a small plant to $898/Mg ($816/ton) for a large plant where no credit is taken for recovered gypsum. Values of the cost effectiveness compared to baseline are from one to four percent lower when credit is assumed for recovered gypsum.

The increases in product cost due to the control equipment range from $.95/Mg ($.86/ton) to $5.05/Mg ($4.59/ton). These increases in cost represent less than five percent of product cost. The highest increase in product cost compared to baseline is the $.62/Mg ($.57/ton) for a small plant (model plant 2) and represents 0.6 percent of product cost.[12]

8.1.1.5 <u>Base Cost of Gypsum Model Plants</u>. The capital costs of the regulatory alternatives may be compared with the total capital cost of model gypsum plants. The capital costs for complete gypsum plants were estimated based on reported cost estimates updated to the first quarter 1980. An eight-tenths power rule was assumed to scale the costs to all plant sizes since most equipment in gypsum manufacturing is involved with solids handling. Plant expansions and replacements were estimated based on cost estimates of the unit operation modules required (grinding mills, calciners, blenders, conveyers, etc.).[13] Table 8-14 presents ranges and average capital costs for complete gypsum manufacturing plants. These values may be compared with the total installed costs of regulatory alternatives given in Table 8-8. The total installed costs

TABLE 8-14. TOTAL INSTALLED COST OF MODEL PLANTS[a]
(March 1980)

Plant Size	Relevant Model Plant Number	Boardline Capacity MM sq.ft./year	Relevant Equipment[b] tph	Cost Range $ millions	Average Cost $ millions
Small	1,2	116		9.2-13.5	11.4
Medium	3,4,5,6	232		16.0-23.5	19.8
Large	7,8	401		25.0-36.5	30.8
Expansion	9		ckc,12		.79
Expansion	10		DCFC,7		.50
Expansion	11	116	ckc,12		6.51
Expansion	12	116	DCFC (2),14		7.03
Replacement	13		plaster mixer		.68

[a]Reference 13.

[b]ckc = continuous kettle calciner; DCFC = direct contact flash calciner.

of the regulatory alternatives under monitoring option B over baseline range from 0.5 to 1.1 percent of the total installed costs for new plants and range from 1.2 to 4.0 percent of the total installed costs for expansions.

8.1.2 Modified/Reconstructed Facilities

As noted in Chapter 5, few modifications or reconstructions of existing equipment are anticipated for the gypsum industry. In addition, most existing sources currently use fabric filters for emissions control. Thus, it is expected that the costs of retrofitting control systems for modified/reconstructed facilities will be small.

8.2 OTHER COST CONSIDERATIONS

8.2.1 Costs Associated With OSHA Compliance

Gypsum plants are affected by two aspects of OSHA regulations. Workroom air must be kept below the general limit of 15 mg/m^3 for "nuisance" or "inert" dust.[14] Gypsum plants are also subject to OSHA's general industrial health and safety standards, which includes regulations covering noise exposure, fixed machinery and hand tools, electrical installations, conditions of floors and stairs, and provisions for lunchrooms, toilets, and first aid.[15]

Costs associated with these provisions are difficult to assess. Hoods and ducting are currently used on boardline operations (scoring and chamfering, board end sawing) to reduce dust levels in the workroom. The increase in pressure drop due to a baghouse for control of these emissions would result in a slight increase in annual energy usage.

8.2.2 Regulatory Agency Manpower Requirements

It is likely that any increase in regulatory agency workload would not have a burdensome effect on state agencies. It should be noted, however, that each of the facilities to be affected by NSPS are currently subject to existing state regulations. The construction of a new gypsum plant in an area would necessitate inspections, observations of compliance tests, recordkeeping, etc., by the agency regardless of whether SIP or NSPS levels were to be enforced. Thus, the additional workload due to NSPS is considered to be minimal.

8.2.3 Costs Associated With Monitoring and Demonstrating Compliance

The costs associated with monitoring and demonstrating compliance include costs for source testing and capital costs for monitoring devices. Monitoring for compliance is expected to involve periodic visible emission observations (monitoring option A) or continuous monitoring of visible emissions (monitoring option B). Equipment and installation costs for monitoring option B are estimated to be about $20,000 per site. Annualized costs for monitoring option B, which include recording and reducing the data, are estimated at about $11,000 per source. Some savings in operating costs may be achieved if multiple systems are used at a given facility. Annualized costs for monitoring option A vary with the number of sources to be observed, ranging from $4,800 to $19,500 per plant. These costs include semi-annual certification for two people to read opacities, making opacity observations, and maintenance of files and records.[16]

The cost of compliance testing has been estimated between $3,000 and $5,000 per stack.[16] This cost includes a pretest survey, formal test plan, sampling and data reduction, and a final test report. The cost does not include, however, travel, per diem, and other direct expenses such as site preparation.

8.3 REFERENCES

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9. Reference 1.

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12. Memo from Stelling, J., Radian Corporation, to file. October 19, 1980. 13 p. Value of manufactured gypsum product.

13. Memo from Stelling, J., Radian Corporation, to file. October 12, 1980. 9 p. Overall cost of gypsum model plants.

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15. U.S. Department of Labor, Occupational Safety and Health Administration. General Industry Safety and Health Standards Digest. In: Occupational Safety and Health Reporter, Volume I. Washington, D.C. Bureau of National Affairs. June 1975. pp. 31:4001 - 31:4012.

16. Memo from Stelling, J., Radian Corporation, to file. October 19, 1980. 8 p. Costs associated with compliance monitoring.

9. ECONOMIC IMPACTS

9.1 INDUSTRY PROFILE

9.1.1 Introduction

The gypsum products manufacturing industry (SIC Code No. 3275) consists of plants producing products composed chiefly or wholly of gypsum. As shown in Figure 9-1, the 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. Manufacture of plasters and wallboard involves a calcining step in which 75 percent of the chemically bound water of raw gypsum ($CaSO_4 \cdot 2H_2O$) is removed by heating. The 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 by crushing, screening and, in the case of agricultural fertilizer, grinding and drying.

By-product or synthetic gypsum, generated from other chemical processes such as neutralization of sulfuric acid waste streams, flue gas desulfurization and phosphoric acid manufacture, is currently used only as an agricultural fertilizer. However, research into manufacturing other products from synthetic gypsum is being conducted by gypsum manufacturers.

9.1.2 Industry Structure and Domestic Supply.

In 1978, upgraded crude gypsum and calcined gypsum products were produced in 74 plants located in 31 states.[1] Calcining was done at 72 plants, and 2 plants operated with stucco gypsum as a raw material. Table 9-1 is a list of the 74 plants identified by the U.S. Bureau of Mines as processing crude gypsum and calcined gypsum products. This list includes the capacity, in millions of square feet, for those plants that publish such information.

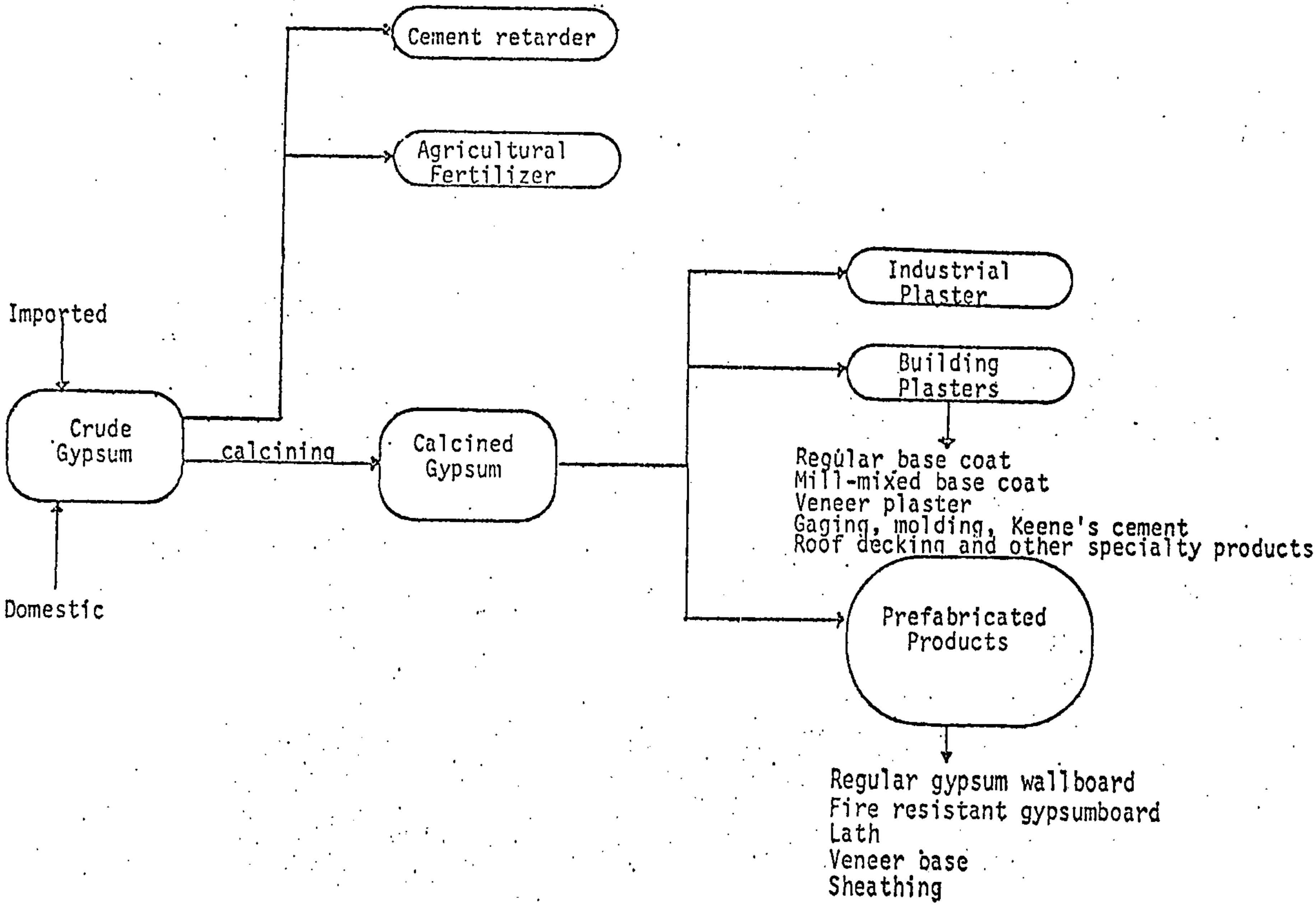


FIGURE 9-1: Gypsum Products

Table 9-1. LOCATION AND CAPACITY OF GYPSUM PLANTS IN THE UNITED STATES

Company[a]	Plant Name	County, State	Capacity (Millions of Square Feet)
American Gypsum Co. P.O. Box 6345 Albuquerque, NM 87197	Albuquerque	Bernadillo, NM	NA
Celotex Division Jim Walter Corp. 1500 N. Dale Highway Tampa, Florida 33607	American #2	Ottawa, Ohio	NA
	Celotex	Webster, Iowa	NA
	Jacksonville	Duval, Florida	NA
	Cody	Park, Wyoming	NA
Domtar Gypsum America, Inc. 1221 Broadway Oakland, CA 94612	Antioch	Contra Costa, CA	NA
	Long Beach	Los Angeles, CA	NA
Flintkote Co. 365 W. Passaick Rochelle Park, NJ 07662	Florence	Freemont, Colorado	100
	Sweetwater	Nolan, Texas	182
	Camden	Camden, New Jersey	141
	Savannah	Chatham, Georgia	165
	Fremont	Alameda, CA	99
	Las Vegas	Clark, Nevada	166
Georgia-Pacific Corp. 900 SW 5th Avenue Portland, Oregon 97204	Lovell	Lovell, Wyoming	NA
	Grand Rapids	Kent, Michigan	NA
	Blue Rapids	Marshall, Kansas	127
	Buchannan	Westchester, New York	276
	Sigurd	Sevier, Utah	160
	Wilmington	Wilmington, Delaware	310
	Fort Dodge	Webster, Iowa	289
	Acme	Hardeman, Texas	460
	Brunswick	Glynn, Georgia	375
	Grand Rapids #2	Kent, Michigan	171
Total		Georgia Pacific Co.	2,414
Grand Rapids Gypsum Co. P.O. Box 2475 Grand Rapids, Michigan	Grand Rapids	Kent, Michigan	171
	Cleveland	Cuyahoga, Ohio	NA
National Gypsum Co. Gold Bond Building Products Division 2001 Rexford Road Charlotte, NC 28211	Long Beach	Los Angeles, CA	NA
	Clarence Center	Erie, New York	NA
	Shoals	Martin, Indiana	NA
	Savannah	Chatham, Georgia	NA
	Baltimore	Baltimore, Maryland	NA
	Garden City	Chatham, Georgia	NA
	Kauffman George	Webster, Iowa	NA

[a]For companies operating more than one plant, the company headquarters address is given.

Table 9-1. (CONTINUED)

Company[a]	Plant Name	County, State	Capacity (Millions of Square Feet)
National Gypsum Co.	Wilmington	New Hanover, NC	NA
Gold Bond Building	Rotan	Fisher, Texas	NA
Products Division	Portsmouth	Rockingham, NH	NA
2001 Rexford Road	Medicine Lodge	Barber, Kansas	NA
Charlotte, NC 28211	Burlington	Burlington, NJ	NA
	Westwego	Jefferson, Louisiana	NA
	Tampa	Hillsborough, Florida	NA
	Waukegan	Lake, Illinois	NA
	Lorain	Lorain, Ohio	NA
	Richmond	Contra Costa, CA	NA
	Phoenix	Maricopa, Arizona	NA
	National City	Iosco, Michigan	NA
	Phoenix	Maricopa, AZ	NA
Northwest Gypsum, Inc.	Seattle	King, Washington	NA
5931 E. Margina Way S.			
Seattle, Washington 98134			
Pacific Coat Building Products, Inc.	Newark	Alameda, CA	NA
37851 Cherry Street	Apex	Clark, Nevada	NA
Newark, CA 94560			
Republic Gypsum Co., Inc.	Duke	Jackson, Oklahoma	NA
Miller Park Drive			
Garland, Texas			
Temple Gypsum Co.	West Memphis	Crittenden, Arkansas	300
P.O. Box 1270			
West Memphis, Arkansas 72301			
Three Rivers Gypsum, Inc.	Longworth	Fisher, Texas	NA
2432 Walnut Ridge Street			
Dallas, Texas 75229			
U.S. Gypsum Co.	Tawas City	Michigan	NA
101 South Wacker Drive	Gypsum	Ottawa, Ohio	NA
Chicago, Illinois 60606	Fort Dodge	Webster, Iowa	NA
	Oakfield	Genessee, New York	NA
	Plaster City	Imperial, CA	NA
	Southard	Blaine, Oklahoma	NA
	New Orleans	Orleans, Louisiana	NA
	Philadelphia	Philadelphia, PA	NA

[a]For companies operating more than one plant, the company headquarters address is given.

Table 9-1. (CONTINUED)

Company[a]	Plant Name	County, State	Capacity (Millions of Square Feet)
U.S. Gypsum Co.	Norfolk	Norfolk, Virginia	NA
101 South Wacker Drive	East Chicago	Lake, Indiana	NA
Chicago, Illinois	Plaster Co. #6	Smythe, Virginia	NA
	Stony Point	Rockland, New York	NA
	Sweetwater	Nolan, Texas	NA
	Shoals	Martin, Indiana	NA
	Sperry	Webster, Iowa	NA
	Baltimore	Baltimore, Maryland	NA
	Detroit	Wayne, Michigan	NA
	Boston	Suffolk, MA	NA
	Empire	Washoe, Nevada	NA
	Sigurd	Sevier, Utah	NA
	Shoemaker Heath	Fergus, Montana	NA
	Galena Park	Harris, Texas	NA
Total		U.S. Gypsum Co.	6,000
Weyerhauser Co., Inc. RR4, Box 78 Nashville, Arkansas 71852	Briar	Howard, Arkansas	NA[c]

[a]For companies operating more than one plant, the company headquarters address is given.
[b]References 7, 21, 22, 23, 24, 25, 26, and 32.
[c]NA = not available.

California, Texas, New York, and Iowa accounted for 38 percent of the total calcined gypsum produced in 1978. Leading states accounting for 71 percent of the crude gypsum produced were Michigan, Texas, Iowa, California, Oklahoma, and Nevada.[2] Total output of crude gypsum in 1979 was 12.98 Tg (14.3 million tons).[3] Domestic reserves are adequate for the foreseeable future.

Plant siting is dictated by economic factors with appropriate consideration to regional market demand, transportation costs and raw material availability. Gypsum ore is a low priced, high tonnage material; therefore, gypsum plants are usually located near the major gypsum deposits as shown in Figure 9-2. For the processing of imported gypsum, plants are located near major seaports on both coasts. Gypsum products generally move from lowest cost supply points into the market. Typically a market radius for a gypsum plant is about 300 miles.[4]

The industry is dominated by five diversified building products companies:

- U.S. Gypsum Company (22 plants)
- National Gypsum Company (Gold Bond Building Products Division) (18 plants)
- Georgia Pacific Corporation (9 plants)
- Flintkote Company (6 plants),* and
- Jim Walter Corporation (Celotex Division) (5 plants).

These five companies accounted for 74 percent of crude gypsum and 94 percent of calcined gypsum products sold in the United States in 1978.[5] Many of the operations of the five companies listed above are integrated mine-plant facilities.

9.1.3 Production and Demand Levels

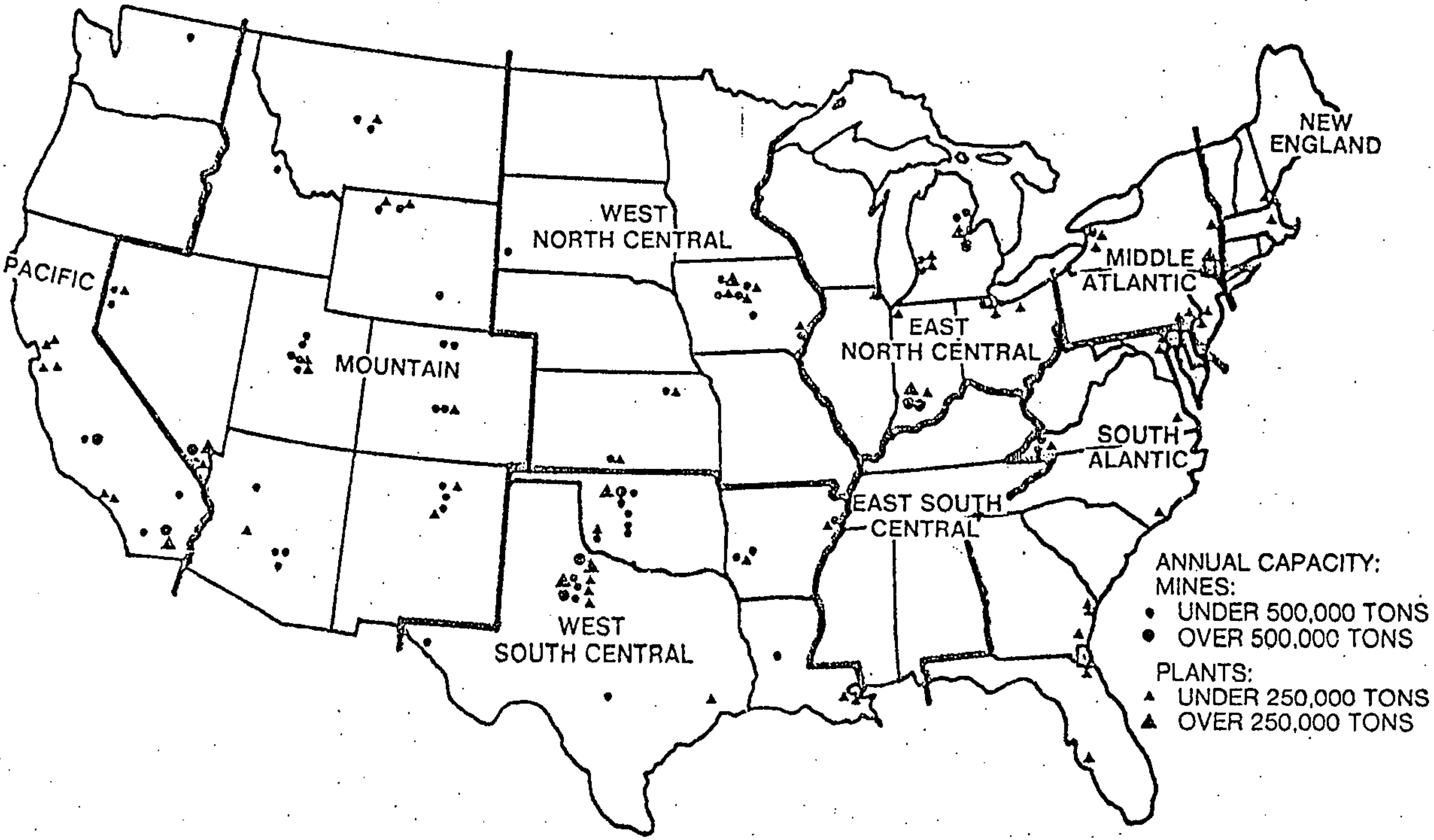
In 1978, 96 percent of the total value of sales and 73 percent by weight of the gypsum products sold or used in the United States were calcined materials used mainly by the building industry. Gypsum wallboard accounted for about 95 percent of the prefabricated gypsum building materials produced in 1978.[6] Table 9-2 provides the distribution for gypsum products sold or used in the U.S. 1978 and 1979.[7] Total capacity of gypsum board plants in 1979 was 1670 km^2/yr (18 billion square feet per year) and with a 93

*Acquired by Genstar Limited in February 1980.

Figure 9-2

GYPSUM MINES AND CALCINING PLANTS BY CAPACITY AND CENSUS REGION

DECEMBER 1978



BUREAU OF MINES
U.S. DEPARTMENT OF THE INTERIOR

Table 9-2. GYPSUM PRODUCTS SOLD OR USED IN THE UNITED STATES[1]

Use	December 1979		November 1979		12 Months 1979		12 Months 1978	
	Mg*	(short tons)	Mg*	(short tons)	Mg*	(short tons)	Mg*	(short tons)
Uncalcined:[2]								
Portland Cement	295,319	(325,600)	272,009	(299,900)	3,569,952	(3,936,000)	3,565,417	(3,931,000)
Agriculture[3]	204,075	(225,000)	154,190	(170,000)	1,394,966	(1,538,000)	1,236,241	(1,363,000)
Fillers and Misc.	10,612	(11,700)	10,431	(11,500)	111,198	(122,600)	126,980	(140,000)
Total[4]	509,915	(562,200)	436,630	(481,400)	5,075,572	(5,596,000)	4,928,638	(5,434,000)
Calcined:								
Board Products[5]	1,155,518	(1,274,000)	1,116,517	(1,231,000)	3,767,353	(15,179,000)	13,680,281	(15,083,000)
Building Plaster	26,847	(29,600)	29,478	(32,500)	366,337	(403,900)	404,341	(445,800)
Industrial Plaster	29,387	(32,400)	31,292	(34,500)	343,934	(379,200)	358,719	(395,500)
Total[4]	1,211,752	(1,336,000)	1,177,286	(1,298,000)	14,477,534	(15,962,000)	14,443,068	(15,924,000)

	December 1979		November 1979		12 Months 1979		12 Months 1978	
	Thousand Sq. Meters	(Thousand Sq. Feet)**	Thousand Sq. Meters	(Thousand Sq. Feet)	Thousand Sq. Meters	(Thousand Sq. Feet)	Thousand Sq. Meters	(Thousand Sq. Feet)
Board Products:								
Regular Board	99,085	(1,043,000)	94,991	(999,900)	1,192,820	(12,556,000)	1,193,770	(12,566,000)
Type X Board	28,358	(298,500)	27,142	(285,700)	310,840	(3,272,000)	264,642	(2,785,700)
Other	7,040	(74,100)	7,781	(81,900)	98,515	(1,037,000)	100,729	(1,060,300)
Total[4]	134,425	(1,415,000)	129,960	(1,368,000)	1,602,175	(16,865,000)	1,559,140	(16,412,000)

[1]In cooperation with the Gypsum Association.
[2]Some data were estimated from quarterly reports.
[3]Includes by-product gypsum.
[4]Data may not add to totals shown because of independent rounding.
[5]Includes weight of paper and other materials.
*1 short ton = .907 Mg.
**1 square foot = .095 square meter.

percent national average utilization factor, a new annual record, production for sale was 1550 km^2/yr (16.7 billion square feet per year).[8]

The demand for gypsum products is determined primarily by the strength of the building construction industry, particularly residential construction. The significant advantages wallboard offers over possible substitute building materials contribute to continued strong demand for this product. This is shown clearly in Figure 9-3 which shows gypsum product demand plotted along with the number of housing starts from 1960-1978.[9,10] Historically a crude production to total demand ratio of tonnage has averaged .65 with a range of .61 to .67 except for 1978 when the ratio reached a 1978 year high of .69. Supply-demand relationships for 1969-1979 are given in Table 9-3[11] and 9-3a where the demand pattern by product category is presented.

9.1.4 Future Production and Demand

As indicated by Figure 9-4,[14] the overall trend for gypsum products is an increasing demand both from the present time through 1985 as well as beyond to 2000. There will, of course, be temporary downturns as demand follows historical construction industry cycles. Domestic demand is expected to increase and reach between 21.8 and 41.7 Tg per year (24 and 46 million tons per year) by 2000 with a probable annual demand of 34.5 Tg (38 million tons). This corresponds to an annual growth rate of 2.7 percent between 1977 and 2000.

Projected growth for individual gypsum product end uses is given in Table 9-4.[13] The historical growth rate of prefabricated products over the last 20 years has been about 3.5 percent per year. For the year 2000, the probable demand is 24.5 Tg (24 million tons) with a possible range of 18.1 to 34.5 Tg (20 to 38 million tons) depending on economic and demographic factors influencing construction activity. Plaster production is projected to decline. Building plaster is expected to reach a likely minimum of 181.4 Gg (200,000 tons) by 2000. If industrial plasters are included, a probable total demand of 544.2 Gg (600,000 tons) is projected. As a cement retarder, a range of 5.0 to 8.4 Tg (5.5 million to 9.3 million tons) is predicted for 2000 with the high value predicated on a continuation of the historical rate of construction activity. Probable demand is 5.9 Tg (6.5 million tons). Agricultural gypsum (land plaster) is projected to be 3.1 Tg (3.4 million tons) by 2000. In fillers and miscellaneous applications the predicted demand is

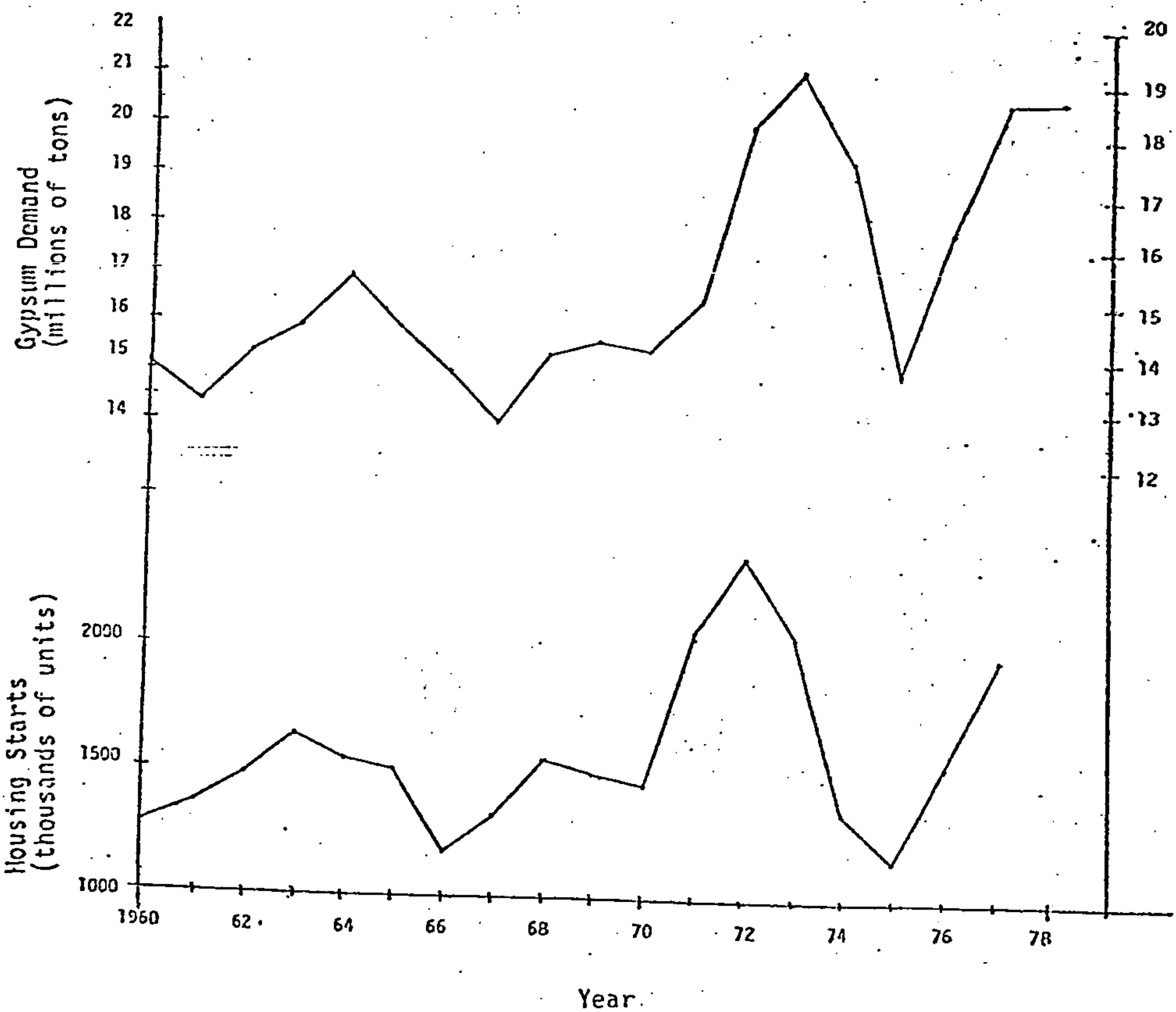


Figure 9-3. Gypsum Demand and Housing Starts 1960-1978.[10,11]

Table 9-3. GYPSUM SUPPLY-DEMAND RELATIONSHIPS, 1969-1979
(Mg)

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979[P]
World Production:											
United States	8,984	8,558	9,449	11,181	12,297	10,883	8,844	10,866	12,145	13,506	13,104
Rest of World	43,242	43,021	43,539	47,293	49,250	50,524	50,364	52,267	55,219	56,334	52,843
Total	52,226	51,579	52,988	58,474	61,547	61,407	59,208	63,133	67,364	69,840	65,947
Components of U.S. Supply:											
Domestic Mines	8,962	8,558	9,449	11,181	12,297	10,883	8,844	10,866	12,145	13,506	13,104
By-Product Gypsum	---	---	---	253	292	420	335	520	723	607	618
Imports, Crude	5,313	5,558	5,527	7,000	6,949	6,734	4,941	5,652	6,416	7,535	7,050
Industry Stocks, Jan. 1	3,451	3,343	3,782	3,380	3,909	4,830	3,628	1,814	1,905	2,358	3,380
Total U.S. Supply	17,726	17,460	18,758	21,815	23,447	22,417	17,748	18,851	21,188	24,006	24,153
Distribution of U.S. Supply:											
Industry Stocks, Dec. 31	3,343	3,782	3,380	3,909	4,381	3,628	1,814	1,905	2,358	3,380	3,356
Exports (Crude, Crushed, or Calcined)	36	37	37	46	57	120	68	258	130	120	83
Industrial Demand	13,189	12,889	15,341	17,606	18,716	16,955	14,138	16,343	18,633	19,581	19,554
U.S. Demand Pattern:											
Prefabricated Products	8,498	7,863	10,079	11,861	12,510	10,781	8,938	10,747	12,658	13,423	13,767
Plaster, Industrial and Building	1,353	1,165	1,069	1,034	1,019	866	752	721	712	824	710
Cement Retarder	3,142	3,046	3,071	3,559	3,762	3,681	2,942	3,099	3,583	3,818	3,570
Agriculture	998	729	1,019	1,039	1,318	1,516	1,344	1,555	1,519	1,368	1,393
Fillers and Miscellaneous	106	87	102	112	106	112	161	221	161	148	112
Total U.S. Demand	14,097	12,890	15,340	17,605	18,715	16,956	14,137	16,343	18,633	19,581	19,554

[P]Preliminary.

Table 9-3a. GYPSUM SUPPLY-DEMAND RELATIONSHIPS, 1969-1979
(Thousand Short Tons)

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979[p]
World Production:											
United States	9,905	9,436	10,418	12,328	13,558	11,999	9,751	11,980	13,390	14,891	14,448
Rest of World	47,676	47,432	48,003	52,142	54,300	55,705	55,528	57,627	60,882	62,111	58,262
Total	57,581	56,868	58,421	64,470	67,858	67,704	65,279	69,607	74,272	77,002	72,710
Components of U.S. Supply:											
Domestic Mines	9,881	9,436	10,418	12,328	13,558	11,999	9,751	11,980	13,390	14,891	14,448
By-Product Gypsum	---	---	---	279	322	463	369	573	797	669	682
Imports, Crude	5,858	6,128	6,094	7,718	7,661	7,424	5,448	6,231	7,074	8,308	7,773
Industry Stocks, Jan. 1	3,805	3,686	4,170	3,727	4,310	4,830	4,000	2,000	2,100	2,600	3,727
Total U.S. Supply	19,544	19,250	20,682	24,052	25,851	24,716	19,568	20,784	23,361	26,486	26,630
Distribution of U.S. Supply:											
Industry Stocks, Dec. 31	3,686	4,170	3,727	4,310	4,830	4,000	2,000	2,100	2,600	3,727	3,700
Exports (Crude, Crushed, or Calcined)	40	41	41	51	63	132	75	284	143	132	91
Industrial Demand	14,542	14,211	16,914	19,411	20,635	18,693	15,588	18,019	20,543	21,589	21,559
U.S. Demand Pattern:											
Prefabricated Products	9,369	8,669	11,112	13,077	13,793	11,886	9,855	11,849	13,956	14,799	15,179
Plaster, Industrial and Building	1,492	1,284	1,179	1,140	1,124	955	829	795	785	909	783
Cement Retarder	3,464	3,358	3,386	3,924	4,148	4,058	3,244	3,417	3,950	4,210	3,936
Agriculture	1,100	804	1,124	1,146	1,453	1,671	1,482	1,714	1,675	1,508	1,536
Fillers and Miscellaneous	117	96	113	124	117	123	178	244	177	163	123
Total U.S. Demand	15,542	14,211	16,914	19,411	20,635	18,693	15,588	18,019	20,543	21,589	21,559

Source: Bureau of Mines

[p]Preliminary.

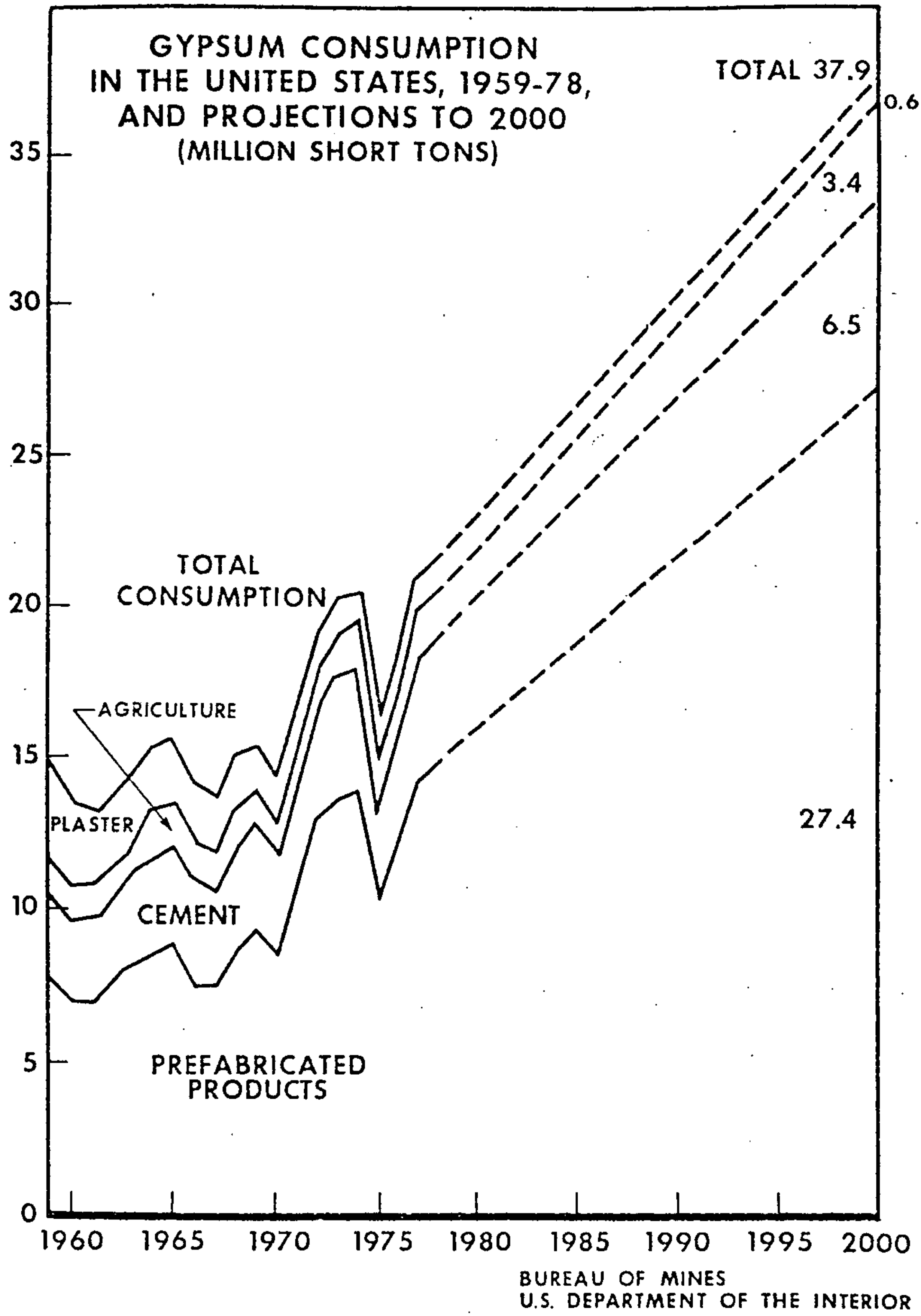


Figure 9-4. U.S. Demand for Gypsum Products Projected Through 2000.

TABLE 9-4. GYPSUM DEMAND THROUGH THE YEAR 2000
(by end use)

Product	1977 Base level		1985 Demand		2000 Demand		Annual Growth Rate	Percentage of Total Demand		
	10^3 tons	Tg	10^3 tons	Tg	10^3 tons	Tg	(%)	1977	1985	2000
Prefabricated gypsum products (Including wallboard, lath sheathing)	13,956	12.67	17,542	15.9	27,000	24.5	2.9	67.9	69.1	72.0
Industrial and Building Plasters	786	0.71	719	0.65	6,000	0.54	-1.1	3.8	2.8	1.6
Total Calcined	14,742	13.38	18,261	16.55	27,600	25.04	2.7	71.7	71.9	73.6
Cement Retarder	3,950	3.59	4,664	4.23	6,500	5.90	2.1	19.2	18.4	17.2
Agricultural Fertilizer	1,675	1.52	2,138	1.94	3,400	3.09	3.1	8.2	8.4	9.0
Filler and Miscellaneous	177	0.16	235	0.21	400	0.36	3.6	0.9	0.9	1.0
GRAND TOTAL	20,544	18.65	25,298	23.0	37,900	34.4	2.6	100	99.6	101.

362.8 Gg (400,000 tons) per year in 2000, taking into account probable competition from materials such as kaolin, calcium carbonate and talc.

Growth in demand for board products should be sustained, as discussed above, through the year 2000. Some reasons for predicted continued demand increases include: 1) gypsum wallboard has remained relatively inexpensive in comparison with other home building costs (wallboard accounts for only about 0.5 to 1 percent of the total cost of construction), 2) gypsum board offers significant fire and noise prevention advantages over possible substitutes such as wood and fiberboard, 3) the use of wallboard in mobile home construction is expected to increase because of recent tightening of fire and safety codes,[14] 4) the use of prefabricated gypsum products in nonresidential construction and home remodeling is expected to increase,[15] and 5) gypsum manufacturers actively seek to develop new gypsum-based products and new uses for existing products through their own research efforts and through their trade organization, the Gypsum Association.

9.1.5 Imports and Exports

Imported crude gypsum accounted for 33 percent of consumption in 1979, which was up from 32 percent in 1978, and 31 percent in 1977, but down from 35 percent and 34 percent respectively in 1976 and 1975.[16] If manufacturers continue to maintain the same production to demand ratios as in the past, then the import percentage will remain at about the same level. Imports occur because local market economics principally in the Northeast and Southwest United States make it preferable to import gypsum by ship primarily from Canada and Mexico rather than pay the higher cost of overland shipment from domestic mines far from the plant site.

Exports are made of crude, crushed, and calcined gypsum. Amounts are relatively insignificant and in 1979 represented only .9 percent of crude gypsum production.

9.1.6 Gypsum Plant Expansions and New Plants

In the 1970's the long range capacity planning was difficult because of sharp rises and declines in the construction activity cycles. During the early 1970's demand was very low. By 1972-73 record levels of demand rapidly increased the industry output. Then in 1975 demand and output fell to very low levels again, but by 1977-79 new record levels of output were reached.

Capacity utilization increased significantly in the 1975-79 period even though there were expansions of capacity. Gypsum board capacity in the period rose from 16.5 billion square feet to 18 billion square feet while capacity utilization grew from 65 percent in 1975 to 85, 91, 94 and 94 percent respectively for the years 1976-79.[17]

In the first three months of 1980 the industry continued operating at nearly full capacity, without the usual winter slowdown. Then the industry experienced the worst decline ever. But later analysis reveals that the decrease in sales was not as severe as originally feared. It was determined that sales did not fall all the way down with housing starts because of areas of new demand in fire resistance and sound control materials. Overall, the decline did amount to 15 to 17 percent. However, in the long range the outlook is much brighter. Also, the members of the Gypsum Association feel that the decade ahead will be good.[18]

To prepare to meet the anticipated growth in demand two new wallboard plants have been constructed since 1977. Eight gypsum board plant expansions and one plant startup increased the national production capacity by 46.45 Km^2 (500 million square feet) of board per year in 1978. According to the 1978 Annual Reports of the five leading companies, 11 plant expansions were completed or in progress at gypsum wallboard plants in 1978. These expansions are listed in Table 9-5. In 1978, U.S. Gypsum increased the capacity of one of its plants by 25 percent to a processing level of 453.5 Gg (500,000 tons) of rock annually, making it the largest board plant in the United States. The capacity increase was accomplished through various process modifications and efficiency improvements. U.S. Gypsum is currently expanding its Sweetwater, Texas plant. When the Sweetwater facility is finished, it will be the world's largest gypsum wallboard plant. This expansion and National Gypsum's recently completed Wilmington, North Carolina plant reflect the industry's market interest in America's Sun Belt states.

Assuming the reported 2.7 percent annual growth rate and a 95 percent capacity factor, the domestic wallboard capacity would have to increase 14 percent to meet the 1985 projected demand. To meet the 1990 projected demand, the capacity would have to be increased 30 percent or 511 km^2 (5.5 billion ft^2).

TABLE 9-5. RECENT NEW PLANT CONSTRUCTIONS AND PLANT EXPANSIONS IN THE GYPSUM INDUSTRY

Company	Location	Completion Date	Capacity Increase
Celotex (Div. of Jim Walter Corp.)	Jacksonville, FL	Expanded in 1978	Total 7%
	Cody, WY	Expanded in 1978	
Flintkote Co.	Florence, CO	To be operational in late 1979	50% expansion
	Sweetwater, TX	1980	50% expansion
Georgia-Pacific	Blue Rapids, KS	1978	36%[c]
	Cuba, MO	1978	New Plant
	Lovell, WY	1978	10%[d]
	Marietta, GA	Completed in 1978	13%
Gold Bond Building Products (National Gypsum)	Portsmouth, NH	Completed in 1978	
	Burlington, NJ	Completed in 1979	
	Rennselear County, NY	Completed in 1978	New Plant
	Rennselear County, NY	Planned for 1979	NA*
	Wilmington, NC	Completed in 1978	New Plant[a]
	Phoenix, AZ	Planned for 1980	40%[b]
U.S. Gypsum	Shoals, IN	1978	25%
	Sigurd, UT	1978	NA
	Norfolk, VA	1978	NA
	Chamblee, GA	1978	NA
	Gypsum, OH	1978	NA
	Plasterco, VA	Begun in 1978	85%
	Oakfield, NY	Begun in 1979, Completion scheduled for mid-1980	100%
	Sweetwater, TX	Begun in 1979, Completion scheduled for early 1981	NA
Domtar Gypsum America	Antioch, CA	Begun in 1979	Total 30%
	Long Beach, CA	Begun in 1979	
	Tacoma, WA	Planned for 1981	New Plant[e]

[a]About 200,000 tons (180 Gg) per year wallboard capacity.
[b]Capital expenditure of $6,000,000.
[c]Capacity increase of about 34,000,000 ft^2/yr (3,200,000 m^2/yr).
[d]Capacity increase of about 19,000,000 ft^2/yr (1,800,000 m^2/yr).
[e]About 300,000,000 ft^2/yr (28,200,000 m^2/yr) wallboard capacity.
[f]References 15, 21, 22, 23, 24, 25, 42, and 43.
*NA = Not Available.

At this time, there is no information concerning future expansions or new construction plans. However, the required increase in capacity to meet demand for gypsum products in the coming years cannot be met solely by improvements in current process equipment. In the fall of 1979, a period of high demand, most plants operated near full capacity. Thus, it is highly probable that future plant expansions will be necessary to meet increased demand. These expansions will involve the addition of new ore dryers and calcining equipment, and board forming lines for the manufacture of pre-fabricated gypsum board. Future expansion plans of manufacturers are usually kept confidential until an appropriate time is determined for release of such information. Future growth and new capital investment will vary in different regions of the country depending on demographic trends.

It should also be recognized it is not unusual for a manufacturer to shut down an older facility completely, and move usable equipment to a new site for inclusion in a new plant or reconstructed facility.

Limited data is available concerning existing plant sizes in the industry and the probable size of future plants. Neither the industry nor its trade organization, the Gypsum Association, would provide capacities of each gypsum plant in the industry. From the information they did provide, as well as information from other sources, a typical existing gypsum plant would produce about 250,000,000 square feet per year (23,220 km^2/yr) of prefabricated products. Approximately 60 of 73 existing plants are below this size and 13 above, based on plant count data available from the Bureau of Mines.[19] One information source stated that this would represent a minimum average size for new construction based on today's economics.[20]

As mentioned earlier, an approximate 14 percent increase in domestic wallboard capacity will be necessary to meet the 1985 projected demand. Table 9-5 has shown that five new plants and expansions are currently planned for completion in 1980 or later (Flintkote - Sweetwater, National - Phoenix, U.S.G. - Oakfield, U.S.G. - Sweetwater, Domtar - Tacoma). These five facilities are equivalent to approximately six percent of the industry's capacity. By subtracting the six percent capacity increase which is currently scheduled, from the total 14 percent increase, the remaining eight percent capacity increase is equivalent to approximately five new plants of 250,000,000 square feet each that will be necessary by 1985 [(16,865,292 thousand $ft.^2$ in 1979 x .08) ÷ 250,000 thousand $ft.^2$ = 5.39 new plants].

9.1.7 Sales and Profits.

From annual reports, sales of the gypsum product divisions of six companies were obtained along with reported operating profits for the divisions. These data are presented in Table 9-6.[21,22,23,24,25,26]

As stated earlier, the gypsum market should be viewed on a regional rather than on a national basis. This is illustrated by the information of Table 9-7 which shows leading sales regions for products in 1979. It is clear that there are regional variations in product mix which will impact future industry trends, depending on regional, demographic, and economic developments. Sales by region for 1979 in thousand square meters and thousand square feet for board products, and in megagrams and tons for other products, are presented in Tables 9-8 and 9-8a.[27]

9.1.8 Prices

Gypsum prices are sensitive to market conditions, fluctuating with the cyclical demand for products. Representative prices for crude gypsum from 1969 through 1978 are given in Table 9-9 in actual dollars and in constant 1978 dollars.[28] Also included are the average crude and calcined prices from 1975 through 1979 and the calculated ratio of calcined to crude prices. The ratio is useful for making estimates of calcined product prices when only crude price information is available. From 1975 through 1978, prices have increased both in real and inflated dollars, reflecting rising energy costs and a favorable market. Between 1973 and 1978, the average rate of price increase was 10 percent annually.[29] Table 9-10 gives product prices by category along with the ratio to crude price.

In addition, Table 9-11 shows that the Bureau of Labor Statistics producer price index for gypsum products between 1969 and 1979 rose at an average annual rate of 9.3 percent from 103.6 (1967 = 100) to 252.3. This was greater than the annual rate increase for a construction materials index of 8.4 percent.

The sensitivity of gypsum board prices over the short term and to local market conditions is illustrated by the following examples: The national average gypsum board price in early 1979 was $99/1000 square feet and by late 1979 the price was $114/1000 square feet.[30] Data available on local price variations for 1975[31] indicated a Dallas price of $44/1000 square feet for one-half inch wallboard while in the Chicago area the price was $90/1000

TABLE 9-6. REVENUES, OPERATING PROFITS, AND PERCENT PROFIT FOR SIX GYPSUM FIRMS[a]
(Dollars in Thousands)

	Year	U.S. Gypsum[b]	National Gypsum[b]	Georgia-Pacific Corp.	Celotex Div. of Jim Walter Homes, Inc.	The Flintkote Company	Republic Gypsum Company[b]
Revenues							
	1975	295,687	171,000*	2,229,000	404,758	194,335	9,121
	1976	363,753	210,000*	2,432,000	443,340	245,668	10,447
	1977	480,494	267,000*	2,575,000	510,599	324,388	13,235
	1978	620,763	341,867	3,153,000	597,128	413,998	18,227
	1979	703,347	391,552	3,370,000	664,696	NA	23,559
Operating Profit							
	1975	36,263	25,000*	97,000	37,005	7,096	196
	1976	46,992	27,000*	190,000	29,416	11,169	362
	1977	91,278	45,000*	347,000	40,837	27,160	1,674
	1978	170,439	86,617	434,000	65,685	48,633	5,536
	1979	187,581	101,198	329,000	63,388	NA	8,780
Operating Profit / Revenues (%)							
	1975	12.3	14.6	4.4	9.1	3.6	2.1
	1976	12.9	12.9	7.8	6.6	4.5	3.4
	1977	19.0	16.9	13.5	8.0	8.4	12.6
	1978	27.4	25.3	13.8	11.0	11.7	30.4
	1979	26.7	25.8	9.8	9.5	NA	37.3

[a]All data are from the listed company's 1979 Annual Report except for Flintkote, which is taken from the 1978 Annual Report. All data represent the "Building Products" business segment of the company (except where noted).

[b]Based on the "Gypsum Products" or "Gypsum Wallboard" segment.

*Rounded.

Table 9-7. THE THREE LEADING SALES REGIONS FOR EACH PRODUCT CATEGORY, 1979

Product	Census Region	Market Percentage
Cement Rock	South Atlantic	15.6
	West South Central	15.4
	Mountain	12.6
Agriculture	Pacific	69.3
	South Atlantic	24.1
	West North Central	2.6
Building Plasters	East North Central	21.4
	South Atlantic	18.3
	Middle Atlantic	18.2
Industrial Plasters	East North Central	21.6
	Pacific	19.9
	Middle Atlantic	17.8
Board Products	South Atlantic	17.8
	Pacific	17.0
	West South Central	14.4

[1]Regions are standard Bureau of Census geographic divisions. See Table 9-7 for footnotes.

Table 9-8. SALES OF GYPSUM IN THE UNITED STATES, BY SALES REGIONS[1,2]

(1979)

	New England	Middle Atlantic	E. North Central	W. North Central	South Atlantic	E. South Central	W. South Central	Mountain	Pacific	Exports	Total
Uncalcined (Mg)											
Portland Cement	28,183	440,883	445,843	446,022	556,989	240,217	551,601	450,541	405,630	4,001	3,569,910
Agriculture	141	1,417	11,870	35,800	336,575	9,231	14,134	15,871	966,473	3,065	1,394,575
Fillers and Miscellaneous	2,291	26,472	26,702	11,029	4,933	2,019	18,237	1,112	13,165	5,204	111,165
Total	30,615	468,772	484,415	492,851	898,497	251,467	583,972	467,524	1,385,268	12,270	5,075,650
Calcined (Mg)											
Building Plasters:											
Regular Basecoat	1,780	16,996	11,980	5,399	22,700	4,713	9,184	3,959	27,286	5,985	109,984
Mill-Mixed Basecoat	4,782	31,480	23,743	5,252	7,601	2,353	2,686	3,311	7,608	290	89,104
Veneer Plaster	18,336	7,074	21,207	5,375	22,066	834	512	1,643	10,890	1,116	89,051
Gauging, Molding, etc.	714	7,807	6,534	1,898	3,919	711	941	440	2,930	1,543	27,437
Roof-Deck Concrete	1,058	3,271	14,826	4,800	10,670	1,837	11,419	658	2,143	91	50,771
Total	26,670	66,628	78,290	22,724	66,956	10,443	24,742	10,011	50,857	9,025	366,347
Industrial Plasters	9,920	61,326	74,211	17,451	39,137	12,983	25,431	12,729	68,512	22,231	343,936
Board Products (Thousand Square Meters)											
Lath	361	2,899	1,764	133	3,215	56	22	171	2,935	331	11,887
Veneer Base	9,235	3,070	10,337	2,336	12,353	323	116	325	3,924	153	42,172
Sheathing	569	974	1,745	1,603	2,496	957	8,807	1,170	2,409	15	20,746
Regular Gypsum Board	44,425	110,825	156,380	91,333	227,947	72,714	179,425	125,174	182,131	2,506	1,192,861
Type X Gypsum Board	11,255	33,948	42,745	27,115	33,963	11,162	38,084	31,826	79,799	970	310,867
Predecorated Board	476	2,217	3,531	1,868	5,816	1,927	5,038	984	1,699	114	23,670
Total	66,321	153,933	216,502	124,388	285,790	87,139	231,492	159,650	272,897	4,089	1,602,203

[1] Some data were collected cooperatively with the Gypsum Association.

[2] Sales region equivalent to Bureau of Census geographic divisions as follows: New England (ME, NH, VT, MA, RI, CT); Middle Atlantic (NY, NJ, PA); East North Central (OH, IN, IL, MI, WI); West North Central (MN, IA, MO, ND, SD, NB, KS); South Atlantic (DE, MD, DC, VA, WV, NC, SC, FL, GA); East South Central (KY, TN, AL, MS); West South Central (AR, LA, OK, TX); Mountain (MT, ID, WY, CO, NM, AZ, UT, NV); Pacific (WA, OR, CA, AK, HI).

Table 9-8a. SALES OF GYPSUM IN THE UNITED STATES, BY SALES REGIONS[1,2]
(1979)

	New England	Middle Atlantic	E. North Central	W. North Central	South Atlantic	E. South Central	W. South Central	Mountain	Pacific	Exports	Total
Uncalcined (Short Tons)											
Portland Cement	31,073	486,089	491,558	491,755	614,100	264,848	608,160	496,738	447,222	4,411	3,935,954
Agriculture	155	1,562	13,087	39,471	371,086	10,177	15,583	17,498	1,065,571	3,379	1,537,569
Fillers and Miscellaneous	2,526	29,186	29,440	12,160	5,439	2,226	20,107	1,226	14,515	5,738	122,563
Total	33,754	516,837	534,085	543,386	990,625	277,251	643,850	515,462	1,527,308	13,528	5,596,086
Calcined (Short Tons)											
Building Plasters:											
Regular Basecoat	1,963	18,739	13,208	5,953	25,028	5,196	10,126	4,365	30,084	6,599	121,261
Mill-Mixed Basecoat	5,272	34,708	26,177	5,790	8,380	2,594	2,961	3,650	8,388	320	98,240
Veneer Plaster	20,216	7,799	23,381	5,926	24,329	919	564	1,811	12,007	1,230	98,182
Gauging, Molding, etc.	787	8,607	7,204	2,093	4,321	784	1,038	485	3,230	1,701	30,250
Roof-Deck Concrete	1,166	3,606	16,346	5,292	11,764	2,025	12,590	725	2,363	100	55,977
Total	29,404	73,459	86,316	25,054	73,822	11,518	27,279	11,036	56,072	9,950	403,910
Industrial Plasters	10,937	67,614	81,820	19,240	43,150	14,320	28,039	14,034	75,537	24,511	379,202
Board Products (Thousand Square Feet)											
Lath	3,796	30,521	18,566	1,402	33,840	589	234	1,798	30,890	3,489	125,125
Veneer Base	97,211	32,318	108,814	24,590	130,032	3,395	1,221	3,423	41,303	1,613	443,920
Sheathing	5,991	10,256	18,364	16,877	26,272	10,074	92,703	12,319	25,362	160	218,378
Regular Gypsum Board	467,636	1,166,582	1,646,100	961,397	2,399,444	765,411	1,888,684	1,317,624	1,917,172	26,378	12,556,428
Type X Gypsum Board	118,476	357,343	449,943	285,420	357,508	117,497	400,888	335,009	839,992	10,209	3,272,285
Predecorated Board	5,007	23,338	37,168	19,667	61,223	20,282	53,036	10,353	17,885	1,197	249,156
Total	698,117	1,620,358	2,278,955	1,309,353	3,008,319	917,248	2,436,766	1,680,526	2,872,604	43,046	16,865,292

[1]Some data were collected cooperatively with the Gypsum Association.

[2]Sales region equivalent to Bureau of Census geographic divisions as follows: New England (ME, NH, VT, MA, RI, CT); Middle Atlantic (NY, NJ, PA); East North Central (OH, IN, IL, MI, WI); West North Central (MN, IA, MO, ND, SD, NB, KS); South Atlantic (DE, MD, DC, VA, WV, NC, SC, FL, GA); East South Central (KY, TN, AL, MS); West South Central (AR, LA, OK, TX); Mountain (MT, ID, WY, CO, NM, AZ, UT, NV); Pacific (WA, OR, CA, AK, HI).

Source: Bureau of Mines

Table 9-9. PRICES FOR CRUDE GYPSUM

	Average Annual Price, Dollars per Short Ton				
	Crude Gypsum		Calcined Gypsum		
Year	Actual Prices	Based on Constant 1978 Dollars	Actual Prices	Based on Constant 1978 Dollars	Ratio Calcined: Crude
1959	3.59	8.09	-*	-	-
1960	3.63	8.04	-	-	-
1961	3.68	8.08	-	-	-
1962	3.65	7.87	-	-	-
1963	3.67	7.80	-	-	-
1964	3.64	7.61	-	-	-
1965	3.73	7.63	-	-	-
1966	3.70	7.33	-	-	-
1967	3.66	7.04	-	-	-
1968	3.67	6.76	-	-	-
1969	3.88	6.80	-	-	-
1970	3.72	6.19	15.63	-	-
1971	3.75	5.94	15.96	-	-
1972	3.93	5.98	16.32	-	-
1973	4.18	6.01	16.31	-	-
1974	4.41	5.78	18.71	-	-
1975	4.58	5.48	16.97	20.20	4.43
1976	5.00	5.69	18.85	21.42	4.29
1977	5.55	5.96	20.57	22.11	3.98
1978	6.23	6.23	27.56	27.56	4.42
1979	6.83	-	30.40	-	4.45
1980	7.65	-	33.44	-	4.37

*- = Not Available.

Table 9-10. GYPSUM PRODUCT PRICES, 1975

Product Category	Price ($/ton)	Ratio* Product Price / Crude Price
Prefabricated products (board)	44.96	9.82
Building plasters	42.27	11.03
Industrial plasters	50.50	9.23
Uncalcined products (cement rock and land plaster	6.74	1.47

*Ratios were calculated from 1975 prices for use in estimating current prices if crude prices are known in the absence of product category price data.

Table 9-11. GYPSUM PRODUCT PRICE INDEX

Year	Gypsum Products Index (1967 = 100)	Percent Change	All Construction Material & Change
1969	103.6	-	-
1970	99.7	- 3.8	0.5
1971	109.3	9.6	6.2
1972	114.7	4.9	5.9
1973	120.9	5.4	9.4
1974	137.6	13.8	16.2
1975	144.0	4.7	8.1
1976	154.4	7.2	7.9
1977	183.5	18.8	9.2
1978	229.1	24.9	11.4
1979	252.3	10.1	10.1

Source: Bureau of Labor Statistics

square feet. For building plaster, prices ranged from $68/ton in Philadelphia to $94/ton in Denver. These market-related variations are typical at any time.

9.1.9 Industry Employment

Table 9-12 presents the distribution of employment at individual gypsum plants as well as total industry employment levels from 1975 through 1980.[32,33] Despite industry growth employment has leveled off in recent years because of automation.

Table 9-12. GYPSUM INDUSTRY EMPLOYMENT

A. Distribution of Employment At Domestic Gypsum Plants

Number of Employees	Number of Plants
20 to 49	10
50 to 99	16
100 to 250	40
250 to 500	7
500 to 1000	1

B. Employment Levels 1975-1980

Year	Number of Employees (Mine and Calcining Plants)	Board Plants (Est.)
1975	5,000	3,750
1976	5,100	3,825
1977	5,300	3,975
1978	5,400	4,050
1979 (est.)	5,400	4,050
1980	5,400	4,050

Source: Bureau of Mines

9.2 Economic Impact Assessment

9.2.1 Introduction and Summary

9.2.1.1 Introduction. This section assesses the economic impact of the regulatory alternatives for the New Source Performance Standard (NSPS) on the gypsum products manufacturing industry. Economic profile information on the industry presented in Section 9.1 is a principal input to this assessment. The impact on individual new plants is assessed by using model plants that represent small, medium, and large members of the industry, as well as potential expansions of existing plants. The model plants are described in earlier sections and will not be repeated here. Various financial analysis techniques are applied to the model plants to determine potential impacts on control affordability and control capital availability. These findings are assessed, based on the industry profile, to determine the industry-wide impacts that are presented in Section 9.3.

As noted in previous chapters, the sources of interest, associated with the gypsum wallboard manufacturing process, are: ore dryer; calciners; board end sawing; scoring and chamfering; stucco continuous mixing and bagging, conveyors, and storage bins; and stucco plaster. Not every model plant contains every facility of interest.

9.2.1.2 Summary. The most costly regulatory alternative (3b) will cause the gypsum board industry to incur additional total capital investment and annual compliance costs (including interest and depreciation) of approximately $0.8 million and $1.0 million, respectively. Considering the growth in demand for gypsum board, as well as the current market structure of the industry, it is likely that the costs will be passed forward. The most costly regulatory alternative could increase the price of gypsum wallboard by a maximum of $1.27 for a new plant. This implies a price increase of 1.1 percent for wallboard that sells for $114 per thousand square feet (MSF).

In the event the costs are not passed through in the form of price increases, but instead are absorbed by the gypsum board manufacturers, the change in estimated net operating profit of new plants would be 5.6 percent, for the most costly regulatory alternative. However, as detailed in the following sections, it is more likely that the maximum change in profit will be less than 5.6 percent.

Even if the profit rate declines by 5.6 percent, this is not expected to deter investment in new plants. Other impacts on the gypsum board industry such as product substitution and foreign trade effects are negligible. Also, secondary impacts on employment and the community are not anticipated.

9.2.2 Ownership, Location, Concentration

Ownership characteristics range from single plant privately held operations to large publicly held corporations that own as many as 22 gypsum plants. The publicly held companies are diversified corporations within which the manufacture of gypsum wallboard may represent one of as many as ten distinct business segments. The various business segments may or may not be related to gypsum, such as: building products, metal products, chemicals, sugar operations, and so on. In the above companies, the sales contribution from gypsum products ranges from less than 5 percent of a company's sales, to greater than 85 percent.[34]

The industry is highly concentrated. The five largest companies own 61 of the industry's total of 74 plants. The 1977 concentration ratios are not currently available, however the 1972 census data reveals that the top four companies producing gypsum building products (board and lath) accounted for 80 percent of the total value of shipments and the top eight had 93 percent. The 1967 census reports a similar concentration and this is probably close to the current situation.[35]

9.2.3 Pricing

The most important gypsum product both in volume and dollar value is 1/2 inch gypsum wallboard. Producers normally quote prices in units of 1,000 square feet (MSF) of board.

An indication of the generally healthy financial condition of the industry is provided by the fact that sales and earnings have been setting records in recent years. Prices for wallboard have increased at an average rate of 10 percent per year for the period 1973 to 1979, due to a combination of higher energy and paper costs, a general inflationary trend, and favorable demand for housing.

The highest price increase if incremental control costs are completely passed through to customers is $1.27 per MSF, for the small model plant. Based on the price of wallboard, as noted in Section 9.1, of $114 per MSF in late 1979 $1.27 maximum increase is equivalent to a percentage price increase of 1.1 percent. Table 9-13 shows the price increase and percentage price increase for each of the model plants for the most costly regulatory alternative, 3b. A potential maximum price increase of 1.1 percent is not excessive when compared with other price increases the industry has experienced in recent years. In fact, according to the 1977 Census of Manufacturers the total cost of materials (including energy consumed by the gypsum products industry) was $418.7 million, which was nearly double the cost reported for 1970 of $210.8 million.[36]

Also, as noted in Section 9.1 prices can vary widely among different geographical areas of the country. The wide variation in prices among different geographical areas of the country suggests that a pollution control cost increase of the magnitude under consideration here, if passed through to customers in the form of slightly higher prices, would not independently cause increased competition from other geographical areas.

Transportation costs are an important element in the price of board. Producers sell board on a freight equalized basis, i.e., the customer pays no more in freight than it would cost from the nearest supplier. If a producer is not the closest supplier to a customer, that producer absorbs the additional freight costs. Therefore, a producer located considerably farther away from a given market area than other producers selling in that area cannot normally sell profitably in that area. Transportation costs normally become prohibitive beyond a radius of approximately 500 miles when another producer is located nearer to the customer.[37] Producers can also compete for sales through means other than price, such as more attractive credit terms.

9.2.4 Supply

The Bureau of Mines estimates that the supply of crude gypsum is virtually unlimited in major producing countries. The United States domestic reserves are estimated to be about 700 million tons compared to the world reserves of 2.4 billion tons. In the United States, the supply of crude gypsum is more than adequate to meet requirements to the year 2000.[38]

The supply of gypsum wallboard capacity is not likely to experience shortages for the foreseeable future. Section 9.1 has noted additional capacity scheduled to begin operation in the near future. Longer term, capacity should remain adequate since entry into the industry is not unusually difficult for several reasons. First, there are no major patent obstacles to prevent the opening of a new plant. Second, high technology is not involved. Finally, capital requirements are not excessive by manufacturing standards.

Table 9-13. PERCENT PRICE INCREASE
($ in 000's)

Plant Size	Relevant Model Plant Number	Baseline Annual Operating Cost	Regulatory Alternative 3b Annual Operating Cost	NSPS Incremental Annual Operating Cost (3b-Baseline)	Capacity mm sq. ft./year	Price Increase ($NSPS/ Capacity)	NSPS Percent Price Increase
Small	1	195	321	126	116	1.09	.9%
Small	2	251	398	147	116	1.27	1.1%
Medium	3	142	292	150	232	.65	.6%
Medium	4	253	447	194	232	.84	.7%
Medium	5	230	435	205	232	.88	.8%
Medium	6	194	278	84	232	.36	.3%
Large	7	64	266	202	401	.50	.4%
Large	8	238	484	246	401	.61	.5%
Expansion	9	(8)	15	23	38	.61	..5%
Expansion	10	24	46	22	38	.58	.5%
Expansion	11	140	225	85	116	.73	.6%
Expansion	12	195	303	108	116	.93	.8%
Replacement	13	97	129	32	56,000*	.57/ton	1.0%

*Tons per year of plaster.

9.2.5 Demand

The demand for gypsum has been strong in recent years with the industry operating at 85, 91, 94 and 94 percent of capacity respectively for the years 1976, 1977, 1978, 1979.[39] In the first three months of 1980 the industry operated at almost full capacity, without the usual winter slowdown. After the first three months, demand fell sharply as the construction industry declined, but it is expected to increase again once activity in the construction industry begins to return to normal.[40] This condition of strong demand suggests that if incremental control costs, of the magnitude under consideration here, are passed forward in the form of higher prices, demand is unlikely to be influenced. Further, the expansion of capacity at some existing plants indicates a belief by industry that, although there may be cyclical ups and downs, the increased demand is likely to persist.

An additional indication that the incremental control costs if passed forward are not likely to reduce demand is provided by the fact that gypsum wallboard is an important product in construction and the cost of gypsum represents a minor portion of the total cost of construction. Therefore a minor increase in the price of gypsum is not likely to influence the demand for gypsum.

There are other building materials, such as plywood, particleboard and wood paneling that are possible substitutes for gypsum board products. However, gypsum board is easier to install and cheaper than other products with similar technical characteristics. Thus, a small increase in the price of gypsum board is not likely to cause a significant rise in the use of substitute products and a decrease in the demand for gypsum board.

9.2.6 Methodology

This section describes the methodology used to assess the economic impact of the regulatory alternatives on the gypsum products manufacturing plants. The principal economic impact which is assessed is the effect of incremental control costs on the profitability of new grassroots plants, or expansions of existing plants.

In the analysis which follows, each model plant is evaluated as if it stands alone, that is, the firm is not associated with any other business activity nor is it associated with any larger parent company. This assumption has the effect of isolating the control cost without any assistance from other business activities or firms. This is a conservative assumption because the larger companies in the gypsum products manufacturing industry are major corporations with substantial management, financial, and other resources, any or all of which could be used to aid other product lines or subsidiaries. For example, a parent corporation could lend money to a subsidiary, or a parent corporation could guarantee repayment of a subsidiary's loan.

Since each State Implementation Plan (SIP) contains particulate emission control standards, any new plant would have to meet SIP standards even in the absence of a NSPS. Incremental control costs are the control costs over and above those baseline costs required to meet the various SIP standards.

This analysis assumes that a plant is profitable in the absence of a NSPS. Therefore, the focus of this analysis is on incremental costs to determine if a plant which would otherwise be profitable is now rendered unprofitable as a result of the incremental control costs.

Economic impact is evaluated on model plants whose description is based on representative characteristics of new or expanded plants, such as production capabilities, asset size, and other financial measures. The model plants provide an indication of the degree of impact on all new plants in the industry by incorporating into the models the major characteristics prevailing in various size segments of the gypsum products manufacturing industry. They do not represent any particular existing plant as any individual plant may differ in one or more of the above characteristics.

As discussed earlier, indications suggest that control costs are likely to be passed forward in the form of higher prices. However, for completeness, an additional assessment is provided to represent control affordability if control costs are completely absorbed by the model plants. The analytical technique employed to assess control affordability if control costs are absorbed, is the change in the net operating profit rate of return. The net operating profit rate of return can be expressed as:

$$\text{Net Operating Profit Rate of Return} = \frac{\text{Earnings before Interest and Taxes}}{\text{Total Investments}}$$

Earnings before interest and taxes is used, rather than Net Profit after Taxes, to focus on earnings before the influence of different methods of financing and different proportions of debt and equity.

The issue of concern for the net operating profit rate of return assessment is whether or not the change in the rate of return, after absorption of control costs, would affect the decision to invest in a plant as described by the model plant.

9.2.7 Calculations

Table 9-14 shows the net operating profit rate of return for the small model plant without incremental controls, the small model plant with incremental controls absorbed, and the change in rate of return after absorption.

The numerator in the rate of return analysis represents the net operating profit for a small model plant. The revenue for a small model plant is represented by production of 116,000 MSF times $114 per MSF for a total annual revenue of $13,224,000. Table 9-6 in Section 9.1 has shown the operating profits as a percent of revenue for six members of the industry. The figures in Table 9-6 are for the business segment that includes gypsum wallboard. For three of the companies, U.S. Gypsum, National Gypsum, and Republic Gypsum, wallboard represents a high percentage of the sales for that business segment, approximately 100 percent. For the other three companies, Georgia-Pacific, Celotex, and Flintkote, gypsum wallboard represents a lower percentage of the sales for that business segment since products other than gypsum wallboard represent a substantial portion of the sales for the business segments. Approximately six to seven percent of the appropriate business segment for Georgia-Pacific is due to wallboard, and approximately 30 percent for Flintkote, and an unknown but lesser percent for Celotex. The three companies with the higher percentage of sales due to wallboard provide the better indication of representative operating profit margins on sales. The average percent of operating profit to sales for the three companies for 1979 is 29.9 percent with a range of 25.8 percent to 37.3 perent. Also, these three companies own a total of 20 plants. By adding Georgia-Pacific and Celotex (Flintkote is not available) the average profit margin for 1979 for the five companies is 21.8 percent.

Therefore, in order to be conservative and to simplify the mathematics of the analysis 20 percent is chosen as the profit margin on sales. The 20 percent figure is less than either of the averages mentioned earlier of 29.9 percent or 21.8 percent, and would tend to overstate the impact of the control costs.

Table 9-14. CHANGE IN NET OPERATING PROFIT RATE OF RETURN FOR A SMALL MODEL ASSUMING COMPLETE CONTROL COST ABSORPTION

116,000	MSF per year
x $114	per MSF
$13,224,000	revenues per year
x 20%	net operating profit margin on sales
$2,644,800	net operating profit

Net Operating Profit Rate of Return -- without controls $= \dfrac{\text{Earnings Before Interest and Taxes}}{\text{Total Investment}}$

$$= \frac{\$2{,}644{,}800}{\$11{,}400{,}000} = 23.2\%$$

Net Operating Profit Rate of Return -- with controls $= \dfrac{\text{Earnings Before Interest and Taxes - Controls}}{\text{Total Investment}}$

$$= \frac{\$2{,}644{,}800 - \$147{,}400}{\$11{,}400{,}000} = 21.9\%$$

Change in Rate of Return = 23.2 - 21.9 = 1.3

Percent Change in Rate of Return $= \dfrac{1.3}{23.2} = 5.6\%$

The denominator in the rate of return analysis represents the capital cost for a small model plant of $11,400,000 as shown on Table 9-14.

9.2.8 Findings

9.2.8.1 Control Affordability. Table 9-14 shows that the maximum change in the net operating profit rate of return is 5.6 percent for a small model plant. The change is less than 5.6 percent for the larger model plants due to economies of scale. Table 9-6 shows that the returns for a single company may commonly vary by 5.6 percent or more from one year to the next. Also, table 9-6 shows that the returns among the companies often vary by 5.6 percent or more for the same year. Additionally, the increasing sales and profits that the industry has experienced in recent years, plus the projections of continued favorable sales and earnings, suggests that a maximum potential change in net operating profit of 5.6 percent would not deter a new investment. Therefore, for the reasons cited above, if in the unlikely event that control costs are absorbed rather than passed forward, the incremental control costs are not likely to cause an investment in a new plant that would otherwise be accepted to now be rejected.

9.2.8.2 Control Capital Availability. Table 9-15 shows the additional capital required for each of the 13 model plants, and the percentage increase the control capital represents when compared to the average capital cost without the incremental costs. The maximum percentage increase for control capital expenditures for a new plant is 1.1 percent for model plant two. The actual capital cost would add $120,000 to an average investment of $11,400,000. The maximum percentage increase for control capital expenditures for an expansion to an existing plant is 4.0 percent for model plant ten. The actual capital cost would add $20,000 to an average investment of $500,000.

As mentioned in Section 9.1 the industry is expected to build capacity equivalent to five medium size plants over the next five years. If those plants require the maximum control capital expenditures then the additional cost will be $160,000 for each plant. This will mean an additional capital expenditure of approximately $160,000 a year, which is small relative to the gypsum board industry's total capital expenditures. A capital expenditure of $160,000 per plant represents only 0.5% of the total industry capital expenditure of $31.4 million in 1977.[41]

Table 9-15 TOTAL INSTALLED COST OF MODEL PLANTS[a]
(March 1980)

Plant Size	Relevant Model Plant Number	Capacity MM sq. ft./ year	Cost Range $ Millions	Average Cost $ Millions	Highest NSPS Capital Cost $ Millions	Percent NSPS Increase
Small	1	116	9.2-13.5	11.4	.100	.9%
Small	2	116	9-2-13.5	11.4	.120	1.1%
Medium	3	232	16.0-23.5	19.8	.120	.6%
Medium	4	232	16.0-23.5	19.8	.160	.8%
Medium	5	232	16.0-23.5	19.8	.160	.8%
Medium	6	232	16.0-23.5	19.8	.080	.4%
Large	7	401	15.0-36.5	19.8	.1599	.5%
Large	8	401	15.0-36.5	19.8	.200	.6%
Expansion	9			.79	.020	2.5%
Expansion	10			.50	.020	4.0%
Expansion	11			6.51	.080	1.2%
Expansion	12			7.03	.100	1.4%
Replacement	13			.68	.020	2.9%

[a]Reference 10.

Neither the additional control capital expenditures for the new plants, nor the additional control capital expenditures for the expansion are likely to prevent investments in the thirteen model plants, when the model plants are assessed on a stand-alone basis. Also, most of the gypsum plants are owned by corporations that own several gypsum plants as well as other business segments and have substantial financial resources and ready access to capital markets. Therefore, to the extent that new plants or expansions to existing plants are built by these major corporations rather than a single stand-alone plant the necessary capital for control expenditures would be equally or more likely to be available.

9.3 Socio-Economic Impact Assessment

9.3.1 Macroeconomic Impact

The purpose of Section 9.3 is to address those tests of macroeconomic impact as presented in Executive Order 12044 and, more generally, to assess any significant impact on small business, as directed by the Regulatory Feasibility Act.

The economic impact assessment is concerned only with the costs or negative impacts of the NSPS. The NSPS will also result in benefits or positive impacts, such as cleaner air and improved health for the population, potential increases in worker productivity, increased business for the pollution control manufacturing industry, and so forth. However, the NSPS benefits will not be discussed here.

There are three principal review criteria to determine significant macroeconomic impact.

1. Additional annual costs of compliance, including capital charges (interest and depreciation), total $100 million (i) within any one of the first five years of implementation, or (ii) if applicable within any calendar year up to the date by which the law requires attainment of the relevant pollution standard.
2. Total additional cost of production of any major industry product or service exceeds 5 percent of the selling price of the product.
3. The Administrator requests such an analysis (for example when there appear to be major impacts on geographical regions or local governments.

The gypsum NSPS will not trigger any of the above tests. Capacity equivalent to five medium size new plants is projected to be built. The annualized costs of compliance will be $204,800 for a medium size plant (Model Plant 5) or a total of $1,024,000, which is far below the $100 million test. Finally, new plants that are subject to the NSPS will be diversified geographically. Therefore, no significant macroeconomic impacts are likely.

9.3.2 Small Business Impact

This section addresses the impact of this regulation on small business in this industry, as directed by the Regulatory Flexibility Act.

This regulation applies directly only to new sources, and not to existing sources. Existing small businesses in this industry will become subject to this regulation only as existing plants modify or reconstruct existing operations and are then classified as new sources as detailed in an earlier section.

There is a total of 74 plants in the industry. Section 9.1.9 has listed the size distribution of plants in the industry according to the number of employees. Total new capacity equivalent to five new medium size plants is projected to be built by 1985. If the current size distribution of plants is maintained for new plants, one new plant in the category of less than 49 employees is likely to be built.

As noted earlier, the total number of small plants likely to be affected by 1985 is small. Also, the economic impact on those small plants that are affected is likely to be minimal.

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APPENDIX A

EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

The purpose of this study was to develop background information to support New Source Performance Standards (NSPS) for the gypsum industry. Work on this study was performed by Radian Corporation under contract to the United States Environmental Protection Agency (EPA), specifically, under the direction of the Office of Air Quality Planning and Standards (OAQPS), Emission Standards and Engineering Division (ESED).

In October 1979, Radian Corporation was contracted to develop a Source Category Survey (Phase I). This phase of the study was a screening study of the gypsum industry. From the screening study it was concluded that NSPS should be developed for the gypsum industry. Radian Corporation then began work on Phase II of this study, development of the Background Information Document (BID). Phase II entailed a more complete and up to date literature search and survey of the industry, including plant visits. The feasibility of conducting emissions testing was determined during the plant visits. Detailed questionnaires were submitted to the gypsum manufacturing plants, under Section 114 of the Clean Air Act, to gather information on plant operations.

The chronology which follows lists the major events which have occurred in the development of background information for New Source Performance Standards for the gypsum industry.

16 October 1979	Draft Work Plan for Phase I submitted; meeting with project team for source category survey of gypsum production.
October 1979	Telephone and literature surveys begun.

28 November 1979	Plant visit to United States Gypsum Company (USG), Shoals, Indiana.
29 November 1979	Plant visit to Flintkote Company, Sweetwater, Texas.
30 November 1979	Visit to Texas Air Control Board, Austin, Texas.
3 December 1979	Visit to North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina.
4 January 1980	Draft Source Category Survey Report submitted.
18 January 1980	Meeting with project team to review Source Category Survey of gypsum production.
11 February 1980	Meeting with project team to review Draft Work Plan for Phase II and Phase III.
15 February 1980	Second draft of Work Plan for Phase II and Phase III submitted.
12 March 1980	Plant visit to National Gypsum Company at Wilmington, North Carolina.
31 March 1980	Meeting with project team to review the proposed emission source test plan.
17 April 1980	Plant visit to USG at Fort Dodge, Iowa.
18 April 1980	Visit to CE Raymond (Division of Combustion Engineering, Inc.) at Abilene, Kansas.
21 April 1980	Plant visit to USG at Sweetwater, Texas.
21 April 1980	Plant visit to Flintkote Company at Sweetwater, Texas.
23 April 1980	Plant visit to Flintkote Company at Blue Diamond, Nevada.
6 May 1980	Plant visit to National Gypsum Company at Savannah, Georgia.
7 May 1980	Visit to Georgia Department of Natural Resources at Atlanta, Georgia.
19-23 May 1980	Emission source tests conducted at National Gypsum Company's wallboard plant at Wilmington, North Carolina.
29 May 1980	Plant visit to USG in East Chicago, Illinois.
3-6 June 1980	Emission source tests conducted at USG's wallboard plant at Shoals, Indiana.
17 June 1980	Meeting with project team to review the status of the emission source test program.

19 June 1980	Plant visit to USG at Southard, Oklahoma.
20 June 1980	Preliminary model plant parameters submitted.
29 June 1980	Pre-test plant visit to National Gypsum Company at Richmond, California.
2 July 1980	Meeting with National Gypsum Company personnel at Charlotte, North Carolina.
14-17 July 1980	Emission source tests conducted at National Gypsum Company's wallboard plant at Richmond, California.
3 August 1980	Meeting with USG personnel at Chicago, Illinois.
4 August 1980	Pre-test plant visit to USG at Fort Dodge, Iowa.
11 August 1980	Response from National Gypsum Company on preliminary model plant parameters.
13 August 1980	Preliminary tabular costs of control equipment submitted.
2 October 1980	Visible emission source tests conducted at National Gypsum Company's wallboard plant at Wilmington, North Carolina.
22 October 1980	Meeting with project team to discuss baseline emission levels, SO_2 emissions, and stockpiling emissions.
24-31 October 1980	Emission source tests conducted at USG's wallboard plant at Fort Dodge, Iowa.
30 October 1980	Final tabular costs of control equipment submitted.
12 November 1980	Dispersion modeling requested.
14 November 1980	Economic impact analysis requested.
26 November 1980	Meeting with project team to discuss the basis of proposed standards.
22 December 1980	Chapters 3-6 of the Background Information Document distributed for industry comment.

APPENDIX B

INDEX TO ENVIRONMENTAL CONSIDERATIONS

This appendix consists of a reference system which is cross indexed with the October 21, 1974, Federal Register (39 FR 37419) containing EPA guidelines for 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.

APPENDIX B

CROSS-INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document (BID)
1. Background and 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 the Standard	The statutory basis for proposing standards is summarized in Chapter 2, Section 2.1.
Industry Affected	A description of the industry to be affected is given in Chapter 3, Section 3.1.
Process Affected	A description of the process to be affected is given in Chapter 3, Section 3.2.
Availability of Control Technology	Information on the availability of control technology is given in Chapter 4.
Existing Regulations at State or Local Level	A discussion of existing regulations for the industry to be affected by the standards are included in Chapter 3, Section 3.3.
2. Environmental, Energy, and Economic Impacts of Regulatory Alternatives	
Health and Welfare Impact	The impact of emission control systems on health and welfare is considered in Chapter 7, Section 7.1.

Continued

CROSS-INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS (Concluded)

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document (BID)
Air Pollution	The air pollution impact of the regulatory alternatives are considered in Chapter 7, Section 7.1.
Water Pollution	The impacts of the regulatory alternatives on water pollution are considered in Chapter 7, Section 7.2.
Solid Waste Disposal	The impact of the regulatory alternatives on solid waste disposal are considered in Chapter 7, Section 7.3.
Energy	The impacts of the regulatory alternatives on energy use are considered in Chapter 7, Section 7.4.
Costs	The cost impact of the emission control systems is considered in Chapter 8.
Economics	Economic impacts of the regulatory alternatives are considered in Chapter 9.

APPENDIX C - SUMMARY OF TEST DATA

The results of particulate and visible emission measurements conducted on sources at nine different gypsum plants are presented in this appendix. The particulate emission measurements include mass emission rates and particle size distributions. The visible emission measurements include opacity readings at stack exits and assessments of capture efficiency at fugitive emission capture points.

The nine plants for which EPA and EPA-approved test data are presented are identified as Plants C, E, J, W, Y, GG, OO, RR and TT. In the development of this document, permit applications, test reports, and National Emissions Data System data for at least 48 gypsum plants were reviewed. These plants are identified as Plants A through VV.

The facilities tested at each plant were as follows:

1. Plant C - direct contact flash calciner with a fabric filter.
2. Plant E
   a. ore dryer with a fabric filter
   b. continuous kettle calciner with a fabric filter
   c. board end sawing with a fabric filter
   d. capture device on board end sawing
   e. plaster mixing and bagging with a fabric filter
   f. capture device on plaster bagging
   g. pin mixing, scoring and chamfering with a cyclone
   h. stucco storage and transfer system with fabric filter
   i. capture device on #1 pin mixer
   j. capture device on #2 pin mixer
3. Plant J - ore dryer with fabric filter
4. Plant W - four kettle calciners, two screw conveyors and two grinding mills with an ESP

5. Plant Y
    a. ore dryer with fabric filter
    b. direct contact flash calciner with fabric filter
    c. stucco storage and transfer system with fabric filter
    d. capture device on board end sawing
    e. capture device on paper scoring
    f. accelerator addition
    g. fiberglass shredder
    h. vermiculite addition
6. Plant GG
    a. plaster mixing and bagging with fabric filter
    b. land plaster storage bins with fabric filter
7. Plant OO
    a. direct contact flash calciner with fabric filter
    b. stucco storage silo with fabric filter
    c. capture effectiveness of stucco transfer system with fabric filter
8. Plant RR - two continuous kettle calciners, two screw conveyors and two grinding mills with an ESP
9. Plant TT
    a. batch kettle calciner with fabric filter
    b. continuous kettle calciner with fabric filter
    c. board end sawing and paper scoring with a fabric filter
    d. capture device on board end sawing
    e. plaster mixing and bagging with fabric filter
    f. land plaster and stucco transfer system with fabric filter

EPA Reference Method 5 was used to determine the particulate concentration in the gas entering and/or exiting the control equipment. EPA Reference Methods 1 through 4 were used to determine other characteristics of the gas stream which are required for the calculations applicable under Method 5. During EPA mass emission testing, three particulate tests were performed at both the inlet and outlet of each emission control system with the exception of tests on board end sawing operations. Three particulate tests were performed at the outlet of each control system during all EPA-approved tests.

During EPA mass emission testing, particle size distributions were determined at the inlet and outlet of the control equipment with the exception of tests performed on kettle calciners. The particle size distributions were performed using an Andersen Cascade Impactor.

Visible emission measurements were conducted according to EPA Reference Method 9 and the proposed EPA Reference Method 22.

Production rates used to determine emission factors are estimates based on records of previous process operation or on material balances using boardline production rates.

C.1 DESCRIPTION OF SOURCES

A brief description of the emission sources tested at each plant is presented in this section. The operating conditions of the process and control equipment is also discussed. Tables and figures summarizing all test results are presented in Section C.2.

Plant C - Industry Test

The direct contact flash calciner tested was controlled with a fabric filter. The calciner operated at full design capacity during the testing and no equipment operating problems were observed. The calciner was fired with residual fuel oil.

Plant E - EPA Test

The rotary ore dryer tested at the plant was controlled by process cyclones followed by a fabric filter. The ore dryer was operated at over 90 percent of design capacity during the testing and was fired with natural gas.

Some fluctuation in the dryer operating temperature was observed during the testing. These fluctuations were the result of manual control of the firing rate. The fluctuation in dryer temperature, however, did not affect the representativeness of the test results. No abnormalities in the fabric filter operating conditions were noted during the testing.

The #4 continuous kettle calciner operated at full capacity during the testing and was burning natural gas. No abnormalities in the calciner or fabric filter operating parameters were noted during the testing.

The board end sawing operation was controlled by a fabric filter. Emissions were collected by a capture hood surrounding the saw. The boardline and fabric filter operated normally during the testing.

The plaster mixing and bagging operation was controlled with a fabric filter. The plaster operation was operated by a single worker. Generally, the process is operated by two operators, one person working the batch mixer and a second working the bagging machine. During the testing, the operator would mix a single batch of plaster, about 3,200 pounds, and then return to the bagging machine. The test data should still be representative since both emission sources, mixing and bagging, were in operation.

The pin mixing, scoring, and chamfering emissions from the number one boardline were controlled with a small cyclone. Visible emission tests on the outlet of the cyclone were performed to aid in characterizing baseline emissions from scoring and chamfering.

The process units vented to the stucco storage and transfer baghouse tested at the plant include a 27 Mg (30 ton) stucco surge bin, an air slide conveyor, a screw conveyor, a boardline dry mixing conveyor and a pin mixer. All of these units and the fabric filter were operated normally during the testing.

The capture devices tested at the pin mixers of both boardlines were vaccum pipes located approximately 2.4 cm (six inches) above the pin mixer vent. Emissions collected at the pin mixer on the number one line were vented with scoring and chamfering emissions to a cyclone. Emissions collected at the pin mixer on the number two line were vented with conveying emissions to a stucco storage bin which was controlled by a fabric filter. Both boardlines operated normally during the tests.

Plant E - Industry Test

The ore dryer was operating at about 70 percent of design capacity during the testing. No equipment operating problems were noted.

The #1 continuous kettle calciner was operating at full capacity during the testing. No equipment operating problems were noted.

Plant J - Industry Test

The rotary ore dryer tested at the plant was controlled with a fabric filter. The dryer was operating at 56 percent of design capacity during the test. No equipment operating problems were observed.

Plant W - Industry Test

The emission sources tested at this plant included four kettle calciners, two screw conveyors and two grinding mills. All of these sources were controlled by a single ESP. The design and operating capacities of the calciners and mills are not available. The operating mode (batch or continuous) of the calciners during the test is also not available. However, all process and control equipment operated normally during the testing.

Plant Y - EPA Test

The rotary ore dryer tested at the plant was controlled by a fabric filter. The dryer was operated at 60 percent of design capacity during the testing and was fired with residual fuel oil. No abnormalities in the dryer or fabric filter operating parameters were noted.

The direct contact calciner operated at full design capacity during the testing and was fired with residual fuel oil. No abnormalities in the calciner or fabric filter operating parameters were noted during the testing.

The process units vented to the stucco storage and transfer baghouse include the following:

- two 136 Mg (150 ton) stucco storage bins,
- five stucco screw conveyors,
- two stucco bucket elevators,
- one pnuematic conveyor,
- one boardline dry mixing conveyor, and
- the outlet of a paper scoring cyclone.

The first visible emissions test conducted on this baghouse was repeated because the filter bags were in operation only several hours prior to the test. The filter bags had not developed a sufficient filter cake to allow operation of the bags at their normal efficiency. No abnormalities in the process or fabric filter operation were noted during the second test.

The capture devices on the board end sawing and paper scoring operations operated normally during the testing.

The remaining operations tested at the plant, which include accelerator addition, fiberglass shredding, and vermiculite addition, also operated normally. Visible emissions tests were conducted on these operations to determine if the operations were major sources of emissions.

Plant GG - Industry Test

The plaster mixing and bagging operation tested at the plant was controlled by a fabric filter. No equipment operating problems were observed.

The land plaster storage operation tested at the plant was controlled by a fabric filter. A complete list of the sources vented to this baghouse is not available. However, no equipment operating problems were noted during the test.

Plant OO - EPA Test

The direct contact flash calciner was controlled with a fabric filter and was operated at greater than 95 percent of design capacity during the testing and was fired with natural gas. No abnormalities in the calciner or fabric filter operating parameters were noted.

The stucco storage silo tested at the plant has a capacity of about 318 Mg (350 ton) and was controlled by a fabric filter. Both the silo and the fabric filter operated normally during the testing.

Visible emission tests were conducted on the stucco transfer system at this plant. These tests were conducted indoors, in a location where fugitive emissions from screw conveyor and bucket elevator transfer points could be observed in accordance with EPA Method 22. The visible tests were conducted to determine the effectiveness of fabric filter control on fugitive emissions from conveying enclosures.

Plant RR - Industry Test

The emission sources tested at this plant were controlled by a single ESP and include two continuous kettle calciners, two screw conveyors and two grinding mills. The capacity factors of the calciners and mills is not available. However, all process and control equipment operated normally during the testing.

Plant TT - EPA Test

The batch kettle calciner tested at the plant was controlled with a fabric filter. The batch cycle lasted approximately two hours and 40 minutes. EPA Method 5 tests on the outlet of the 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 batch kettle operated normally during the 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 on 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. The batch kettle outlet data collected at the plant, therefore, does not represent normal fabric filter operation on a batch kettle calciner. 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 kettle and control device as the batch kettle tests. The outlet continuous kettle data, therefore, do not represent normal fabric filter emission control capabilities. During the testing, the continuous kettle calciner operated at full capacity and was fired with natural gas. The calciner operated normally. Tests conducted at the inlet of the continuous kettle calciner fabric filter are representative of normal inlet loadings for this unit.

The board end sawing and paper scoring operations tested at the plant were vented to a fabric filter. The boardline operated normally during the actual sampling. However, during the first run, the boardline was shut down and sampling was stopped until both the scoring and board end sawing opeations were again operating simultaneously. The board end sawing capture device operated normally during the testing.

The plaster mixing and bagging operation was controlled with a fabric filter. The unit was handling about 9 Mg/hr (10 ton/hr) of plaster. The capacity of the mixer was 680 kg (1500 lb) per batch. The mixing and bagging operation operated normally during the tests.

The process units vented to the land plaster and stucco transfer system baghouse include five land plaster screw conveyors, two stucco screw conveyors, and two stucco bucket elevators. The transfer system operated normally during the testing.

C.2 SUMMARY OF TEST DATA

The EPA and EPA-approved test data are presented in this section. Summaries of test data collected at each plant are presented in the following tables and figures:

Plant C: Table C-1.

Plant E: Tables C-2 to C-18, and Figures C-1 to C-3.

Plant J: Table C-19.

Plant W: Tables C-20.

Plant Y: Tables C-21 to C-33 and Figures C-4 to C-7.

Plant GG: Tables C-34 and C-35.

Plant OO: Tables C-36 to C-40 and Figures C-8 and C-9.

Plant RR: Table C-41.

Plant TT: Tables C-42 to C-52 and Figure C-10.

TABLE C-1. PLANT C. SUMMARY OF EMISSION TEST RESULTS

Direct Contact Flash Calciner - Outlet of Fabric Filter

Emission Control Data

Cleaning Mechanism: Pulse-jet
Actual Air-to-Cloth Ratio ($cfm:ft^2$): 3.2:1
Filter Fabric: Nomex
Date of Last Bag Replacement: N/A

Run Number	1	2	3	Average
General Data				
Date	3/21/78	3/21/78	3/21/78	-
Time	1214-1317	1351-1454	1527-1642	-
Sampling duration (min)	60	60	60	-
Isokinetic ratio (%)	105.8	97.0	102.6	101.8
Production rate (Mg/hr)	6.4	6.4	6.4	6.4
Production rate (ton/hr)	7.0	7.0	7.0	7.0
Exit Gas Data				
Temperature (K)	452	452	452	452
Temperature (°F)	355	354	354	354
Moisture (%)	39.0	33.0	39.0	37.0
Flow rate (m^3/s)	1.49	1.46	1.46	1.47
Flow rate (ACFM)	3158	3103	3094	3118
Flow rate (dNm^3/s)	0.59	0.64	0.58	0.60
Flow rate (DSCFM)	1253	1355	1229	1279
Particulate Emissions				
g/dNm^3	.078	.089	.087	.085
gr/dscf	.034	.039	.038	.037
g/m^3	.030	.039	.034	.034
gr/acf	.013	.017	.015	.015
kg/hr	.166	.206	.184	.185
lb/hr	.365	.453	.405	.408
g/kg	.026	.033	.029	.029
lb/ton	.052	.065	.058	.058

TABLE C-2. PLANT E. SUMMARY OF EMISSION TEST RESULTS

Ore Dryer - Inlet to Fabric Filter[a]

Run Number	1	2	3	Average
General Data				
Date	6/5/80	6/6/80	6/6/80	-
Time	1809-1933	0934-1056	1150-1311	-
Sampling duration (min)	64	64	64	-
Isokinetic ratio (%)	107.0	108.9	109.3	108.4
Production rate (Mg/hr)	63.6	63.6	63.6	63.6
Production rate (ton/hr)	70	70	70	70
Exit Gas Data				
Temperature (K)	352	351	354	352
Temperature (°F)	174	173	178	175
Moisture (%)	9.1	8.9	9.0	9.0
Flow rate (m^3/s)	4.69	4.50	4.53	4.58
Flow rate (ACFM)	9950	9550	9600	9700
Flow rate (dNm^3/s)	3.54	3.37	3.37	3.43
Flow rate (DSCFM)	7500	7150	7150	7267
Particulate Emissions				
g/dNm^3	7.40	9.57	9.46	8.81
gr/dscf	3.23	4.18	4.13	3.85
g/m^3	5.56	7.17	7.05	6.60
gr/acf	2.43	3.13	3.08	2.88
kg/hr	94.4	117	115	109
lb/hr	208	257	253	239
g/kg	1.49	1.84	1.81	1.71
lb/ton	2.97	3.67	3.61	3.42

[a]This test data was taken downstream of four process cyclones but upstream of fabric filter.

TABLE C-3. PLANT E. SUMMARY OF EMISSION TEST RESULTS
Ore Dryer - Outlet of Fabric Filter

Emission Control Data

Cleaning Mechanism: Pulse-jet
Actual Air-to-Cloth Ratio (cfm:ft^2): 6.4:1
Filter Fabric: Orlon
Date of Last Bag Replacement: 1/26/80

Run Number	1	2	3	Average
General Data				
Date	6/5/80	6/6/80	6/6/80	-
Time	1810-1924	0823-1100	1150-1311	-
Sampling duration (min)	64	64	64	-
Isokinetic ratio (%)	105.7	103.6	109.6	106.3
Production rate (Mg/hr)	64	64	64	64
Production rate (ton/hr)	70	70	70	70
Exit Gas Data				
Temperature (K)	350	349	352	350
Temperature (°F)	172	169	174	172
Moisture (%)	9.0	9.2	9.4	9.2
Flow rate (m^3/s)	4.88	4.86	4.69	4.81
Flow rate (ACFM)	10,350	10,300	9,950	10,200
Flow rate (dNm^3/s)	3.73	3.70	3.54	3.66
Flow rate (DSCFM)	7900	7850	7500	7750
Particulate Emissions				
g/dNm^3	.009	.009	.011	.009
gr/dscf	.004	.004	.005	.004
g/m^3	.007	.007	.007	.007
gr/acf	.003	.003	.003	.003
kg/hr	.137	.125	.155	.139
lb/hr	.302	.275	.341	.306
g/kg	.002	.002	.003	.002
lb/ton	.004	.004	.005	.004

TABLE C-4. PLANT E. SUMMARY OF VISIBLE EMISSIONS
Ore Dryer

Emission Control Data

Control Method: Baghouse — Air-to-Cloth Ratio (cfm:ft^2): 6.4:1
Cleaning Mechanism: Pulse-jet — Fabric Type: Orlon
Date of Last Bag Replacement: 1/26/80

General Data:

Date: 6/5/80 & 6/6/80 — Type of Plant: Gypsum

Type of Discharge: Stack — Discharge Location: Baghouse outlet

Height of Point of Discharge: Second level plus 20 feet

Observer's Location

Distance to Discharge Point: 15 feet — Height of Observation Point: 10 ft below top of stack

Direction from Discharge Point: West

Background Description: Gray building

Weather: Overcast, slight rain

Wind Direction: West — Wind Velocity: 3-5 mph

Plume Description

Detached: Yes — Color: White

Estimated Distance Plume Visible: Approximately 3-5 feet

Summary of Average Opacity

Date	Set #	Time Start	Time End	Opacity Sum	Opacity Average	Date	Set #	Time Start	Time End	Opacity Sum	Opacity Average
6/5/80 Run #1	1	6:10	6:16	0	0	6/6/80	8	10:12	10:18	0	0
	2	6:16	6:22	5	0.2		9	10:18	10:24	0	0
	3	6:22	6:28	0	0		10	10:24	10:30	0	0
	4	6:28	6:34	0	0		11	10:30	10:36	0	0
	5	6:34	6:40	5	0.2		12	10:36	10:42	0	0
	6	6:47	6:46	0	0		13	10:42	10:48	0	0
	7	6:46	6:52	0	0		14	10:48	10:54	5	0.2
	8	6:52	6:58	0	0						
	9	6:58	7:04	0	0	6/6/80 Run #3	1	11:50	11:56	0	0
	10	7:04	7:10	0	0		2	11:56	12:02	0	0
	11	7:10	7:16	0	0		3	12:02	12:08	5	0.2
	12	7:16	7:22	5	0.2		4	12:08	12:14	5	0.2
	13	7:22	7:28	0	0		5	12:14	12:20	0	0
	14	7:28	7:34	0	0		6	12:20	12:26	0	0
	15	7:34	7:40	0	0		7	12:26	12:32	0	0
	16	7:40	7:46	0	0		8	12:32	12:38	10	0.4
							9	12:38	12:44	0	0
6/6/80 Run #2	1	9:30	9:36	0	0		10	12:44	12:50	0	0
	2	9:36	9:42	0	0		11	12:50	12:56	0	0
	3	9:42	9:48	5	0.2		12	12:56	1:02	0	0
	4	9:48	9:54	0	0		13	1:02	1:08	0	0
	5	9:54	10:00	5	0.2		14	1:08	1:14	0	0
	6	10:00	10:06	0	0		15	1:14	1:20	0	0
	7	10:06	10:12	5	0.2						

TABLE C-5. PLANT E. SUMMARY OF EMISSION TEST RESULTS

Continuous Kettle Calciner (#4) - Inlet to fabric Filter

Run Number	1	2	3	Average
General Data				
Date	6/3/80	6/3/80	6/4/80	-
Time	0932-1110	1402-1528	0838-0959	-
Sampling duration (min)	27	27	27	-
Isokinetic ratio (%)	104.9	103.0	97.9	
Production rate (Mg/hr)	10.4	10.4	10.4	10.4
Production rate (ton/hr)	11.5	11.5	11.5	11.5
Exit Gas Data				
Temperature (K)	402	402	399	401
Temperature (°F)	264	264	259	262
Moisture (%)	69.8	72.2	73.4	71.8
Flow rate (m^3/s)	1.22	1.23	1.23	1.23
Flow rate (ACFM)	2590	2600	2610	2600
Flow rate (dNm^3/s)	0.266	0.246	0.238	0.250
Flow rate (DSCFM)	564	522	505	530
Particulate Emissions				
g/dNm^3	221	259	273	252
gr/dscf	96.7	113	119	110
g/m^3	48.3	52.0	52.7	51.3
gr/acf	21.1	22.7	23.0	22.4
kg/hr	212	230	234	225
lb/hr	467	507	515	496
g/kg	20.3	22.1	22.4	21.6
lb/ton	40.6	44.1	44.8	43.2

TABLE C-6. PLANT E. SUMMARY OF EMISSION TEST RESULTS
Continuous Kettle Calciner (#4) - Outlet to Fabric Filter

Emission Control Data

Cleaning Mechanism: Pulse jet
Actual Air-to-Cloth Ratio (cfm:ft^2): 2.9:1
Filter Fabric: Orlon
Date of Last Bag Replacement: 2/29/80

Run Number	1	2	3	Average
General Data				
Date	6/3/80	6/3/80	6/4/80	-
Time	0932-1150	1400-1610	0837-1030	-
Sampling duration (min)	96	96	96	-
Isokinetic ratio (%)	104.9	103.3	108.2	105.5
Production rate (Mg/hr)	10.4	10.4	10.4	10.4
Production rate (ton/hr)	11.5	11.5	11.5	11.5
Exit Gas Data				
Temperature (K)	391	393	387	390
Temperature (°F)	245	248	238	244
Moisture (%)	68.9	69.1	69.9	69.3
Flow rate (m^3/s)	1.10	1.11	1.12	1.11
Flow rate (ACFM)	2340	2360	2370	2357
Flow rate (dNm^3/s)	0.256	0.255	0.254	0.255
Flow rate (DSCFM)	542	540	538	540
Particulate Emissions				
g/dNm^3	.046	.014	.023	.027
gr/dscf	.020	.006	.010	.012
g/m^3	.011	.002	.005	.007
gr/acf	.005	.001	.002	.003
kg/hr	.042	.013	.023	.026
lb/hr	.093	.028	.050	.057
g/kg	.004	.001	.002	.002
lb/ton	.008	.002	.004	.005

TABLE C-7. PLANT E. SUMMARY OF VISIBLE EMISSIONS
Continuous Kettle Calciner

Emission Control Data

Control Method: Baghouse　　Air-to-Cloth Ratio (cfm:ft^2): 1.9:1
Cleaning Mechanism: Pulse-jet　　Fabric Type: Orlon
Date of Last Bag Replacement: 2/29/80

General Data:

Date: 6/3/80 & 6/4/80　　Type of Plant: Gypsum

Type of Discharge: Stack　　Discharge Location: Baghouse outlet

Height of Point of Discharge: Second level plus 50 feet

Observer's Location

Distance to Discharge Point: 90-100 ft. Height of Observation Point: ground level

Direction from Discharge Point: SW of stack

Background Description: 6/3: Blue sky w/occasional clouds; 6/4: Cloudy

Weather: Partly Cloudy

Wind Direction: West　　Wind Velocity: 5 mph

Plume Description

Detached: Yes　　Color: White

Estimated Distance Plume Visible: Approximately 3 feet

Summary of Average Opacity

Date	Set	Time Start	Time End	Opacity Sum	Opacity Average
6/3/80 Run #1	1	9:30	9:36	0	0
	2	9:36	9:42	5	0.2
	3	9:42	9:48	0	0
	4	9:48	9:54	0	0
	5	9:54	10:00	5	0.2
	6	10:00	10:06	0	0
	7	10:06	10:12	0	0
	8	10:12	10:18	0	0
	9	10:18	10:24	0	0
	10	10:24	10:30	0	0
	11	10:39	10:36	5	0.2
	12	10:36	10:42	0	0
	13	10:42	10:48	0	0
	14	10:48	10:54	0	0
	15	10:54	11:00	0	0
	16	11:00	11:06	0	0
6/3/80 Run #2	1	2:00	2:06	0	0
	2	2:06	2:12	5	0.2
	3	2:12	2:18	0	0
	4	2:18	2:24	0	0
	5	2:24	2:30	0	0
	6	2:30	2:36	0	0
	7	2:36	2:42	0	0
	8	2:42	2:48	5	0.2
6/3/80	9	2:46	2:54	0	0
	10	2:54	3:00	0	0
	11	3:00	3:06	5	0.2
	12	3:06	3:12	0	0
	13	3:12	3:18	0	0
	14	3:18	3:24	10	0.4
	15	3:24	3:30	0	0
	16	3:30	3:36	0	0
6/4/80 Run #3	1	10:00	10:06	0	0
	2	10:06	10:12	0	0
	3	10:12	10:18	0	0
	4	10:18	10:24	0	0
	5	10:24	10:30	0	0
	6	10:30	10:36	0	0
	7	10:36	10:42	0	0
	8	10:42	10:48	0	0
	9	10:48	10:54	0	0
	10	10:54	11:00	0	0
	11	11:00	10:06	0	0
	12	11:06	11:12	0	0
	13	11:12	11:18	0	0
	14	11:18	11:24	0	0
	15	11:24	11:30	0	0
	16	11:30	11:36	0	0

TABLE C-8. PLANT E. SUMMARY OF EMISSION TEST RESULTS
Board End Sawing - Outlet of Fabric Filter

Emission Control Data

Cleaning Mechanism: Shaker
Actual Air-to-Cloth Ratio (cfm:ft^2): 1.5:1
Filter Fabric: Cotton
Date of Last Bag Replacement: 3/23/80

Run Number	1	2	3	Average
General Data				
Date	6/5/80	6/5/80	6/5/80	-
Time	1215-1329	1418-1529	1545-1707	-
Sampling duration (min)	64	64	64	-
Isokinetic ratio (%)	104.4	103.8	103.7	104.0
Production rate (Mg/hr)	29.2	29.2	29.2	29.2
Production rate (ton/hr)	32.2	32.2	32.2	32.2
Exit Gas Data				
Temperature (K)	306	308	305	306
Temperature (°F)	92	95	90	92
Moisture (%)	1.6	1.7	1.4	1.6
Flow rate (m^3/s)	1.70	1.65	1.75	1.70
Flow rate (ACFM)	3600	3500	3700	3600
Flow rate (dNm^3/s)	1.60	1.56	1.67	1.61
Flow rate (DSCFM)	3400	3300	3550	3417
Particulate Emissions				
g/dNm^3	.005	.016	.023	.014
gr/dscf	.002	.007	.010	.006
g/m^3	.005	.016	.023	.014
gr/acf	.002	.007	.010	.006
kg/hr	.030	.089	.139	.086
lb/hr	.066	.197	.307	.190
g/kg	.001	.003	.005	.003
lb/ton	.002	.006	.010	.006

TABLE C-9. PLANT E. SUMMARY OF VISIBLE EMISSIONS
Board End Sawing

Emission Control Data

Control Method: Baghouse
Air-to-Cloth Ratio (cfm:ft^2): 1.5:1
Cleaning Mechanism: Shaker
Fabric Type: Cotton
Date of Last Bag Replacement: 3/23/80

General Data:

Date: 6/5/80
Type of Plant: Gypsum

Type of Discharge: Stack
Discharge Location: Baghouse outlet

Height of Point of Discharge: Second level

Observer's Location

Distance to Discharge Point: ~90 ft.
Height of Observation Point: same level

Direction from Discharge Point: NE

Background Description: Green trees

Weather: Clear

Wind Direction: West
Wind Velocity: 3 mph

Plume Description

Detached: Yes
Color: White

Estimated Distance Plume Visible: 5-10 feet

Summary of Average Opacity

Date	Set #	Time Start	Time End	Opacity Sum	Opacity Average
6/5/80 (Run #1)	1	12:00	12:06	0	0
	2	12:06	12:12	0	0
	3	12:12	12:18	0	0
	4	12:18	12:24	0	0
	5	12:24	12:30	0	0
	6	12:30	12:36	20	0.8
	7	12:36	12:42	0	0
	8	12:42	12:48	0	0
	9	12:48	12:54	0	0
	10	12:54	1:00	20	0.8
	11	1:00	1:06	10	0.4
	12	1:06	1:12	0	0
	13	1:12	1:18	10	0.4
	14	1:18	1:24	75	3.1
6/5/80 (Run #2)	1	2:10	2:16	30	1.3
	2	2:16	2:22	0	0
	3	2:22	2:28	45	1.9
	4	2:28	2:34	5	0.2
6/5/80	5	2:34	2:40	10	0.4
	6	2:40	2:46	110	4.6
	7	2:46	2:52	30	1.3
	8	2:52	2:58	5	0.2
	9	2:58	3:04	0	0
	10	3:04	3:10	15	0.6
	11	3:10	3:16	75	3.1
6/5/80 (Run #3)	1	4:00	4:06	40	1.7
	2	4:06	4:12	80	3.3
	3	4:12	4:18	10	0.4
	4	4:18	4:24	40	1.7
	5	4:24	4:30	45	1.9
	6	4:30	4:36	5	0.2
	7	4:36	4:42	10	0.4
	8	4:42	4:48	10	0.4
	9	4:48	4:54	60	2.5
	10	4:54	5:00	40	1.7
	11	5:00	5:06	0	0

TABLE C-10. PLANT E. SUMMARY OF FUGITIVE EMISSIONS
Board End Sawing

General Data

Date: 6/6/80 Duration of Observation: three hours

Type of Discharge: Fugitive

Location of Discharge Point: Board end sawing pickups

Description of Discharge: Emission created by cutting of boards is picked up with a capture device or hood which surrounds the saws. Some dust escapes capture. Collected dust is ducted to a baghouse.

Summary of Fugitive Emissions

Time	Observation Period (Min:Sec)	Percent Time with Visible Emission
N/A	20:00	0.0
	20:00	0.0
	20:00	0.0
N/A	20:00	0.0
	20:00	0.0
	20:00	3.8
N/A	20:00	0.0
	20:00	0.0
	20:00	0.0

TABLE C-11. PLANT E. SUMMARY OF VISIBLE EMISSIONS
Plaster Mixing and Bagging

Emission Control Data

Control Method: Baghouse   Air-to-Cloth Ratio (cfm:ft^2): 2:1
Cleaning Mechanism: Pulse-jet   Fabric Type: (suited to 300°F)
Date of Last Bag Replacement: 5/28/80

General Data:

Date: 6/4/80 & 6/5/80   Type of Plant: Gypsum   Duration of Observation: 3 hrs.

Type of Discharge: Stack   Discharge Location: Baghouse outlet

Height of Point of Discharge: second level plus 25 feet

Observer's Location

Distance to Discharge Point: 15 ft.   Height of Observation Point: same level

Direction from Discharge Point: NE of stack

Background Description: gray

Weather: overcast - partly cloudy

Wind Direction: West   Wind Velocity: 3 mph

Plume Description

Detached: No   Color: White

Estimated Distance Plume Visible: ≈1 foot

Summary of Average Opacity

		Time		Opacity	
Date	Set Number	Start	End	Sum	Average
6/4/80 (Run #1)	1-10	9:00	10:00	0	0
6/4/80 (Run #2)	1-5	11:00	11:30	0	0
	5-6	1:00	1:30	0	0
6/4/80	1-4	1:38	2:02	0	0
6/5/80 (Run #3)	6-10	8:30	9:06	0	0

TABLE C-12. PLANT E. SUMMARY OF FUGITIVE EMISSIONS
Plaster Bagging

General Data

Date: 6/3/80 & 6/4/80 Duration of Observation: two hours

Type of Discharge: Fugitive

Location of Discharge Point: Plaster bagging machine

Description of Discharge: The packer used valve type bags. The material entered the bag through a nozzle inserted into the bag opening. Fugitive emissions occurred when the bag was removed from the nozzle. The packer had four nozzles.

Summary of Fugitive Emissions

Date	Observation Period (Min:Sec)	Percent Time with Visible Emission
6/3/80	20:00	31.8
	20:00	41.2
	20:00	54.5
6/4/80	20:00	51.0
	20:00	62.8
	20:00	49.2

TABLE C-13. PLANT E. SUMMARY OF VISIBLE EMISSIONS
Pin Mixing, Scoring and Chamfering

Emission Control Data

Control Method: Cyclone

General Data:

Date: 6/3/80 Type of Plant: Gypsum Duration of Observation: 3 hrs.

Type of Discharge: Stack Discharge Location: Cyclone outlet

Height of Point of Discharge: Second level plus 20-30 feet

Observer's Location

Distance to Discharge Point: 50 feet Height of Observation Point: 11 ft. below stack

Direction from Discharge Point: SE of stack

Background Description: Green trees

Weather: Overcast - partly cloudy

Wind Direction: West Wind Velocity: 5 mph

Plume Description

Detached: Yes Color: White

Estimated Distance Plume Visible: 5-6 feet

Summary of Average Opacity

		Time		Opacity				Time		Opacity	
Date	Set #	Start	End	Sum	Average	Date	Set #	Start	End	Sum	Average
6/3/80	1	8:30	8:36	340	14.2	6/3/80	6	12:45	12:51	245	10.2
(Run #1)	2	8:36	8:42	260	10.8		7	12:51	12:57	250	10.4
	3	8:42	8:48	305	12.7		8	12:57	1:03	300	12.5
	4	8:48	8:54	340	14.2		9	1:03	1:09	255	10.6
	5	8:54	9:00	235	9.8		10	1:09	1:15	260	10.8
	6	9:00	9:06	215	9.0	6/3/80	1	3:50	3:56	230	9.6
	7	9:06	9:12	240	10.0	(Run #3)	2	3:56	4:02	220	9.2
	8	9:12	9:18	250	10.4		3	4:02	4:08	155	6.5
	9	9:18	9:24	230	9.6		4	4:08	4:14	150	6.3
	10	9:24	9:30	250	10.4		5	4:14	4:20	175	7.3
6/3/80	1	12:15	12:21	265	11.0		6	4:20	4:26	180	7.5
(Run #2)	2	12:21	12:27	340	14.2		7	4:26	4:32	170	7.1
	3	12:27	12:33	265	11.0		8	4:32	4:38	160	6.7
	4	12:33	12:39	280	11.7		9	4:38	4:44	180	7.5
	5	12:39	12:45	235	9.8		10	4:44	4:50	195	8.1

TABLE C-14. PLANT E. SUMMARY OF VISIBLE EMISSIONS
Stucco Storage and Transfer

Emission Control Data

Control Method: Baghouse   Air-to-Cloth Ratio ($cfm:ft^2$): 2:1
Cleaning Mechanism: Shaker   Fabric Type: Cotton
Date of Last Bag Replacement: 4/21/79

General Data:

Date: 6/10/80   Type of Plant: Gypsum   Duration of Observation: 3 hrs.

Type of Discharge: Stack   Discharge Location: Baghouse outlet

Height of Point of Discharge: Second level plus 20 feet

Observer's Location

Distance to Discharge Point: 20 ft.   Height of Observation Point: 20 ft. below stack

Direction from Discharge Point: East of stack

Background Description: Green trees

Weather: Clear

Wind Direction: East   Wind Velocity: 2 mph

Plume Description

Detached: Yes   Color: White

Estimated Distance Plume Visible: Approximately 5 feet

Summary of Average Opacity

Date	Set #	Time Start	Time End	Opacity Sum	Opacity Average	Date	Set #	Time Start	Time End	Opacity Sum	Opacity Average
6/10/80	1	12:45	12:51	10	0.4	6/10/80	6	2:18	2:24	5	0.2
Run #1	2	12:51	12:57	20	0.8		7	2:24	2:30	15	0.6
	3	12:57	1:03	15	0.6		8	2:30	2:36	10	0.4
	4	1:03	1:09	10	0.4		9	2:36	2:42	15	0.6
	5	1:09	1:15	10	0.4		10	2:42	2:48	5	0.2
	6	1:15	1:21	10	0.4						
	6	1:21	1:27	20	0.8	6/10/80	1	2:50	2:56	10	0.4
	8	1:27	1:33	15	0.6	Run #3	2	2:56	3:02	10	0.4
	9	1:33	1:39	15	0.6		3	3:02	3:08	5	0.2
	10	1:39	1:45	20	0.8		4	3:08	3:14	5	0.2
							5	3:14	3:20	5	0.2
6/10/80	1	1:48	1:54	20	0.8		6	3:20	3:26	5	0.2
Run #2	2	1:54	2:00	10	0.4		7	3:26	3:32	5	0.2
	3	2:00	2:06	20	0.8		8	3:32	3:38	0	0
	4	2:06	2:12	15	0.6		9	3:38	3:44	10	0.4
	5	2:12	2:18	5	0.2		10	3:44	3:50	5	0.2

TABLE C-15. PLANT E. SUMMARY OF FUGITIVE EMISSIONS
Number 1 - Pin Mixer

General Data

Date: 6/3/80 Duration of Observation: two hours

Type of Discharge: Fugitive

Location of Discharge Point: Head of boardline - at pin mixer

Description of Discharge: Emissions from pin mixer vent (7 inch diameter) collected by suction into 5 inch diameter pipe.

Summary of Fugitive Emissions

Time Start-End	Observation Period (Min:Sec)	Percent Time with Visible Emission
12:30 - 1:30	60:00	0.00
2:30 - 3:30	60:00	0.00

TABLE C-16. PLANT E. SUMMARY OF FUGITIVE EMISSIONS
Number 2 - Pin Mixer

General Data

Date: 6/3/80 Duration of Observation: three hours

Type of Discharge: Fugitive

Location of Discharge Point: Head of boardline - at pin mixer

Description of Discharge: Emissions from pin mixer vent (7 inch diameter) collected by suction into 5 inch diameter pipe. Emissions escaped capture when collection pipe became clogged with moist gypsum. The pipe was unclogged manually.

Summary of Fugitive Emissions

Time Start - End		Observation Period (Min:Sec)	Percent Time with Visible Emission
8:30 - 9:30	vacuum	20:00	85
	pipe	20:00	2.7
	clogged	20:00	0.0
9:40 - 10:40	vacuum	20:00	0.0
	pipe	20:00	24.
	clogged	20:00	0.0
10:50 - 11:50		20:00	0.0
		20:00	0.0
		20:00	0.0

TABLE C-17. PLANT E. SUMMARY OF EMISSION TEST RESULTS
Ore Dryer - Outlet of Fabric Filter (Industry Test)

Emission Control Data

Cleaning Mechanism: Pulse jet
Actual Air-to-Cloth Ratio (cfm:ft^2): 7.0:1
Filter Fabric: Orlon
Date of Last Bag Replacement: N/A

Run Number	1	2	3	Average
General Data				
Date	11/18/75	11/18/75	11/18/75	-
Time	N/A	N/A	N/A	-
Sampling duration (min)	65	65	65	-
Isokinetic ratio (%)	102.	100.	102.	101.
Production rate (Mg/hr)	47.7	45.4	49.9	47.7
Production rate (ton/hr)	52.5	50.0	55.0	52.5
Exit Gas Data				
Temperature (K)	361	360	360	360
Temperature (°F)	190	189	188	189
Moisture (%)	5.4	5.2	7.1	5.9
Flow rate (m^3/s)	5.31	5.26	5.32	5.30
Flow rate (ACFM)	11,267	11,147	11,271	11,228
Flow rate (dNm^3/s)	4.06	4.03	4.00	4.03
Flow rate (DSCFM)	8599	8544	8476	8540
Particulate Emissions				
g/dNm^3	.082	.046	.096	.076
gr/dscf	.036	.020	.042	.033
g/m^3	.062	.034	.071	.056
gr/acf	.027	.015	.031	.024
kg/hr	1.2	.68	1.4	1.1
lb/hr	2.6	1.5	3.0	2.4
g/kg	.025	.015	.030	.023
lb/ton	.050	.030	.060	.047

TABLE C-18. PLANT E. SUMMARY OF EMISSION TEST RESULTS
Continuous Kettle Calciner (#1) - Outlet of Fabric Filter (Industry Test)[a]

Emission Control Data

Cleaning Mechanism: Pulse-jet
Actual Air-to-Cloth Ratio (cfm:ft^2): 2.3:1
Filter Fabric: Orlon
Date of Last Bag Replacement: N/A

Run Number	1	2	3	Average
General Data				
Date	11/19/75	11/19/75	11/19/75	-
Time	N/A	N/A	N/A	-
Sampling duration (min)	66	65	65	-
Isokinetic ratio (%)	121.	102.	94.	106.
Production rate (Mg/hr)	10.0	10.0	10.0	10.0
Production rate (ton/hr)	11.0	11.0	11.0	11.0
Exit Gas Data				
Temperature (K)	391	391	391	391
Temperature (°F)	245	245	244	245
Moisture (%)	65.6	64.6	60.8	63.7
Flow rate (m^3/s)	0.875	0.885	0.885	0.882
Flow rate (ACFM)	1856	1877	1877	1870
Flow rate (dNm^3/s)	0.223	0.232	0.257	0.237
Flow rate (DSCFM)	472	492	544	503
Particulate Emissions				
g/dNm^3	.014	.007	.076	.032
gr/dscf	.006	.003	.033	.014
g/m^3	.005	.002	.023	.009
gr/acf	.002	.001	.010	.004
kg/hr	.009	.005	.091	.035
lb/hr	.020	.010	.200	.077
g/kg	.001	.001	.009	.003
lb/ton	.002	.001	.018	.007

[a]The first test run was conducted at a high isokinetic sampling rate. However, the data were considered acceptable since the average isokinetic ratio is within the required range.

TABLE C-19. PLANT J. SUMMARY OF EMISSION TEST RESULT

Ore Dryer - Outlet of Fabric Filter

Emission Control Data

Cleaning Mechanism: Reverse air
Actual Air-to-Cloth Ratio (cfm:ft^2): 2.3:1
Filter Fabric: Dacron
Date of Last Bag Replacement: N/A

Run Number	1	2	3	Average
General Data				
Date	6/14/79	6/14/79	6/14/79	-
Time	0900-1032	1206-1339	1453-1626	-
Sampling duration (min)	88	88	88	-
Isokinetic ratio (%)	102.5	102.2	100.7	101.8
Production rate (Mg/hr)	25.3	25.4	25.4	25.4
Production rate (ton/hr)	27.9	28.0	28.0	28.0
Exit Gas Data				
Temperature (K)	355	357	354	355
Temperature (°F)	179	183	177	180
Moisture (%)	6.7	5.7	5.4	5.9
Flow rate (m^3/s)	5.25	5.11	5.04	5.13
Flow rate (ACFM)	11,140	10,836	10,678	10,885
Flow rate (dNm^3/s)	4.11	4.01	4.00	4.04
Flow rate (DSCFM)	8,718	8,510	8,489	8,572
Particulate Emissions				
g/dNm^3	.018	.021	.023	.021
gr/dscf	.008	.009	.110	.009
g/m^3	.014	.016	.018	.016
gr/acf	.006	.007	.008	.007
kg/hr	.283	.288	.329	.300
lb/hr	.624	.635	.725	.661
g/kg	.011	.011	.013	.012
lb/ton	.022	.022	.026	.023

TABLE C-20. PLANT W. SUMMARY OF EMISSION TEST RESULTS
Kettle Calciners and Grinding Mills -
Outlet of Electrostatic Precipitator (Industry Test)

Source Description

Emission sources controlled by the electrostatic precipitator include two grinding mills, four kettle calciners and two screw conveyors. The operating mode of the calciners during the test (batch or continuous) is not available.

Run Number	1	2	3	Average
General Data				
Date	6/28/77	6/28/77	6/28/77	-
Time	N/A	N/A	N/A	-
Sampling duration (min)	60	60	60	-
Isokinetic ratio (%)	102	91	106	100
Production rate[a] (Mg/hr)	71.6	71.6	71.6	71.6
Production rate[a] (ton/hr)	78.8	78.8	78.8	78.8
Exit Gas Data				
Temperature (K)	349	354	351	351
Temperature (°F)	168	178	173	173
Moisture (%)	13.3	12.5	16.7	14.2
Flow rate (m^3/s)	18.9	18.6	18.4	18.6
Flow rate (ACFM)	39,986	39,456	39,102	39,515
Flow rate (dNm^3/s)	13.8	13.5	12.7	13.4
Flow rate (DSCFM)	29,209	28,632	26,904	28,448
Particulate Emissions				
g/dNm^3	.110	.092	.046	.092
gr/dscf	.050	.040	.020	.040
g/m^3	.092	.068	.032	.064
gr/acf	.040	.030	.014	.028
kg/hr	5.7	4.4	2.1	4.1
lb/hr	12.5	9.8	4.6	9.0
g/kg	.08	.06	.03	.06
lb/ton	.16	.12	.06	.11

[a]Production rate given includes total weight of stucco produced plus weight of rock milled per hour.

TABLE C-21. PLANT Y. SUMMARY OF EMISSION TEST RESULTS
Ore Dryer - Inlet to Fabric Filter

Run Number	1	2	3	Average
General Data				
Date	5/21/80	5/22/80	5/22/80	-
Time	1145-1343	0845-1037	1235-1450	-
Sampling duration (min)	96	96	96	-
Isokinetic ratio (%)	99.8	98.9	95.9	98.2
Production rate (Mg/hr)	27	27	27	27
Production rate (ton/hr)	30	30	30	30
Exit Gas Data				
Temperature (K)	375	375	375	375
Temperature (°F)	215	216	215	215
Moisture (%)	8.5	8.9	7.0	8.1
Flow rate (m^3/s)	7.41	7.55	7.64	7.53
Flow rate (ACFM)	15,700	16,000	16,200	15,970
Flow rate (dNm^3/s)	5.33	5.38	5.57	5.42
Flow rate (DSCFM)	11,300	11,400	11,800	11,500
Particulate Emissions				
g/dNm^3	116.	119.	117.	117.
gr/dscf	50.7	51.9	51.2	51.3
g/m^3	83.6	84.7	85.4	84.5
gr/acf	36.5	37.0	37.3	36.9
kg/hr	2225	2302	2352	2293
lb/hr	4900	5070	5180	5050
g/kg	81.5	84.5	86.5	84.0
lb/ton	163	169	173	168

TABLE C-22. PLANT Y. SUMMARY OF EMISSION TEST RESULTS

Ore Dryer - Outlet of Fabric Filter

Emission Control Data

Cleaning Mechanism: Pulse jet
Actual Air-to-Cloth Ratio (cfm:ft^2): 5.5:1
Filter Fabric: Nomex
Date of Last Bag Replacement: 5/17/80

Run Number	1	2	3	Average
General Data				
Date	5/21/80	5/22/80	5/22/80	-
Time	1145/1340	0845-1035	1235-1415	-
Sampling duration (min)	96	96	96	-
Isokinetic ratio (%)	99.6	103.6	100.9	101.4
Production rate (Mg/hr)	27	27	27	27
Production rate (ton/hr)	30	30	30	30
Exit Gas Data				
Temperature (K)	366	367	368	367
Temperature (°F)	200	202	203	202
Moisture (%)	8.3	9.5	9.0	8.9
Flow rate (m^3/s)	7.55	7.41	7.64	7.53
Flow rate (ACFM)	16,000	15,700	16,200	15,970
Flow rate (dNm^3/s)	5.57	5.38	5.57	5.50
Flow rate (DSCFM)	11,800	11,400	11,800	11,670
Particulate Emissions				
g/dNm^3	.062	.044	.041	.049
gr/dscf	.027	.019	.018	.021
g/m^3	.046	.032	.030	.037
gr/acf	.020	.014	.013	.016
kg/hr	1.22	0.83	0.80	0.95
lb/hr	2.69	1.83	1.77	2.10
g/kg	.045	.031	.030	.035
lb/ton	.090	.061	.059	.070

TABLE C-23. PLANT Y. SUMMARY OF VISIBLE EMISSIONS

Ore Dryer

Emission Control Data

Control Method: Baghouse   Air-to-Cloth Ratio ($cfm:ft^2$): 5.5:1
Cleaning Mechanism: Pulse-jet   Fabric Type: Nomex
Date of Last Bag Replacement: 5/17/80

General Data:

Date: 5/21/80 to 5/22/80   Type of Plant: Gypsum

Type of Discharge: Stack   Discharge Location: Baghouse outlet

Height of Point of Discharge: 8 feet above roof

Observer's Location

Distance to Discharge Point: 15 ft.   Height of Observation Point: 4 ft.

Direction from Discharge Point: South

Background Description: Clear blue sky

Weather: 8/21 - Clear; 8/22 - Partly cloudy

Wind Direction: N/A   Wind Velocity: 5-10 mph

Plume Description

Detached: No   Color: White

Estimated Distance Plume Visible: 5 ft.

Summary of Average Opacity

Date	Set #	Time Start	Time End	Opacity Sum	Opacity Average	Date	Set #	Time Start	Time End	Opacity Sum	Opacity Average
5/21/80 (Run #1)	1	11:57	12:03	35	1.5	5/22/80 (Run #2)	1	8:49	8:55	15	0.6
	2	12:03	12:09	45	1.9		2	8:55	9:01	5	0.2
	3	12:09	12:15	35	1.5		3	9:01	9:07	10	0.4
	4	12:15	12:21	35	1.5		4	9:07	9:13	0	0
	5	12:21	12:27	35	1.5		5	1:13	9:19	10	0.4
	6	12:27	12:33	45	1.9		6	9:19	9:25	0	0
	7	12:33	12:39	40	1.7		7	9:25	9:31	5	0.2
	8	12:39	12:45	30	1.3		8	9:31	9:39	0	0
	9	12:45	12:51	30	1.3		9	9:37	9:43	5	0.2
	10	12:51	12:57	30	1.3		10	9:43	9:49	0	0
	11	12:57	1:03	15	0.6		11	9:49	9:55	0	0
	12	1:03	1:09	15	0.6		12	9:55	10:01	10	0.4
	13	1:09	1:15	10	0.4		13	10:01	10:07	0	0
	14	1:15	1:21	5	0.2		14	10:07	10:13	5	0.2
	15	1:21	1:27	25	1.0		15	10:13	10:19	5	0.2
	16	1:27	1:33	15	0.6		16	10:19	10:25	5	0.2
						5/22/80 (Run #3)	1-16	12:30	2:27	0	0

TABLE C-24. PLANT Y. SUMMARY OF EMISSION TEST RESULTS

Direct Contact Flash Calciner - Inlet to Fabric Filter

Run Number	1	2	3	Average
General Data				
Date	5/19/80	5/20/80	5/20/80	-
Time	1358-1532	0917-1030	1315-1436	-
Sampling duration (min)	60	60	60	-
Isokinetic ratio (%)	108.6	106.5	103.5	106.2
Production rate (Mg/hr)	6.4	6.4	6.4	6.4
Production rate (ton/hr)	7.0	7.0	7.0	7.0
Exit Gas Data				
Temperature (K)	461	462	460	461
Temperature (°F)	370	373	369	371
Moisture (%)	38.9	40.9	43.0	40.9
Flow rate (m^3/s)	1.85	1.94	1.93	1.91
Flow rate (ACFM)	3920	4110	4100	4043
Flow rate (dNm^3/s)	0.72	0.72	0.70	0.71
Flow rate (DSCFM)	1520	1530	1480	1510
Particulate Emissions				
g/dNm^3	50.4	49.5	48.5	49.5
gr/dscf	22.0	21.6	21.2	21.6
g/m^3	19.5	18.4	17.5	18.5
gr/acf	8.53	8.04	7.65	8.07
kg/hr	131	129	122	127
lb/hr	288	284	269	280
g/kg	20.5	20.3	19.2	20.0
lb/ton	41.0	40.6	38.4	40.0

TABLE C-25. PLANT Y. SUMMARY OF EMISSION TEST RESULTS

Direct Contact Calciner - Outlet of Fabric Filter

Emission Control Data

Cleaning Mechanism: Pulse-jet
Actual Air-to-Cloth Ratio (cfm:ft^2): 4.2:1
Filter Fabric: Nomex
Date of Last Bag Replacement: 1/20/80

Run Number	1	2	3	Average
General Data				
Date	5/19/80	5/20/80	5/20/80	-
Time	14b0-1630	0930-1110	1340-1530	-
Sampling duration (min)	120	100	100	-
Isokinetic ratio (%)	108.5	101.4	103.3	104.4
Production rate (Mg/hr)	6.4	6.4	6.4	6.4
Production rate (ton/hr)	7.0	7.0	7.0	7.0
Exit Gas Data				
Temperature (K)	445	444	445	445
Temperature (°F)	341	340	341	341
Moisture (%)	38.1	41.5	42.5	40.7
Flow rate (m^3/s)	1.84	1.92	1.89	1.89
Flow rate (ACFM)	3910	4070	4010	4000
Flow rate (dNm^3/s)	0.76	0.75	0.72	0.74
Flow rate (DSCFM)	1610	1580	1530	1573
Particulate Emissions				
g/dNm^3	.048	.055	.060	.055
gr/dscf	.021	.024	.026	.024
g/m^3	.020	.020	.023	.020
gr/acf	.009	.009	.010	.009
kg/hr	.128	.148	.152	.143
lb/hr	.232	.325	.335	.314
g/kg	.020	.023	.024	.022
lb/ton	.040	.046	.048	.044

TABLE C-26. PLANT Y. SUMMARY OF VISIBLE EMISSIONS
Direct Contact Flash Calciner

Emission Control Data

Control Method: Baghouse   Air-to-Cloth Ratio (cfm:ft^2): 4.2:1
Cleaning Mechanism: Pulse-jet   Fabric Type: Nomex
Date of Last Bag Replacement: 1/20/80

General Data:

Date: 5/19/80 to 5/20/80   Type of Plant: Gypsum

Type of Discharge: Stack   Discharge Location: Baghouse outlet

Height of Point of Discharge: 10 feet

Observer's Location

Distance to Discharge Point: 25 ft.   Height of Observation Point: 6 ft.

Direction from Discharge Point: South

Background Description:

Weather: 5/19 - Partly cloudy; 5/20 - Partly cloudy to overcast

Wind Direction: out of west   Wind Velocity: 5/19 - 10-15 mph
5/20 - 10-20 mph

Plume Description: Another stack and a railing

Detached: No   Color: White

Estimated Distance Plume Visible: N/A

Summary of Average Opacity

Date	Set #	Time Start	Time End	Opacity Sum	Opacity Average
5/19/80	1-9	2:00	2:54	0	0
(Run #1)	10	2:54	3:00	10	0.4
	11	3:00	3:06	5	0.2
	12	3:06	3:12	20	1.8
	13	3:12	3:18	5	0.2
	14	3:18	3:24	15	0.6
	15	3:24	2:20	20	0.8
	16	3:30	3:36	10	0.4
	17	3:36	3:42	10	0.4
	18	3:42	3:48	10	0.4
	19	3:48	3:54	15	0.6
	20	3:54	4:00	10	0.4
5/20/80	1	9:34	9:40	20	0.8
(Run #2)	2	9:40	9:46	15	0.6
	3	9:46	9:52	25	1.0
	4	9:52	9:58	25	1.0
	5	9:58	10:04	40	1.7
	6	10:04	10:10	20	0.8
	7	10:10	10:16	25	1.0
	8	10:16	10:22	40	1.7
	9	10:22	10:28	35	1.5
	10	10:28	10:34	30	1.3
5/20/80	11	10:34	10:40	35	1.5
	12	10:40	10:46	35	1.5
	13	10:46	10:52	35	1.5
	14	10:52	10:58	45	1.9
	15	10:58	11:04	45	1.9
	16	11:04	11:10	45	1.9
5/20/80	1	1:33	1:39	40	1.7
(Run #3)	2	1:39	1:45	35	1.5
	3	1:45	1:51	55	2.3
	4	1:51	1:57	40	1.7
	5	1:57	2:03	45	1.9
	6	2:03	2:09	45	1.9
	7	2:09	2:15	35	1.5
	8	2:15	2:21	45	1.9
	9	2:21	2:27	40	1.7
	10	2:27	2:33	35	1.5
	11	2:33	2:39	40	1.7
	12	2:39	2:45	45	1.9
	13	2:45	2:51	35	1.5
	14	2:51	2:57	25	1.0
	15	2:57	3:03	35	1.5
	16	3:03	3:09	35	1.5

TABLE C-27. PLANT Y. SUMMARY OF VISIBLE EMISSIONS

Stucco Storage and Transfer - Outlet of Fabric Filter[a]

Emission Control Data

Fabric Type: Dacron　　Air-to-Cloth Ratio (cfm:ft^2): 5.0:1
Cleaning Mechanism: Pulse-jet
Date of Last Bag Replacement: 5/24/80

General Data:

Date: 5/27/80　　Type of Plant: Gypsum　　Duration of Observation: 3 hrs.

Type of Discharge: Stack　　Discharge Location: Outlet of baghouse

Height of Point of Discharge: 15 feet from roof

Observer's Location

Distance to Discharge Point: 20 feet　　Height of Observation Point: Roof level

Direction from Discharge Point: West

Background Description: Gray stack cover

Weather: Clear

Wind Direction: NE　　Wind Velocity: N/A

Plume Description

Detached: No　　Color: White

Estimated Distance Plume Visible: 3 feet

Summary of Average Opacity

Date	Set #	Time Start	Time End	Opacity Sum	Opacity Average	Date	Set #	Time Start	Time End	Opacity Sum	Opacity Average
5/27/80	1	1330	1336	90	3.8		6	1510	1516	55	2.3
(Run #1)	2	1336	1342	95	4.0		7	1516	1522	110	4.6
	3	1342	1348	70	2.9		8	1522	1528	105	4.4
	4	1348	1354	110	4.6		9	1528	1534	65	2.7
	5	1354	1400	115	4.8		10	1534	1540	100	4.2
	6	1400	1406	120	5.0	5/27/80	1	1605	1611	95	4.0
	7	1406	1412	60	2.5	(Run #3)	2	1611	1617	70	2.9
	8	1412	1418	75	3.1		3	1617	1623	90	3.8
	9	1418	1424	60	2.5		4	1623	1629	100	4.2
	10	1424	1430	75	3.1		5	1629	1635	75	3.1
5/27/80	1	1440	1446	35	1.5		6	1635	1641	75	3.1
(Run #2)	2	1446	1452	45	1.9		7	1641	1647	90	3.8
	3	1452	1458	60	2.5		8	1647	1653	100	4.2
	4	1458	1504	80	3.3		9	1653	1659	95	4.0
	5	1504	1510	85	3.5		10	1659	1705	85	3.5

[a]This visible emission test was repeated on 10/2/80 due to the non-representativeness of the baghouse during the test. The filter bags were in operation only several hours prior to the test and had not been conditioned sufficiently to allow operation of the fabric filter at normal efficiency.

TABLE C-28. PLANT Y. SUMMARY OF VISIBLE EMISSIONS

Stucco Storage and Transfer -
Outlet of Fabric Filter

Emission Control Data

Fabric Type: Dacron Air-to-Cloth Ratio (cfm:ft^2): 5.0:1
Cleaning Mechanism: Pulse-jet
Date of Last Bag Replacement: 5/24/80

General Data:

Date: 10/2/80 Type of Plant: Gypsum Duration of Observation: 3 hrs.

Type of Discharge: Stack Discharge Location: Outlet of baghouse

Height of Point of Discharge: 7 feet above roof

Observer's Location

Distance to Discharge Point: 20 ft. Height of Observation Point: Roof level

Direction from Discharge Point: East

Background Description: Gray stack cover

Weather: Overcast - partly cloudy

Wind Direction: WNW Wind Velocity: 10-20 mph

Plume Description

Detached: No Color: White

Estimated Distance Plume Visible: 3 feet

Summary of Average Opacity

Date	Set #	Time Start	Time End	Opacity Sum	Opacity Average	Date	Set #	Time Start	Time End	Opacity Sum	Opacity Average
10/2/80	1	1220	1226	25	1.0	10/2/80	6	1400	1406	30	1.3
(Run #1)	2	1226	1232	35	1.5		7	1406	1412	30	1.3
	3	1232	1238	40	1.7		8	1412	1418	30	1.3
	4	1238	1244	30	1.3		9	1418	1424	35	1.5
	5	1244	1250	45	1.9		10	1424	1430	35	1.5
	6	1250	1256	35	1.5	10/2/80	1	1445	1451	35	1.5
	7	1256	1302	40	1.7	(Run #3)	2	1451	1457	35	1.5
	8	1302	1308	50	2.1		3	1457	1503	35	1.5
	9	1308	1314	25	1.0		4	1503	1509	50	2.1
	10	1314	1320	40	1.7		5	1509	1515	45	1.9
10/2/80	1	1330	1336	45	1.9		6	1515	1521	40	1.7
(Run #2)	2	1336	1342	40	1.7		7	1521	1527	50	2.1
	3	1342	1348	30	1.7		8	1527	1533	50	2.1
	4	1348	1354	55	2.3		9	1533	1539	45	1.9
	5	1354	1400	30	1.3		10	1539	1545	45	1.9

TABLE C-29. PLANT Y. SUMMARY OF FUGITIVE EMISSIONS
Board End Sawing

General Data

Date: 5/19/80 & 5/20/80   Duration of Observation: three hours

Type of Discharge: Fugitive

Location of Discharge Point: End of boardline

Description of Discharge: Dust from sawing the end of wallboard is collected by a hood surrounding the saw. Some dust escapes capture by the hood. Emissions were visible to approximately 4 inches from saw. Captured dust is ducted to a baghouse.

Summary of Fugitive Emissions

Date	Time	Observation Period (Min:Sec)	Percent Time with Visible Emission
5/19/80 Run #1[a]	1405-1425	20:00	39.6
	1427-1447	20:00	36.8
	1452-1512	20:00	36.3
5/19/80 Run #2[a]	1530-1550	20:00	33.3
	1555-1615	20:00	41.9
	1618-1638	20:00	33.8
5/20/80 Run #3[b]	0820-0840	20:00	21.8
	0842-0902	20:00	20.3
	0905-0925	20:00	18.8

[a]During Run #1 and Run #2 the plant was producing 1/2" x 4' x 12' board.
[b]During Run #3 the plant was producing 1/2" x 4' x 12' board.

Table C-30. PLANT Y. SUMMARY OF FUGITIVE EMISSIONS

Paper Scoring

General Data

Date: 5/20/80 Duration of Observation: three hours

Type of Discharge: Fugitive

Location of Discharge Point: Paper scoring wheel at head of boardline

Description of Discharge: Paper particles from scoring of the wallboard paper are captured by a hood which covers the scoring wheel. Some particles potentially escape capture by the hood. Captured particles are ducted to a cyclone/fabric filter.

Summary of Fugitive Emissions

Time	Observation Period (Min:Sec)	Percent Time with Visible Emission
1012-1032	20:00	0.0
1035-1055	20:00	0.0
1057-1117	20:00	0.0
1120-1140	20:00	0.0
1141-1201	20:00	0.0
1205-1225	20:00	0.0
1226-1246	20:00	0.0
1246-1306	20:00	0.0
1307-1327	20:00	0.0

TABLE C-31. PLANT Y. SUMMARY OF FUGITIVE EMISSIONS
Accelerator Addition

General Data

Date: 5/20/80 & 5/21/80 Duration of Observation: three hours

Type of Discharge: Fugitive

Location of Discharge Point: Dry mixing area

Description of Discharge: Accelerator additives were added to the boardline dry mixing conveyor with a measuring screw. No emissions.

Summary of Fugitive Emissions

Date	Time	Observation Period (Min:Sec)	Percent Time with Visible Emission
5/20/80	1415-1425	20:00	0.0
	1435-1455	20:00	0.0
	1455-1515	20:00	0.0
5/20/80	1515-1525	20:00	0.0
	1535-1555	20:00	0.0
	1555-1615	20:00	0.0
5/21/80	0900-0920	20:00	0.0
	0930-0950	20:00	0.0
	0950-1010	20:00	0.0

TABLE C-32. PLANT Y. SUMMARY OF FUGITIVE EMISSIONS
Fiber glass Shredder

General Data

Date: 5/21/80 Duration of Observation: three hours

Type of Discharge: Fugitive

Location of Discharge Point: Dry mixing area

Description of Discharge: Fiberglass was shredded by a rotating knife-edged wheel. Some fugitive emissions occurred. However, particles were so large they fell directly to the floor.

Summary of Fugitive Emissions

Time	Observation Period (Min:Sec)	Percent Time with Visible Emission
1245-1305	20:00	0.2
1305-1325	20:00	0.3
1325-1345	20:00	0.2
1350-1410	20:00	0.3
1410-1430	20:00	0.4
1430-1450	20:00	0.3
1450-1510	20:00	0.3
1510-1530	20:00	0.6
1530-1550	20:00	0.3

TABLE C-33. PLANT Y. SUMMARY OF FUGITIVE EMISSIONS
Vermiculite Addition

General Data

Date: 5/22/80 Duration of Observation: 29 min.

Type of Discharge: Fugitive

Location of Discharge Point: Dry mixing area

Description of Discharge: Vermiculite poured into an open bin caused fugitive emissions at the top of the bin. Emissions occurred only when the bin was being filled.

Summary of Fugitive Emissions

Time	Observation Period (Min:Sec)	Percent Time with Visible Emission
1420-1429	29:00	65.5

TABLE C-34. PLANT GG. SUMMARY OF EMISSION TEST RESULTS

Plaster Mixing and Bagging - Outlet of Fabric Filter (Industry Test)

Emission Control Data

Cleaning Mechanism: N/A
Actual Air-to-Cloth Ratio ($cfm:ft^2$): N/A
Filter Fabric: N/A
Date of Last Bag Replacement: N/A

Run Number	1	2	3	Average
General Data				
Date	8/13/73	8/14/73	8/14/73	-
Time	1320-1445	0836-0946	1024-1123	-
Sampling duration (min)	60	60	60	-
Isokinetic ratio (%)	97.9	91.1	92.1	93.7
Production rate (Mg/hr)	3.6	3.6	3.6	3.6
Production rate (ton/hr)	4.0	4.0	4.0	4.0
Exit Gas Data				
Temperature (K)	320	305	319	315
Temperature (°F)	116	90	114	107
Moisture (%)	0.54	1.3	0.61	0.82
Flow rate (m^3/s)	2.04	2.42	2.55	2.34
Flow rate (ACFM)	4331	5135	5396	4954
Flow rate (dNm^3/s)	1.59	1.98	1.70	1.76
Flow rate (DSCFM)	3374	4200	3608	3727
Particulate Emissions				
g/dNm^3	.009	.011	.014	.011
gr/dscf	.004	.005	.006	.005
g/m^3	.007	.009	.009	.009
gr/acf	.003	.004	.004	.004
kg/hr	.050	.079	.064	.064
lb/hr	.111	.174	.141	.142
g/kg	.014	.022	.018	.018
lb/ton	.028	.044	.035	.036

TABLE C-35. PLANT GG. SUMMARY OF EMISSION TEST RESULTS

Land Plaster Storage Bins - Outlet of Fabric Filter
(Industry Test)

Emission Control Data

Cleaning Mechanism: N/A
Actual Air-to-Cloth Ratio ($cfm:ft^2$): N/A
Filter Fabric: N/A
Date of Last Bag Replacement: N/A

Run Number	1	2	3	Average
General Data				
Date	8/16/73	8/16/73	8/16/73	-
Time	1006-1123	1217-1325	1407-1516	-
Sampling duration (min)	64	64	64	-
Isokinetic ratio (%)	110.	104.	106.	108.7
Production rate (Mg/hr)	a	a	a	a
Production rate (ton/hr)	a	a	a	a
Exit Gas Data				
Temperature (K)	382	379	383	381
Temperature (°F)	109	106	110	108
Moisture (%)	1.2	1.3	0.75	1.1
Flow rate (m^3/s)	3.53	3.65	3.60	3.59
Flow rate (ACFM)	7487	7732	7628	7616
Flow rate (dNm^3/s)	2.89	3.00	2.94	3.94
Flow rate (DSCFM)	6127	6361	6231	6240
Particulate Emissions				
g/dNm^3	.005	.005	.005	.005
gr/dscf	.002	.002	.002	.002
g/m^3	.005	.005	.005	.005
gr/acf	.002	.002	.002	.002
kg/hr	.048	.049	.059	.052
lb/hr	.106	.108	.130	.115
g/kg	a	a	a	a
lb/ton	a	a	a	a

[a]Production data are not available.

TABLE C-36. PLANT OO. SUMMARY OF EMISSION TEST RESULTS
Direct Contact Flash Calciner - Inlet to Fabric Filter

Run Number	1	2	3	Average
General Data				
Date	7/15/80	7/16/80	7/16/80	-
Time	1524-2016	0913-1057	1248-1412	-
Sampling duration (min)	60	60	60	-
Isokinetic ratio (%)	109.7	101.3	108.1	106.4
Production rate (Mg/hr)	6.4	6.4	6.4	6.4
Production rate (ton/hr)	7.0	7.0	7.0	7.0
Exit Gas Data				
Temperature (K)	422	421	425	422
Temperature (°F)	300	298	306	301
Moisture (%)	52.6	45.2	50.0	49.3
Flow rate (m^3/s)	1.75	1.75	1.76	1.75
Flow rate (ACFM)	3705	3717	3731	3718
Flow rate (dNm^3/s)	0.574	0.667	0.605	0.616
Flow rate (DSCFM)	1217	1414	1283	1305
Particulate Emissions				
g/dNm^3	48.8	48.5	52.2	49.9
gr/dscf	21.3	21.2	22.8	21.8
g/m^3	16.1	18.5	18.0	17.5
gr/acf	7.01	8.06	7.86	7.64
kg/hr	101	117	114	111
lb/hr	223	257	251	244
g/kg	15.9	18.4	18.0	17.4
lb/ton	31.8	36.7	35.9	34.8

TABLE C-37. PLANT OO. SUMMARY OF EMISSION TEST RESULTS

Direct Contact Flash Calciner - Outlet of Fabric Filter

Emission Control Data

Cleaning Mechanism: Pulse-jet
Actual Air-to-Cloth Ratio (cfm:ft^2): 4.3:1
Filter Fabric: Nomex
Date of Last Bag Replacement: Early May 1980

Run Number	1	2	3	Average
General Data				
Date	7/16/80	7/16/80	7/16/80	-
Time	0926-1044	1327-1517	1612-1754	-
Sampling duration (min)	72	96	96	-
Isokinetic ratio (%)	109.3	108.5	102.7	106.9
Production rate (Mg/hr)	6.4	6.4	6.4	6.4
Production rate (ton/hr)	7.0	7.0	7.0	7.0
Exit Gas Data				
Temperature (K)	438	439	439	439
Temperature (°F)	329	331	331	330
Moisture (%)	46.2	47.6	49.3	47.7
Flow rate (m^3/s)	1.98	1.90	1.90	1.93
Flow rate (ACFM)	4198	4037	4019	4085
Flow rate (dNm^3/s)	0.718	0.671	0.647	0.679
Flow rate (DSCFM)	1522	1423	1371	1439
Particulate Emissions				
g/dNm^3	.021	.011	.009	.014
gr/dscf	.009	.005	.004	.006
g/m^3	.007	.005	.005	.005
gr/acf	.003	.002	.002	.002
kg/hr	.054	.027	.023	.036
lb/hr	.120	0.060	0.050	0.080
g/kg	.009	.005	.004	.006
lb/ton	.017	.009	.007	.011

TABLE C-38. PLANT OO. SUMMARY OF VISIBLE EMISSIONS
Direct Contact Flash Calciner

Emission Control Data

Control Method: Baghouse
Cleaning Mechanism: Pulse-jet
Air-to-Cloth Ratio (cfm:ft^2): 4.3:1
Fabric Type: Nomex
Date of Last Bag Replacement: Early May 1980

General Data:

Date: 7/15/80 and 7/16/80

Type of Plant: Gypsum

Type of Discharge: Stack

Discharge Location: Baghouse outlet

Height of Point of Discharge: N/A

Observer's Location

Distance to Discharge Point: 25 feet

Height of Observation Point: 15 feet above stack

Direction from Discharge Point: above stack

Background Description: Ground (blacktop road)

Weather: Clear

Wind Direction: NW   Wind Velocity: 5-10 mph

Plume Description

Detached: Yes (steam plume in morning)

Color: White

Estimated Distance Plume Visible:

Summary of Average Opacity

Date	Set Number	Time Start	Time End	Opacity Sum	Opacity Average
7/15/80 (Run #1/ Inlet)	1-10	1655	1755	0	0
	11-20	1755	1855	0	0
7/16/80 (Run #2 (Inlet and Run #1 Outlet)	1-10	0926	1026	0	0
	11-15	1026	1056	0	0
7/16/80 (Run #3 Inlet and Run #2 Outlet)	1-10	1250	1350	0	0
	11-20	1350	1450	0	0
7/16/80 (Run #3 Outlet)	1-10	1620	1720	0	0
	11-15	1720	1754	0	0

TABLE C-39. PLANT OO. SUMMARY OF VISIBLE EMISSIONS
Stucco Silo

Emission Control Data

Control Method: Baghouse — Air-to-Cloth Ratio (cfm:ft^2): 3.4:1
Cleaning Mechanism: Shaker — Fabric Type: Cotton
Date of Last Bag Replacement: 7/12/80

General Data:

Date: 7/15/80 — Type of Plant: Gypsum — Duration of Observation: 3 hrs.

Type of Discharge: Stack — Discharge Location: Baghouse outlet

Height of Point of Discharge: N/A

Observer's Location

Distance to Discharge Point: ≈60 ft. — Height of Observation Point: 15 ft. above

Direction from Discharge Point: N/A

Background Description: N/A

Weather: Clear

Wind Direction: from NW — Wind Velocity: 10-15 mph

Plume Description

Detached: No — Color: White

Estimated Distance Plume Visible: N/A

Summary of Average Opacity

Date	Set Number	Time Start	Time End	Opacity Sum	Opacity Average
7/15/80 (Run #1)	1-10	1130	1230	0	0
7/16/80 (Run #2)	1	1100	1106	0	0
	2	1106	1112	0	0
	3	1112	1118	35	1.5
	4-10	1118	1200	0	0
7/16/80 (Run #3)	1-6	1520	1602	0	0
	7	1602	1608	30	1.3
		1608	1614	50	2.1
		1614	1620	0	0

TABLE C-40. PLANT OO. SUMMARY OF FUGITIVE EMISSIONS
Stucco Storage and Transfer

General Data

Date: 7/16/80 Duration of Observation: three hours

Type of Discharge: Fugitive

Location of Discharge Point: Screw conveyor, bucket elevator and storage bin transfer points

Description of Discharge: Potential fugitive emissions from openings in conveyor enclosures at transfer points and along conveyor. Transfer and storage system operated under negative pressure. Captured fugitive emissions ducted to fabric filter.

Summary of Fugitive Emissions

Time	Observation Period (Min:Sec)	Percent Time with Visible Emission
1400-1420	20:00	0.0
1425-1445	20:00	0.0
1450-1510	20:00	0.0
1515-1535	20:00	0.0
1540-1600	20:00	0.0
1605-1625	20:00	0.0
1630-1650	20:00	0.0
1655-1715	20:00	0.0
1720-1740	20:00	0.0

TABLE C-41. PLANT RR. SUMMARY OF EMISSION TEST RESULTS

Continuous Kettle Calciners and Grinding Mills - Outlet of Electrostatic Precipitators (Industry Test)

Source Description

Emission sources controlled by the electrostatic precipitator include two grinding mills, two continuous kettle calciners and two screw conveyors.

Run Number	1	2	3	Average
General Data				
Date	12/5/79	12/5/79	12/5/79	-
Time	0804-0910	1257-1403	1440-1546	-
Sampling duration (min)	64	64	64	-
Isokinetic ratio (%)	110.	110.	106.	108.7
Production rate[a] (Mg/hr)	65.2	65.2	65.2	65.2
Production rate[a] (ton/hr)	71.8	71.8	71.8	71.8
Exit Gas Data				
Temperature (K)	355	356	359	357
Temperature (°F)	180	182	187	183
Moisture (%)	13.5	14.6	13.8	14.0
Flow rate (m^3/s)	10.7	10.7	10.7	10.7
Flow rate (ACFM)	22,714	22,629	22,714	22,686
Flow rate (dNm^3/s)	6.62	6.49	6.53	6.55
Flow rate (DSCFM)	14,036	13,768	13,835	13,880
Particulate Emissions				
g/dNm^3	.170	.076	.055	.100
gr/dscf	.075	.033	.024	.044
g/m^3	.098	.044	.032	.055
gr/acf	.043	.019	.014	.025
kg/hr	4.70	1.78	1.29	2.38
lb/hr	8.87	3.93	2.84	5.25
g/kg	.06	.03	.02	.04
lb/ton	.12	.05	.04	.07

[a] Production rate given includes total weight of stucco produced plus weight of rock milled per hour.

TABLE C-42. PLANT TT. SUMMARY OF EMISSION TEST RESULTS

Batch Kettle Calciner - Inlet to Fabric Filter

Run Number	1	2	3	Average[a]
General Data				
Date	10/28/80	10/28/80	10/29/80	-
Time	1400-1600	1640-1940	9040-1210	-
Sampling duration (min)	40	18.5	19	-
Isokinetic ratio (%)	109.4	98.1	138.8	103.8
Production rate (Mg/hr)	4.4	4.4	4.4	4.4
Production rate (ton/hr)	4.9	4.9	4.9	4.9
Exit Gas Data				
Temperature (K)	347	345	353	346
Temperature (°F)	166	161	176	164
Moisture (%)	32.7	33.0	46.9	32.9
Flow rate (m^3/s)	1.38	1.41	1.21	1.40
Flow rate (ACFM)	2927	2988	2560	2958
Flow rate (dNm^3/s)	0.79	0.81	0.54	0.80
Flow rate (DSCFM)	1674	1716	1140	1696
Particulate Emissions				
g/dNm^3	72.6	47.2	35.5	60.0
gr/dscf	31.7	20.6	15.5	26.2
g/m^3	41.7	25.6	25.8	33.7
gr/acf	18.4	11.2	6.92	14.7
kg/hr	207	138	69.0	172
lb/hr	456	303	152	379
g/kg	47	31	16	39
lb/ton	93	62	31	78

[a]This represents the average of the first two runs only. The third run had an unacceptable isokinetic sampling rate.

TABLE C-43. PLANT TT. SUMMARY OF EMISSION TEST RESULTS
Batch Kettle Calciner - Outlet of Fabric Filter

Emission Control Data

Cleaning Mechanism: Pulse-jet
Actual Air-to-Cloth Ratio (cfm:ft^2): 4.6:1
Filter Fabric: Nomex
Date of Last Bag Replacement: 9/10/80

Run Number	1	2	3	Average
General Data				
Date	10/28/80	10/28/80	10/31/80	-
Time	1400-1600	1730-2015	9045-1233	-
Sampling duration (min)	160	160	160	-
Isokinetic ratio (%)	97.8	102.9	110.0	103.6
Production rate (Mg/hr)	4.4	4.4	4.4	4.4
Production rate (ton/hr)	4.9	4.9	4.9	4.9
Exit Gas Data				
Temperature (K)	341	341	353	345
Temperature (°F)	154	154	176	161
Moisture (%)	25.1	23.6	29.1	26.0
Flow rate (m^3/s)	1.37	1.35	1.38	1.37
Flow rate (ACFM)	2911	2852	2922	2895
Flow rate (dNm^3/s)	0.88	0.89	0.81	0.86
Flow rate (DSCFM)	1860	1881	1724	1821
Particulate Emissions				
g/dNm^3	.089	.009	.069	.057
gr/dscf	.039	.004	.030	.025
g/m^3	.057	.007	.041	.034
gr/acf	.025	.003	.018	.015
kg/hr	.285	.030	.202	.173
lb/hr	.628	.065	.446	.380
g/kg	.064	.007	.046	.039
lb/ton	.128	.013	.091	.078

TABLE C-44. PLANT TT. SUMMARY OF VISIBLE EMISSIONS

Batch Kettle Calciner

Emission Control Data

Control Method: Fabric Filter   Air-to-Cloth Ratio ($cfm:ft^2$): 5.2:1
Cleaning Mechanism: Pulse-jet   Fabric Type: Nomex
Date of Last Bag Replacement: 9/10/80

General Data:

Date: 10/28/80, 10/29/80 & 10/31/80   Type of Plant: Gypsum
Type of Discharge: Stack   Discharge Location: Baghouse outlet

Height of Point of Discharge: 60 feet from ground

Observer's Location

Distance to Discharge Point: 25 ft   Height of Observation Point: 62 ft. from ground

Direction from Discharge Point: NW

Background Description: Plant buildings

Weather: Partly cloudy - clear

Wind Direction: SW   Wind Velocity: 5-10 mph

Plume Description: clean steam plume

Detached: Yes   Color: White

Estimated Distance Plume Visible: 30 feet

Summary of Average Opacity

		Time		Opacity	
Date	Set Number	Start	End	Sum	Average
10/28/80 (Run #1)	1-27	1359	1641	0	0
10/29/80 (Run #3/ inlet)	1-20	0858	1058	0	0
10/31/80 (Run #3/ outlet)	1-20	0909	1109	0	0

TABLE C-45. PLANT TT. SUMMARY OF EMISSION TEST RESULTS
Continuous Kettle Calciner - Inlet to Fabric Filter

Run Number	1	2	3	Average
General Data				
Date	10/30/80	10/30/80	10/30/80	-
Time	0930-1018	1312-1404	1523-1603	-
Sampling duration (min)	20	20	20	-
Isokinetic ratio (%)	96.5	95.6	103.4	98.5
Production rate (Mg/hr)	10.0	10.0	10.0	10.0
Production rate (ton/hr)	11.0	11.0	11.0	11.0
Exit Gas Data				
Temperature (K)	399	404	397	400
Temperature (°F)	258	268	256	261
Moisture (%)	59.1	58.8	61.4	59.8
Flow rate (m^3/s)	1.49	1.50	1.35	1.45
Flow rate (ACFM)	3156	3182	2865	3068
Flow rate (dNm^3/s)	0.454	0.456	0.389	0.433
Flow rate (DSCFM)	963	967	824	918
Particulate Emissions				
g/dNm^3	113	133	128	125
gr/dscf	49.5	58.1	55.7	54.4
g/m^3	34.6	40.5	36.6	37.3
gr/acf	15.1	17.7	16.0	16.3
kg/hr	186	219	179	194
lb/hr	409	482	394	428
g/kg	18.6	21.9	17.9	19.5
lb/ton	37.2	43.8	35.8	38.9

TABLE C-46. PLANT TT. SUMMARY OF EMISSION TEST RESULTS

Continuous Kettle Calciner - Outlet of Fabric Filter

Emission Control Data

Cleaning Mechanism: Pulse-jet
Actual Air-to-Cloth Ratio (cfm:ft^2): 5.5:1
Filter Fabric: Nomex
Date of Last Bag Replacement: 9/10/80

Run Number[a]	2	3	4	Average
General Data				
Date	10/30/80	10/30/80	10/30/80	-
Time	1230-1350	1452-1559	1704-1810	-
Sampling duration (min)	80	64	64	-
Isokinetic ratio (%)	100.0	100.4	104.4	101.6
Production rate (Mg/hr)	10.0	10.0	10.0	10.0
Production rate (ton/hr)	11.0	11.0	11.0	11.0
Exit Gas Data				
Temperature (K)	383	384	386	384
Temperature (°F)	230	232	235	232
Moisture (%)	51.1	51.1	53.0	51.7
Flow rate (m^3/s)	1.34	1.34	1.32	1.33
Flow rate (ACFM)	2845	2851	2801	2832
Flow rate (dNm^3/s)	0.51	0.50	0.47	0.49
Flow rate (DSCFM)	1072	1070	1004	1049
Particulate Emissions				
g/dNm^3	.22	.21	.22	.22
gr/dscf	.095	.090	.096	.094
g/m^3	.082	.078	.078	.080
gr/acf	.036	.034	.034	.035
kg/hr	.396	.373	.375	.381
lb/hr	.872	.821	.827	.840
g/kg	.040	.038	.038	.038
lb/ton	.079	.075	.075	.076

[a]The first outlet test was discarded because of an unacceptable isokinetic sampling rate.

TABLE C-47. PLANT TT. SUMMARY OF VISIBLE EMISSIONS
Continuous Kettle Calciner

Emission Control Data

Control Method: Fabric Filter Air-to-Cloth Ratio ($cfm:ft^2$): 5.5:1
Cleaning Mechanism: Pulse-jet Fabric Type: Nomex
Date of Last Bag Replacement: 9/10/80

General Data:

Date: 10/30/80 Type of Plant: Gypsum

Type of Discharge: Stack Discharge Location: Outlet of baghouse

Height of Point of Discharge: 60 feet from ground

Observer's Location

Distance to Discharge Point: 12 ft. Height of Observation Point: same as stack outlet

Direction from Discharge Point: SW

Background Description: Blue sky

Weather: Clear

Wind Direction: W-NW Wind Velocity: 10 mph

Plume Description: Clean steam plume

Detached: Yes Color: White

Estimated Distance Plume Visible: 30-40 feet

Summary of Average Opacity

Date	Set Number	Time Start	Time End	Opacity Sum	Opacity Average
10/30/80	1-10	1250	1350	0	0
10/30/80	1-10	1440	1540	0	0
10/30/80	1-10	1540	1640	0	0

TABLE C-48. PLANT TT. SUMMARY OF EMISSION TEST RESULTS

Board End Sawing and Paper Scoring - Outlet of Fabric Filter

Emission Control Data

Cleaning Mechanism: Shaker
Actual Air-to-Cloth Ratio (cfm:ft^2): 4.6:1
Filter Fabric: Cotton
Date of Last Bag Replacement: 10/6/80

Run Number	1	2	3	Average
General Data				
Date	10/31/80	10/31/80	10/31/80	-
Time	1115-1200	1310-1415	1607-1655	-
Sampling duration (min)	40	40	40	-
Isokinetic ratio (%)	96.8	93.6	97.3	95.9
Production rate (Mg/hr)	27.9	27.9	27.9	27.9
Production rate (ton/hr)[a]	30.7	30.7	30.7	30.7
Exit Gas Data				
Temperature (K)	295	297	294	295
Temperature (°F)	71	75	70	72
Moisture (%)	1.2	1.5	0.72	1.1
Flow rate (m^3/s)	1.90	1.85	1.86	1.87
Flow rate (ACFM)	4026	3930	3951	3969
Flow rate (dNm^3/s)	1.90	1.84	1.88	1.87
Flow rate (DSCFM)	4029	3897	3982	3969
Particulate Emissions				
g/dNm^3	.021	.018	.032	.023
gr/dscf	.009	.008	.014	.010
g/m^3	.021	.018	.032	.023
gr/acf	.009	.008	.014	.010
kg/hr	.144	.127	.212	.161
lb/hr	.318	.280	.466	.354
g/kg	.005	.005	.008	.006
lb/ton	.010	.009	.015	.012

[a]Estimated from boardline speed.

TABLE C-49. PLANT TT. SUMMARY OF VISIBLE EMISSIONS
Board End Sawing and Paper Scoring

Emission Control Data

Control Method: Baghouse
Air-to-Cloth Ratio ($cfm:ft^2$): 4.6:1
Cleaning Mechanism: Shaker
Fabric Type: Cotton
Date of Last Bag Replacement: 10/6/80

General Data:

Date: 10/31/80
Type of Plant: Gypsum

Type of Discharge: Stack
Discharge Location: Baghouse outlet

Height of Point of Discharge: 40 feet from ground

Observer's Location

Distance to Discharge Point: 20 ft.
Height of Observation Point: 30-32 ft. above ground

Direction from Discharge Point: South

Background Description: Blue sky

Weather: Clear

Wind Direction: WSW
Wind Velocity: 2-5 mph

Plume Description: No plume

Detached:
Color:

Estimated Distance Plume Visible:

Summary of Average Opacity

		Time		Opacity	
Date	Set Number	Start	End	Sum	Average
10/31/80 (Run #1)	1-8	1125	1213	0	0
10/31/80 (Run #2)	1-4	1310	1334	0	0
10/31/80 (Run #3)	1-10	1517	1617	0	0

TABLE C-50. PLANT TT. SUMMARY OF FUGITIVE EMISSIONS
Board End Sawing Operation

General Data

Date: 10/31/80

Duration of Observation: three hours

Type of Discharge: Fugitive

Location of Discharge Point: Board end sawing operation at end of boardline

Description of Discharge: Particulate emissions from board sawing are captured by a hood surrounding the saw. Some emissions escape capture. Collected dust is ducted to a fabric filter.

Summary of Fugitive Emissions

Time	Observation Period (Min:Sec)	Percent Time with Visible Emission
1415-1425	20:00	11.7
1430-1445	15:00	8.5
1600-1620	20:00	16.7
1620-1640	20:00	14.8
1640-1700	20:00	16.3
1700-1720	20:00	6.4
1725-1745	20:00	2.8
1750-1830	40:00	4.3

TABLE C-51. PLANT TT. SUMMARY OF VISIBLE EMISSIONS
Plaster Mixing and Bagging Operation

Emission Control Data

Control Method: Baghouse — Air-to-Cloth Ratio (cfm:ft^2): 1:1
Cleaning Mechanism: Shaker — Fabric Type: Cotton
Date of Last Bag Replacement: unknown

General Data:

Date: 10/29/80 — Type of Plant: Gypsum — Duration of Observation: 1½ hrs.

Type of Discharge: Stack — Discharge Location: Outlet of baghouse

Height of Point of Discharge: 50 feet above ground

Observer's Location

Distance to Discharge Point: 75 ft. — Height of Observation Point: Ground level

Direction from Discharge Point: SW

Background Description: Blue Sky

Weather: Partly cloudy - clear

Wind Direction: SW — Wind Velocity: 5-10 mph

Plume Description: No Plume

Detached: — Color:

Estimated Distance Plume Visible:

Summary of Average Opacity

Date	Set Number	Time Start	Time End	Opacity Sum	Opacity Average
10/29/80	1-5	1128	1158	0	0
10/29/80	1-10	1245	1345	0	0

TABLE C-52. PLANT TT. SUMMARY OF VISIBLE EMISSIONS
Land Plaster and Stucco Transfer System

Emission Control Data

Control Method: Baghouse — Air-to-Cloth Ratio (cfm:ft^2): 6.4:1
Cleaning Mechanism: Pulse-jet — Fabric Type: Dacron
Date of Last Bag Replacement: 9/25/80

General Data:

Date: 10/29/80 & 10/30/80 — Type of Plant: Gypsum — Duration of Observation: 3 hrs.

Type of Discharge: Stack — Discharge Location: Baghouse outlet

Height of Point of Discharge: 100 feet from ground

Observer's Location

Distance to Discharge Point: 100' (10/29) 30' (10/30) — Height of Observation Point: 90' (10/29) 70' (10/30)

Direction from Discharge Point: NE on 10/29 & N on 10/30

Background Description: Blue sky

Weather: Clear

Wind Direction: SW — Wind Velocity: 5-15 mph

Plume Description: No plume

Detached: — Color:

Estimated Distance Plume Visible: N/A

Summary of Average Opacity

Date	Set #	Time Start	Time End	Opacity Sum	Opacity Average	Date	Set #	Time Start	Time End	Opacity Sum	Opacity Average
10/29/80	1	1400	1406	0	0	10/30/80	6	0933	0939	25	1.0
(Run #1)	2	1406	1412	0	0		7	0939	0945	15	0.6
	3	1412	1418	0	0		8	0945	0951	25	1.0
	4	1418	1424	0	0		9	0951	0957	25	1.0
	5	1424	1430	0	0		10	0957	1003	0	0
	6	1430	1436	0	0	10/30/80	1	1003	1009	10	0.4
	7	1436	1442	0	0	(Run #3)	2	1009	1015	20	0.8
	8	1442	1448	0	0		3	1015	1021	20	0.8
	9	1448	1454	0	0		4	1021	1027	10	0.4
	10	1454	1500	0	0		5	1027	1033	20	0.8
10/30/80	1	0903	0909	0	0		6	1033	1039	45	1.9
(Run #2)	2	0909	0915	0	0		7	1039	1045	40	1.7
	3	0915	0921	0	0		8	1045	1051	30	1.3
	4	0921	0927	0	0		9	1051	1057	95	4.0
	5	0927	0933	0	0		10	1057	1103	40	1.7

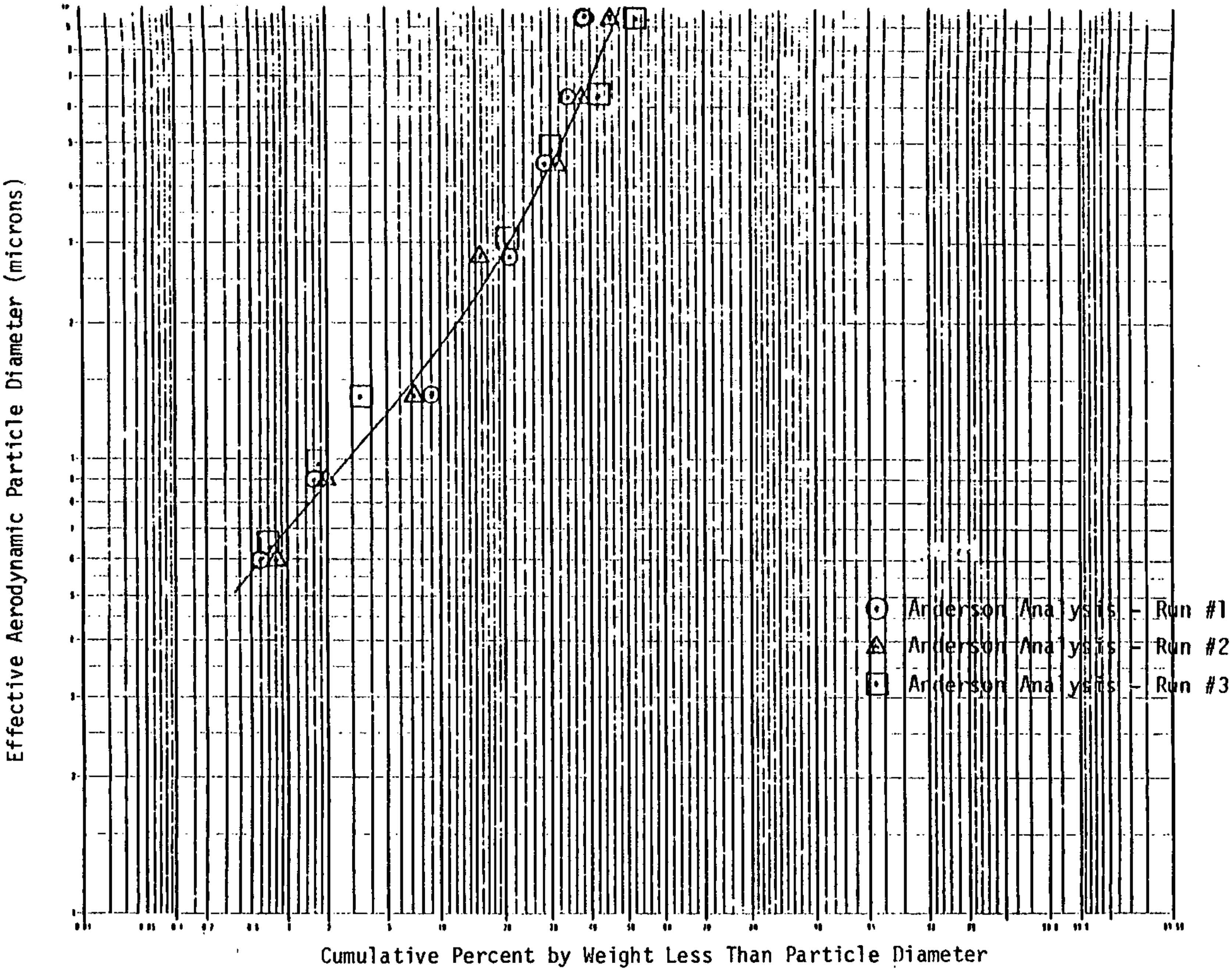

Figure C-1. Plant E. Particle size analysis for ore dryer - inlet to fabric filter downstream of process cyclones.

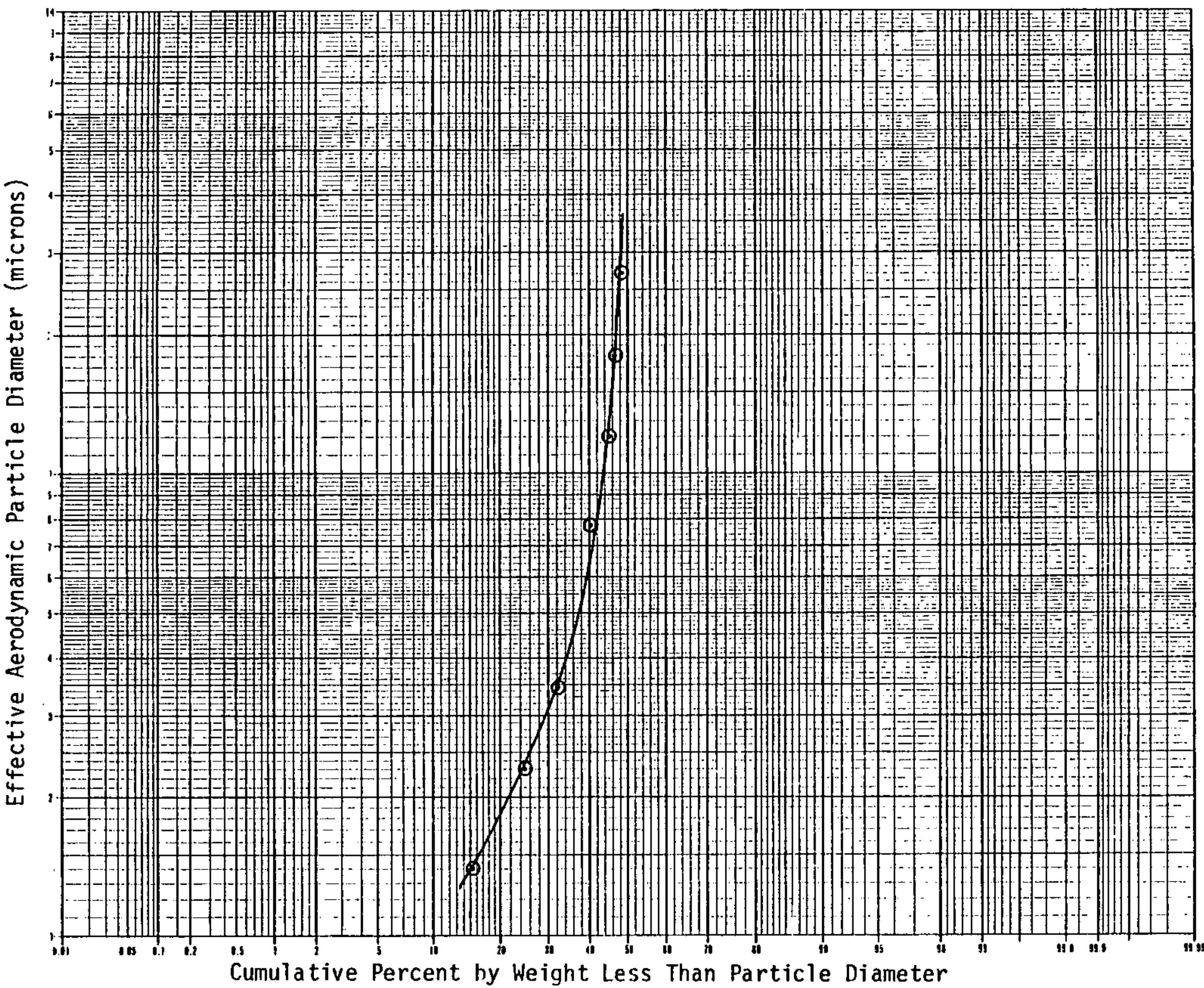

Figure C-2. Plant E. Particle size analysis for ore dryer - outlet of fabric filter.

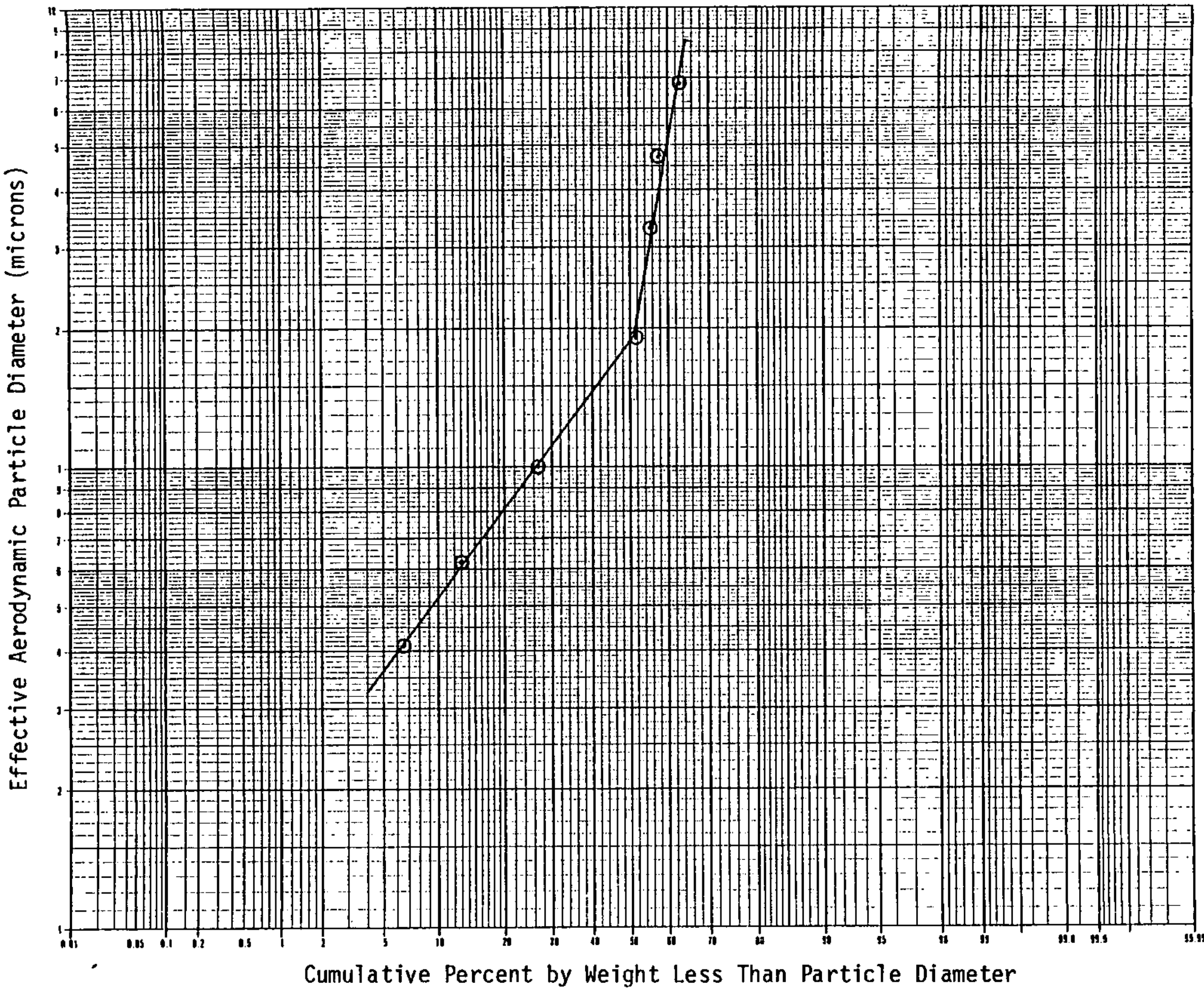

Figure C-3. Plant E. Particle size analysis for board end sawing - outlet of fabric filter

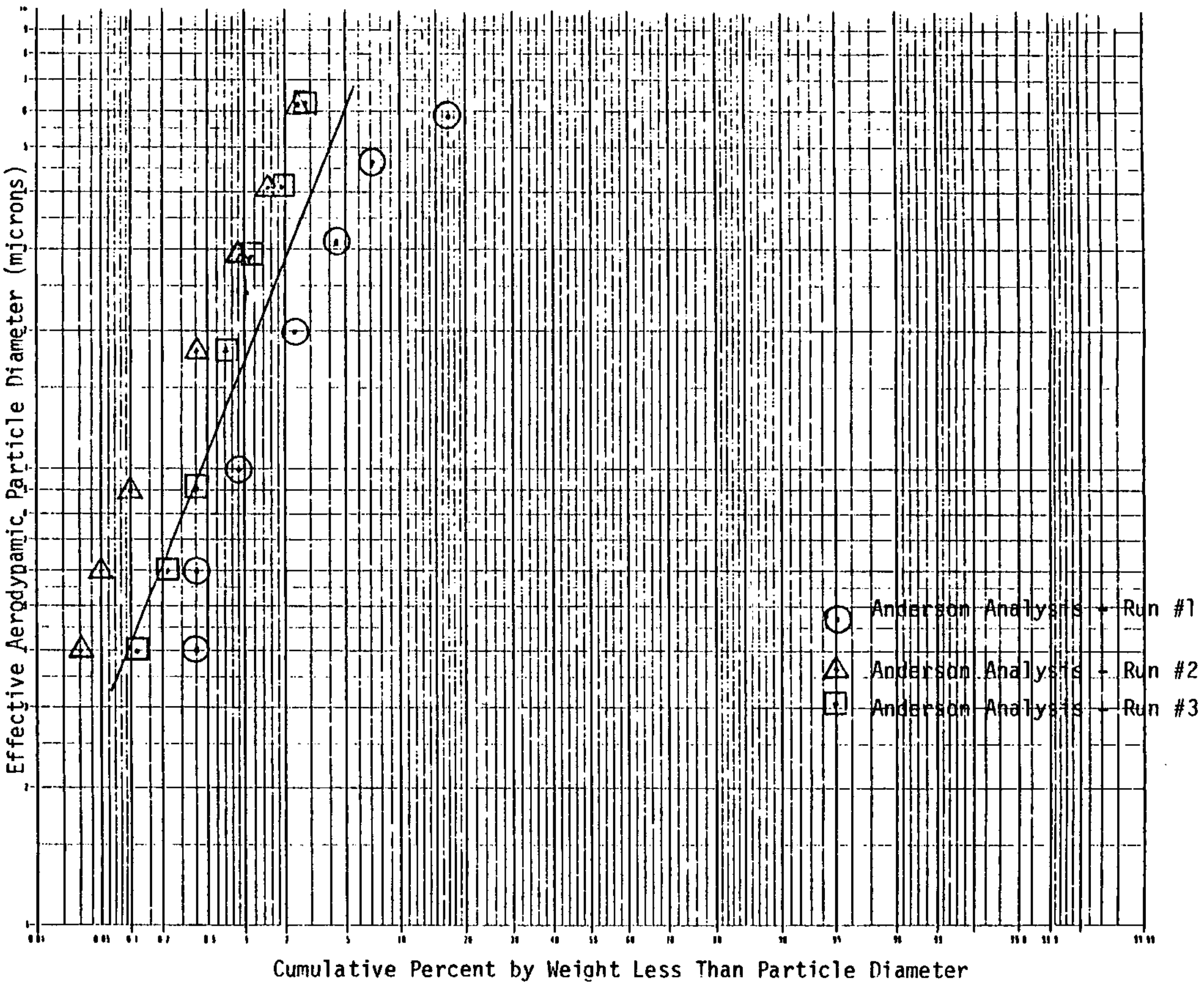

Figure C-4. Plant Y. Particle size analysis for ore dryer - inlet to fabric filter.

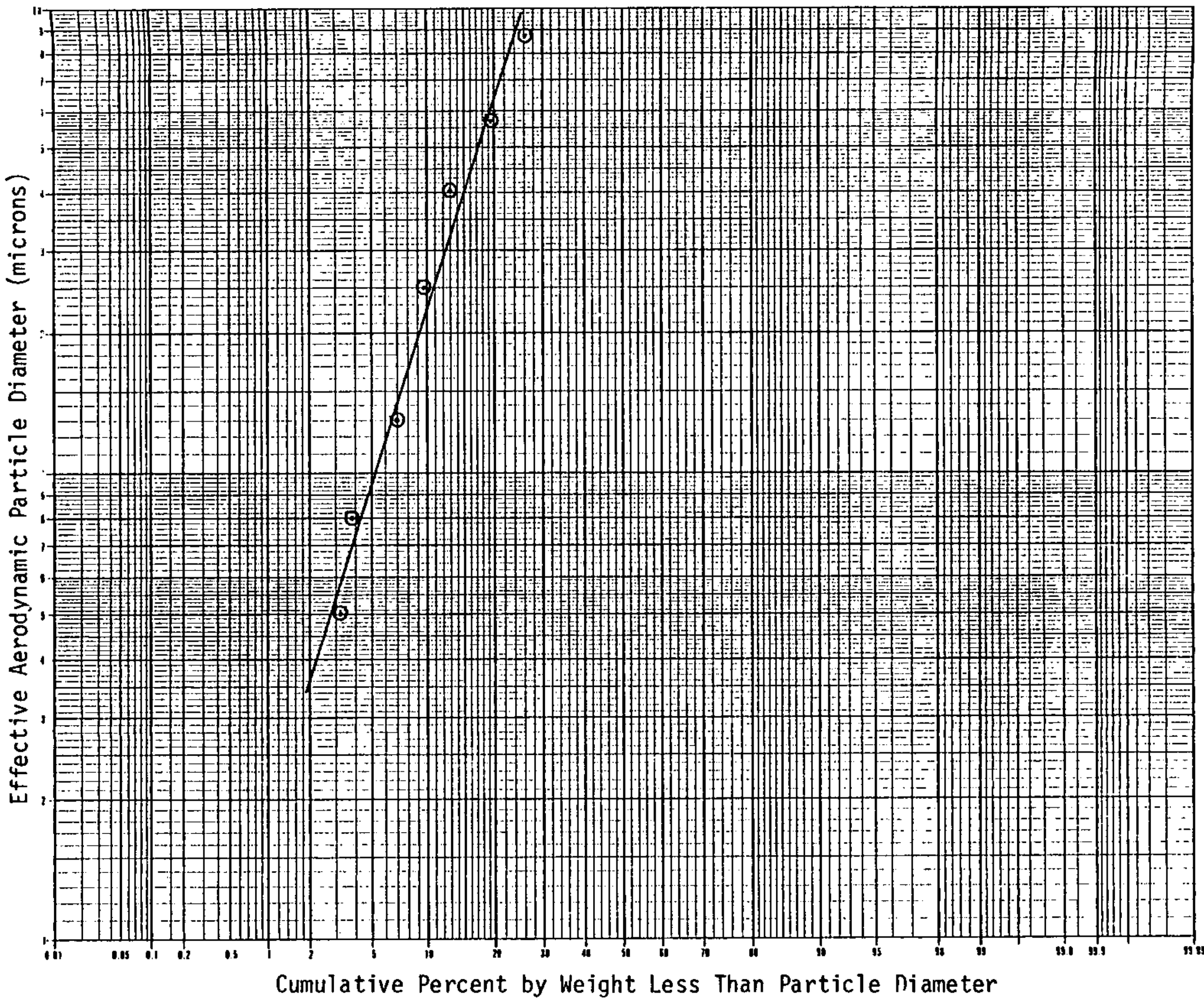

Figure C-5. Plant Y. Particle size analysis for ore dryer - outlet of fabric filter.

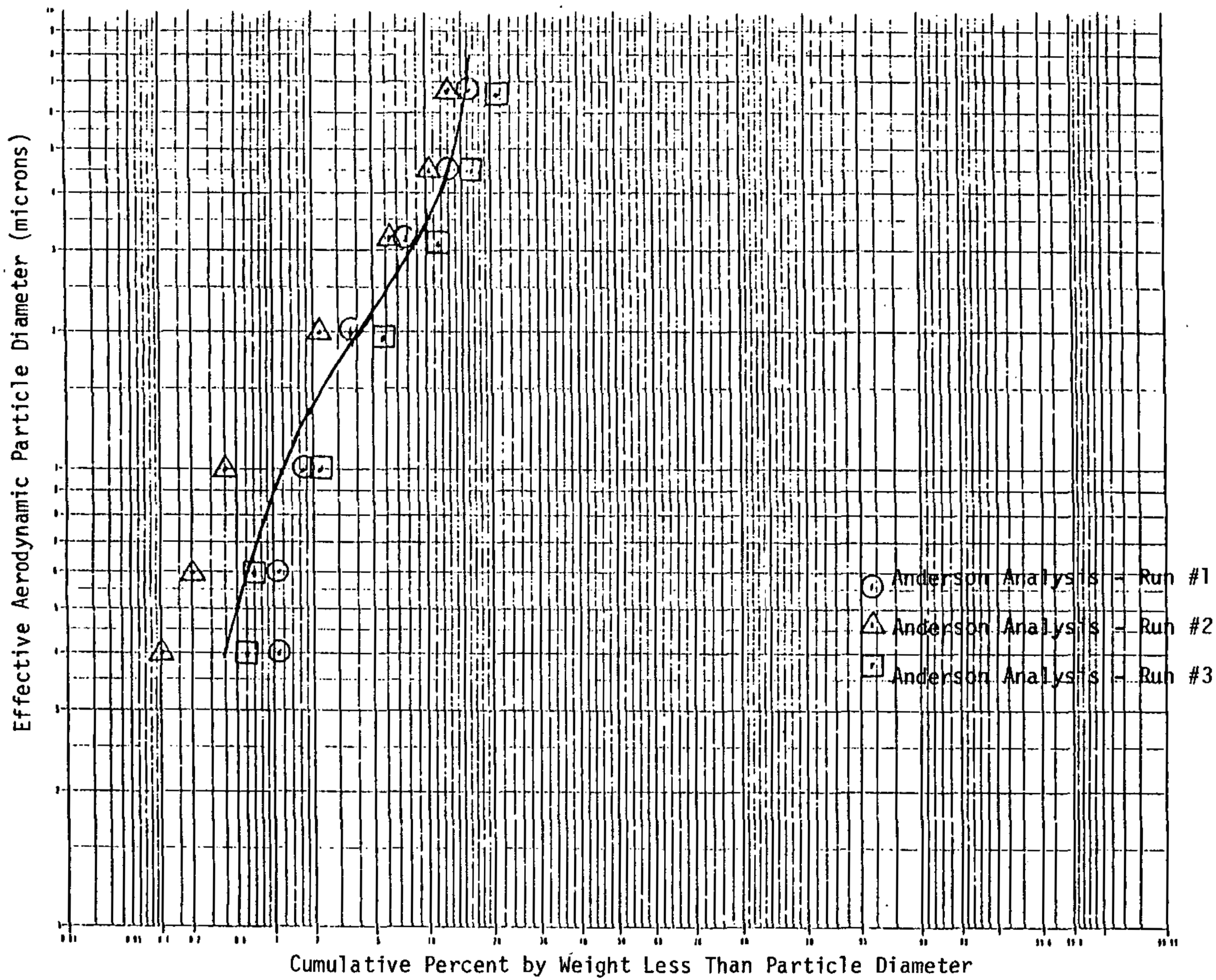

Figure C-6. Plant Y. Particle size analysis for direct contact flash calciner - inlet to fabric filter.

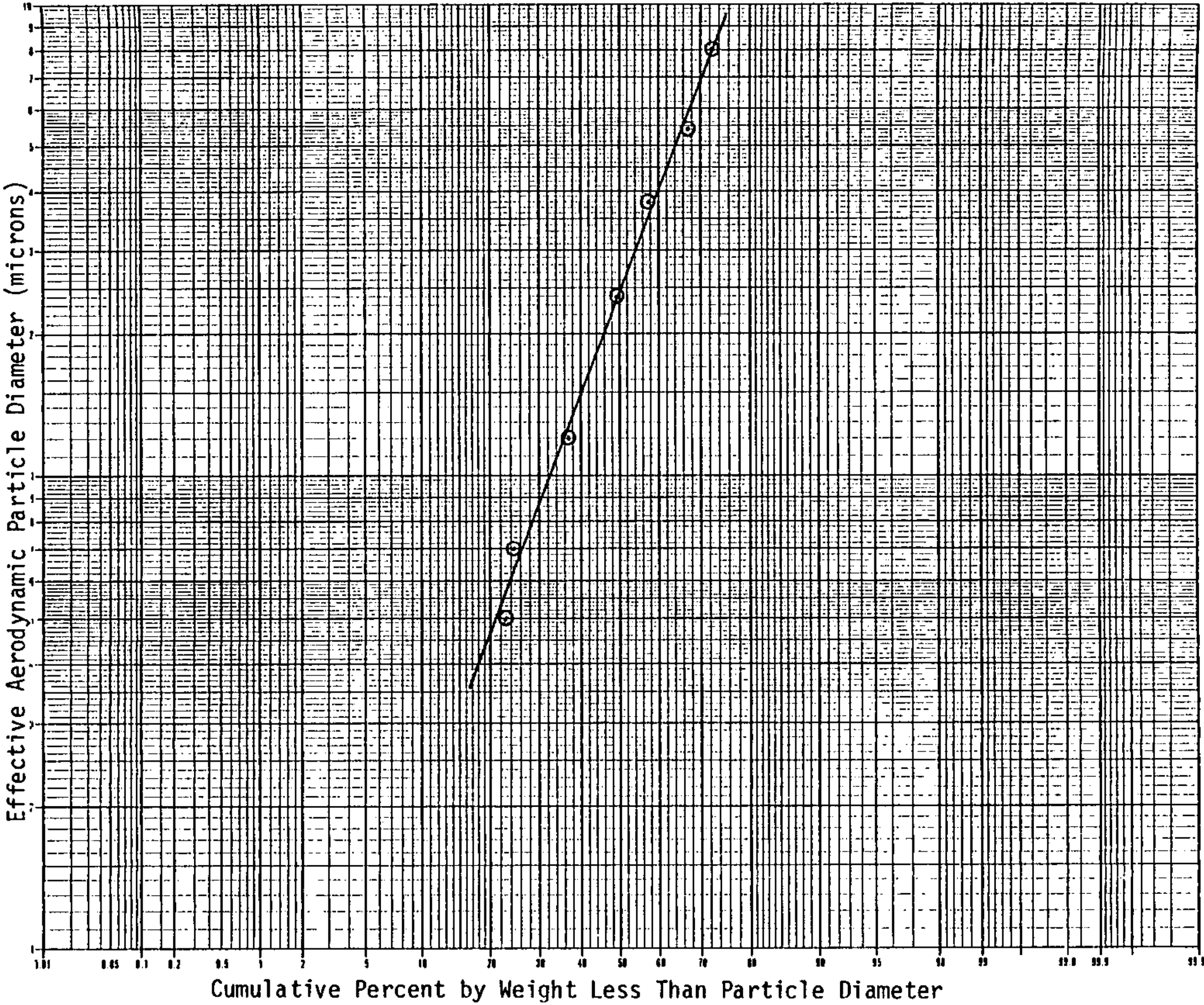

Figure C-7. Plant Y. Particle size analysis for direct contact flash calciner - outlet of fabric filter.

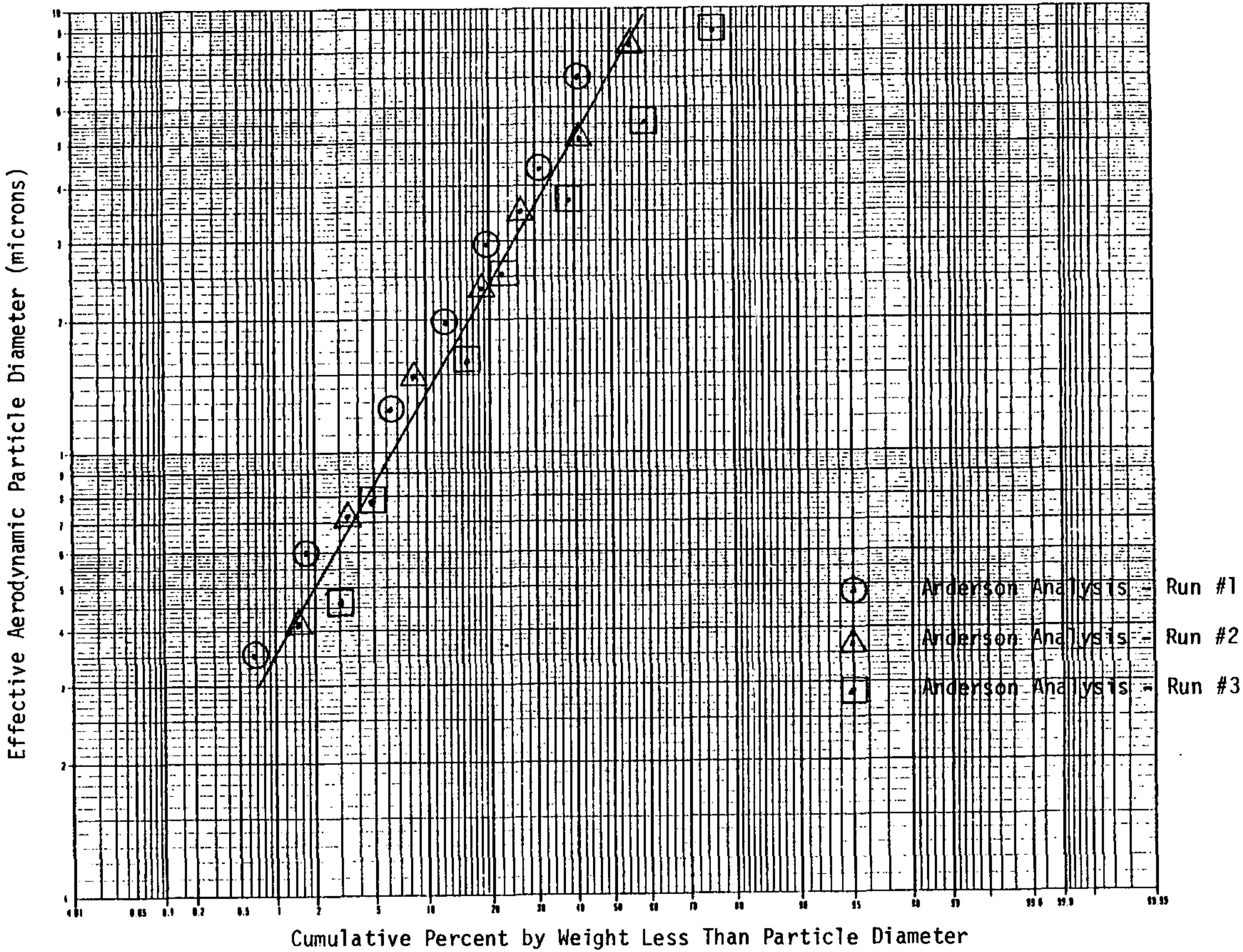

Figure C-8. Plant OO. Particle size analysis for direct contact flash calciner - inlet to fabric filter.

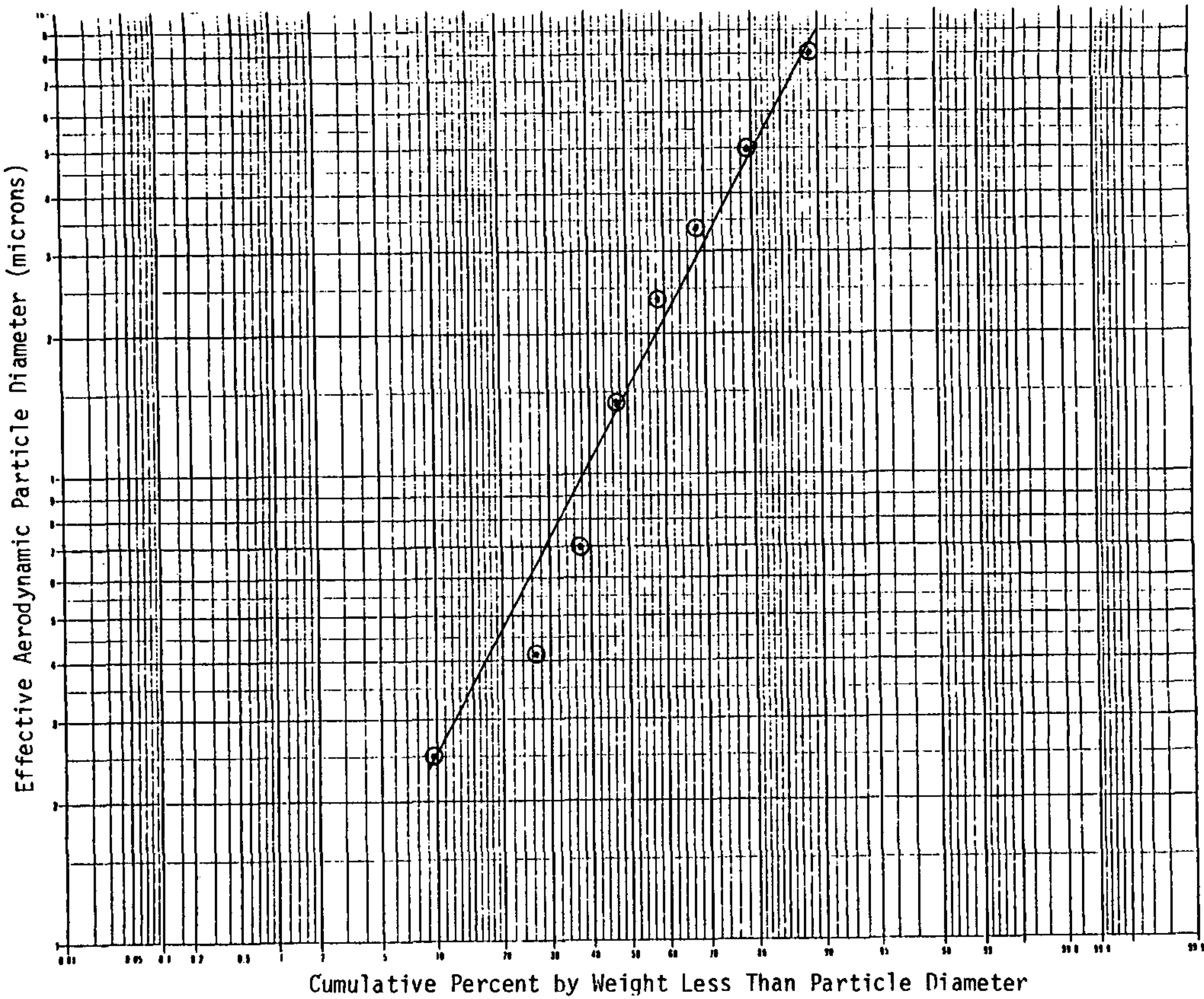

Figure C-9. Plant OO. Particle size analysis for direct contact flash calciner - outlet of fabric filter.

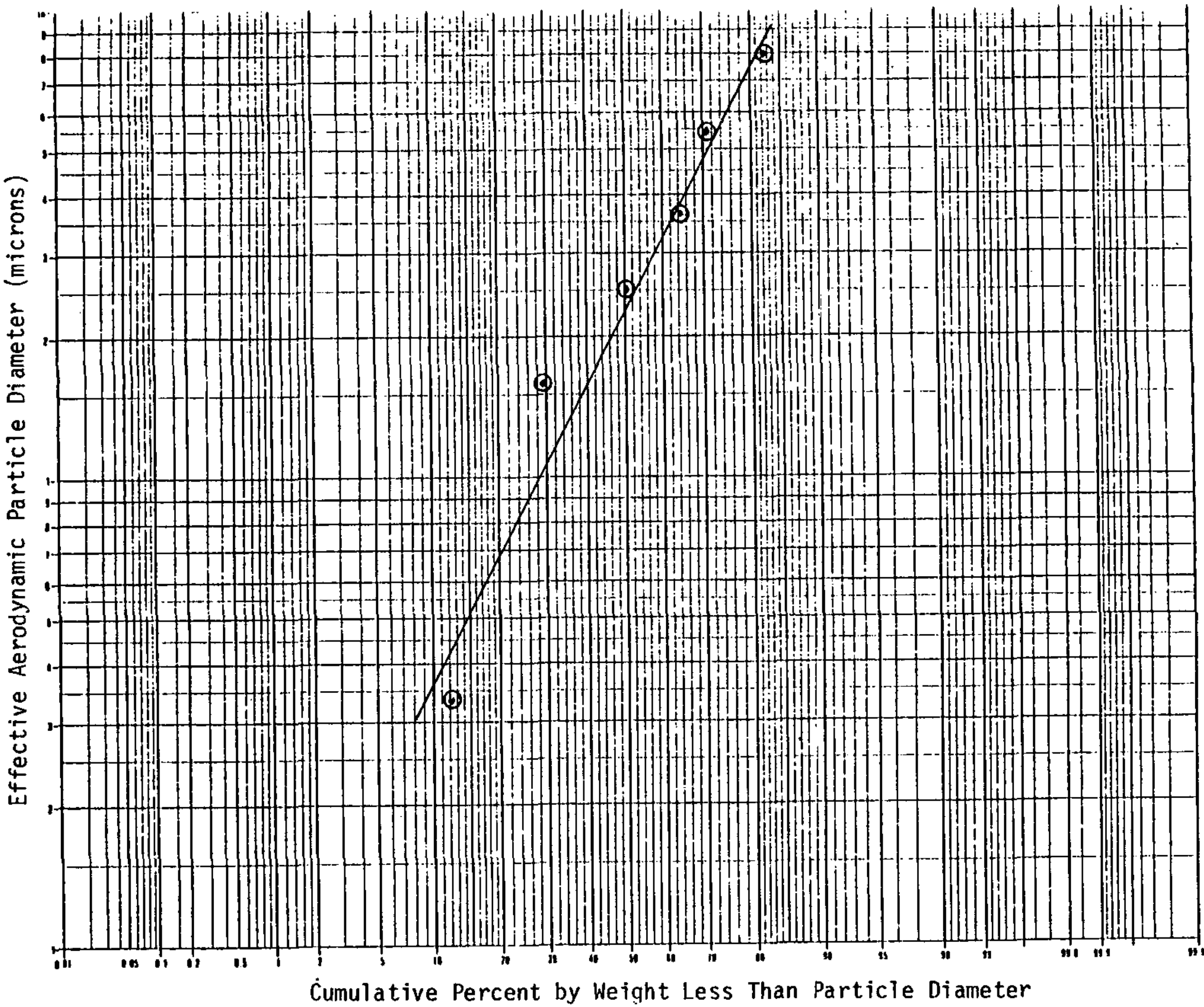

Figure C-10 Plant TT. Particle size analysis for board end sawing - outlet of fabric filter.