IN-DEPTH SURVEY REPORT:

CONTROL TECHNOLOGY FOR THE CERAMIC INDUSTRY

at

American Olean Tile Company
Jackson, Tennessee

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NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
Division of Physical Sciences and Engineering
Engineering Control Technology Branch
4676 Columbia Parkway
Cincinnati, Ohio 45226

PLANT SURVEYED:	American Olean Tile Company American Drive P.O. Drawer 2768 Jackson, Tennessee 38301
SIC CODE:	3253 - Ceramic Floor and Wall Tile
SURVEY DATE:	April 26-28, 1983
SURVEY CONDUCTED BY:	Frank W. Godbey William N. McKinnery Paul E. Caplan Thomas C. Cooper
EMPLOYER REPRESENTATIVES CONTACTED:	G. E. Fullerton, Jr., Plant Manager, (901) 424-1314 Tommie S. Franklin, Plant Engineer, (901) 424-1314 Ralph Williams, Supervisor, Grinding Plant, (901) 424-1314
EMPLOYEE REPRESENTATIVES CONTACTED:	William Evans, President, Aluminum, Brick, and Glass Workers' Union, Local 440
ANALYTICAL WORK PERFORMED BY:	Utah Biomedical Test Laboratory

I. INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency engaged in occupational safety and health research. Located in the Department of Health and Human Services (formerly DHEW), it was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with the methods for controlling occupational exposure to potential chemical and physical hazards. The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

Since 1976, ECTB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. Examples of these completed studies include the foundry industry; various chemical manufacturing or processing operations; spray painting; and the recirculation of exhaust air. The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concepts or techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

This study of the ceramics industry is being undertaken because there are approximately 100,000 employees potentially exposed to various chemical and physical agents. Other NIOSH studies have indicated that the handling of dry material, such as pesticides and silica flour, is an important source of airborne dust generation in the workplace. The latter, silica flour, study revealed that as much as one-half of the environmental silica dust problems may be effectively controlled by good work practices and effective housekeeping practices. The problem of dust dispersion during material handling spans many industries and can be a major source of chemical exposure. Although several industries may have devised successful methods of dust control, our literature review revealed that there is presently no centralized information base making the solutions universally available. The results of this study will help overcome this shortcoming.

Health hazard evaluations (HHE's) of ceramics industry workplaces have shown the importance of effective engineering controls. Three Health Hazard Evaluations attribute the existence of unhealthful conditions at the time of the surveys to inadequate ventilation. In all of these studies where high workroom-air contamination and adverse health effects were documented or suspected, inadequate ventilation was identified as a contributing factor. In addition to improved local exhaust ventilation, other control measures recommended in the reports include modified work practices, better worker education about occupational hazards, and the appropriate use of personal protective equipment. In total, these studies show a need for continuing activity in control technology development.

During the period July 1974 through June 1979, the Occupational Safety and Health Administration (OSHA) reported that 83% of the silica tests they conducted in the ceramics industry exceeded the permissible exposure level (PEL). Our preliminary surveys and contacts with industry personnel seem to indicate that there are now controls in place that prevent these excesses. This study will document the existence and usage of these controls.

NIOSH's major goal in undertaking this study is to identify and promote the use of cost effective health hazard control technology strategies in the ceramics industry. The primary focus will be on the control of airborne dust concentrations during the raw materials crushing and grinding operations. The control methods assessed will be documented in sufficient detail so that the information can be used in similar industrial situations.

The American Olean Tile Company, Jackson Plant, was selected for an in-depth study because a walk-through survey indicated the following:

1. The plant was performing extensive crushing and grinding of Newfoundland pyrophyllite.

2. The pyrophyllite, because of its source, is known to be contaminated with in excess of one percent (actual range 10-33%) crystalline silica (quartz).
3. Potentially effective controls were being used to prevent harmful exposure to employees.

The purpose of this study was to evaluate, document, and discuss the effectiveness of the health hazard control procedures being used by this plant during the crushing and grinding of the pyrophyllite. The specific objectives were:

1. To evaluate and document the effectiveness of the individual health hazard control technology methods in use: local exhaust ventilation, material transfer point enclosures, operation isolation, automation, vacuum cleaning system, enclosure of product handling equipment, environmental monitoring program, work practices, and general housekeeping.

2. To make general observations, draw conclusions, and discuss the results of the above evaluations and their documentation in such a way as to make the information useful to those who have similar needs.

II. PLANT AND PROCESS DESCRIPTION

A. PLANT DESCRIPTION

The American Olean Tile Company is a subsidiary of the National Gypsum Company. The Jackson Plant produces several million units of glazed floor and wall tile each year in a variety of shades and colors from ball clays, pyrophyllite, and flint. The company employs approximately 360 workers and operates two shifts a day, five days a week. The grinding plant employs three workers on each of the two shifts. Except for the grinding plant, all of the plant operations are under one roof, an area of approximately 400,000 square feet. This production building was built in 1963 on 55 acres of land. The grinding plant (the area being evaluated) was built in 1980 and is located approximately 350 feet from the production building. It is a sheet metal wall and concrete floor structure with open bays, metal trussed, and no basement. The building is separated by a floor-to-ceiling sheet metal wall into two main areas, the pyrophyllite storage area and the processing area. The storage area occupies approximately 25,000 square feet and consists of one working level. The processing area occupies approximately 10,000 square feet and consists of four platform working levels above the main floor.

B. PROCESS DESCRIPTION

Tennessee and Kentucky ball clays and West Virginia flint, ground to production specifications, are brought to the plant by truck and stored in the production building for use directly in the production process. Bulk pyrophyllite from Newfoundland is brought to the plant by ship and truck and stored in the grinding plant storage area. The process evaluated involves the preparation (crushing and grinding) of this pyrophyllite for production use. A air-conditioned, cab-enclosed frontend loader is used to move the bulk pyrophyllite from the in-plant storage pile to the coarse crushing circuit located in the corner of the storage area (Figure 1). The bulk pyrophyllite is dumped from the frontend loader into a grizzly hopper and feeder where it is gravity-fed into a 12-inch by 24-inch jaw crusher for coarse crushing. The coarse-crushed material flows by gravity

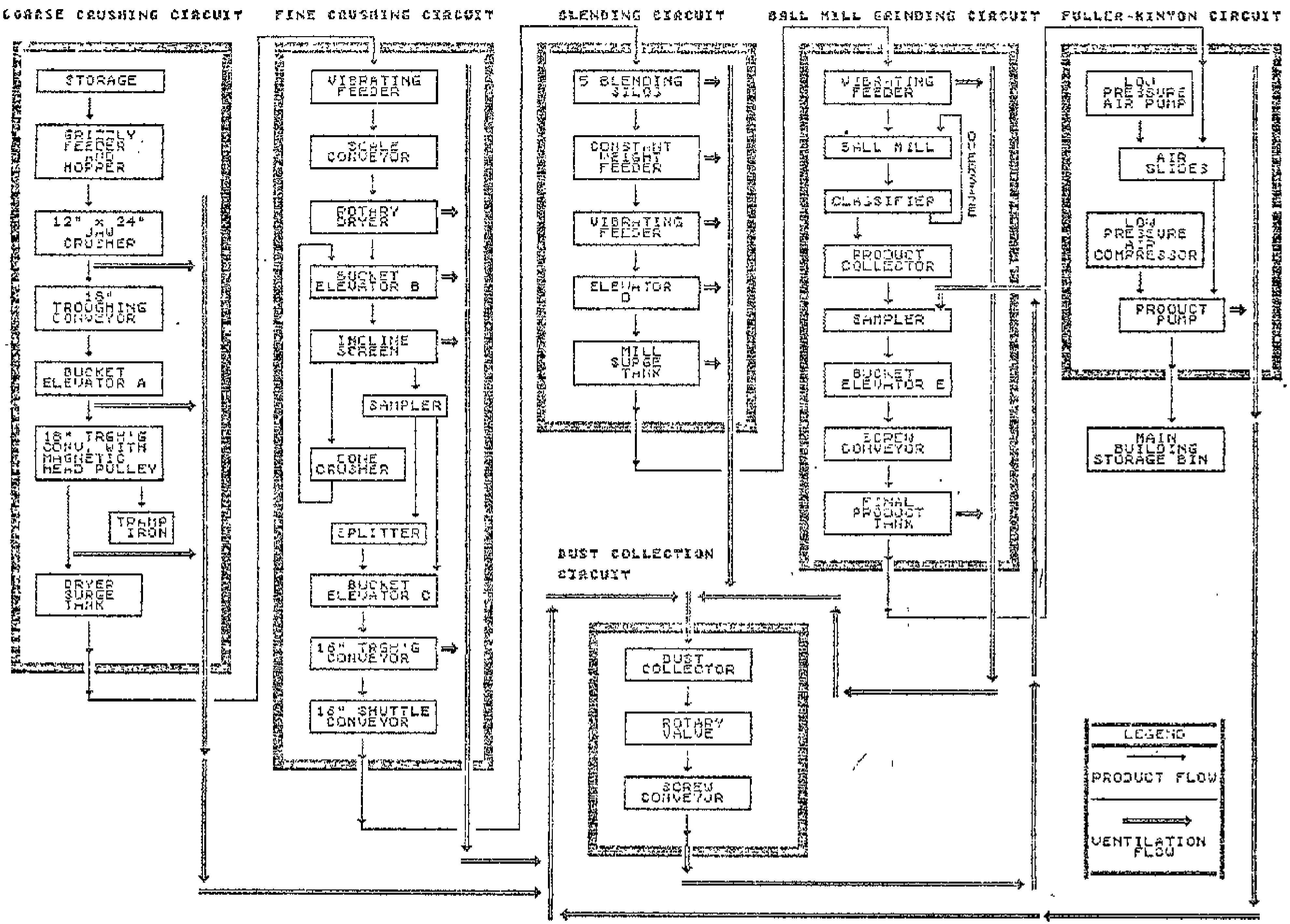


Figure 1. Process Flow

from the jaw crusher onto an 18-inch troughing conveyor where it is transported through an opening in the wall separating the storage area from the grinding plant to bucket elevator A. The material is elevated up to an 18-inch troughing conveyor, equipped with a magnet head pulley, where tramp iron is removed and discharged into a hopper, and the iron-free material is discharged into a drier surge tank. The material flows by gravity from the drier surge tank to a vibrating feeder where it is fed onto a scale conveyor for transport to a rotary drier. The dried material is discharged from the rotary drier to bucket elevator B where it is elevated up to an incline screen. The properly-sized material passes through the incline screen to bucket elevator C and the oversize material is discharged into a cone crusher for fine crushing. The fine-crushed material is discharged from the cone crusher to bucket elevator B for elevation up to the incline screen where the cycle is repeated. The finely-crushed material is elevated by bucket elevator C up to a 16-inch troughing conveyor for transport to a 16-inch shuttle conveyor. The shuttle conveyor transports the material for discharge into one of five blending silos in the blending circuit. The material is fed from the blending silos onto a constant weight feeder for blending before being discharged to bucket elevator D. The material is elevated by bucket elevator D up to a ball mill surge tank in the ball mill grinding circuit where it is fed by a vibrator feeder into the ball mill for fine grinding. The fine-ground material is discharged from the ball mill to a classifier where the properly-sized material passes to a product collector and the oversize material is returned to the ball mill for further grinding. The production-size pyrophyllite is transferred from the product collector to bucket elevator E where it is elevated to a screw conveyor for transport to a final product tank in the Fuller-Kinyon circuit. The final product is discharged from the final product tank by a low pressure air pump to air slides and by a high pressure air pump through a 6-inch pipe approximately 350 feet to the production building storage bin.

C. POTENTIAL HAZARDS

The only raw material involved in the crushing and grinding operation in this plant is pyrophyllite, a mineral resembling talc. Instead of being a magnesium silicate, it is an aluminum silicate, $H_2Al_2(SiO_3)_4$. This plants source of pyrophyllite is Newfoundland where the deposits are known to be contaminated with quartz, a crystalline form of silica.

Exposure to silica can produce silicosis, a debilitating respiratory disease, caused by inhalation of fine crystalline silica dust that is retained in the lungs. The amount of dust inhaled, the percentage of free or uncombined silica in the dust, the size of the dust particles, and the length of exposure all affect the onset and severity of silicosis. The inhaled dust deposited in the bronchioles and alveoli reacts within the lung tissue to form silicotic nodules.

The OSHA standard, or Permissible Exposure Limit (PEL), for respirable crystalline silica (quartz) is determined by the equation:

$$\text{PEL} = \frac{10}{\%\ \text{silica} + 2} \text{ milligrams per cubic meter of air } (\text{mg/m}^3)$$

For 100% silica dust (respirable), this calculated PEL is approximately equivalent to 0.1 mg/m^3 or 100 ug/m^3. Although the PEL pertains specifically to the 8-hour time-weighted average (TWA) exposure to employees, in this research, it is used as an environmental criterion to evaluate the effectiveness of the control technology used to control dust emissions from approximately 13 material transfer points. The hazards associated with pyrophyllite preparation are summarized in Table 1.

Table 1. Summary of Hazards Associated with Pyrophyllite Preparation (Crushing and Grinding)

Materials or Agents	PEL[1] mg/m^3	TLV[2] mg/m^3	NIOSH[3] Recommended Level mg/m^3	Major[3] Health Effects
Crystalline Silica (Respirable)	$\frac{10\ mg/m^3}{\%\ SiO_2 + 2}$	$\frac{10\ mg/m^3}{\%\ SiO_2 + 2}$	0.05	Silicosis
Total Particulates (Respirable)	15	10	NA	Pneumoconiosis

[1] Permissible Exposure Limit; this is the legally enforceable standard.

[2] Threshold Limit Value; this is a voluntary level recommended by the American Conference of Governmental Industrial Hygienists.

[3] Criteria Document - Occupational Exposure to Crystalline Silica.

III. METHODOLOGY

A. LIST OF EQUIPMENT

Air movement and airborne respirable free silica and total dust concentrations were measured to evaluate the effectiveness of the controls. The major pieces of equipment used in the study are listed in Table 2.

Table 2. Equipment Items Used in the Study

Item	Model	Used For
DuPont Gravimetric Dust Sampler with Cyclone	P2500	Respirable Dust Sampling
High Volume Dust Sampler with Cyclone		Bulk Respirable Dust Sampling
Alnor Velometer	Jr.	Hood Air Velocity
Alnor Velometer	Sr.	Hood Air Velocity
TSI Air Velocity Meter	1650	Duct Air Velocity
Kurz Air Velocity Meter		Duct Air Velocity
TSI Respirable Dust Monitor		Bulk Respirable Dust Measurement
Gastec Smoke Tubes		Air Flow Patterns

B. MEASUREMENT OF CONTROL PARAMETERS

1. Ventilation Control Measurements

Ventilation and airflow pattern measurements were made to evaluate the effectiveness of local exhaust ventilation systems.

a. Velocity measurements were made of 13 local exhaust hoods with a TSI Air Velocity Meter, Model 1650. This instrument had been calibrated previously at the NIOSH Industrial Hygiene Laboratory Wind Tunnel.

b. The air flow through 5 exhaust ducts was measured by traversing across the diameter of these ducts with the TSI Air Velocity Meter. Readings were verified at one location with a standard Pitot static tube and a calibrated Dwyer 2-inch magnehelic gauge.

c. Airflow patterns around dust capture hoods were evaluated with Gastec Smoke Tester Tubes.

2. The effectiveness of other dust control procedures was also evaluated. These included: vacuum cleaning systems, enclosure of product handling equipment, environmental monitoring programs, work practices, and general housekeeping.

C. SAMPLING PROCEDURES

Personal and area air samples were collected for respirable crystalline silica and total dust for the duration of the workshift on three consecutive days. Breathing zone samples for crystalline silica were collected on the two day-shift production workers. These workers were in the grinding plant except for occasional short breaks in the office area. All breathing zone samples were clipped to the collar, on the front side of the work shirt. This placed them in the breathing zone, only a few inches below the face, in a manner so as not to interfere with the workers activities. Area samples were placed at fixed locations throughout the grinding plant. Thirteen of the area samples were positioned immediately above material transfer points that were equipped with local exhaust ventilation hoods. The remainder (15) were positioned at strategic background locations at various working levels throughout the grinding plant.

Personal and area samples for respirable crystalline silica and total dust were collected using closed-face, two-piece cassettes with preweighed 37 mm polyvinyl chloride membrane filters of five micron pore size. Air was pulled through the filter at a flow rate of 1.7 liters of air per minute using DuPont, P2500, gravimetric air samplers preceded by a 10 mm nylon cyclone. Bulk air samples were collected for the duration of the workshift on three consecutive days. These were collected using closed-face, three-piece cassettes with preweighed 37 mm polyvinyl chloride membrane filters of five micron pore size. Air was pulled through the filter at a flow rate of 9 liters of air per minute using a hi-vol pump preceded by a 0.5-inch HASL cyclone. In addition, bulk rafter dust samples, a bulk raw material sample, and a bulk finished product sample were collected.

All samples were analyzed by the Utah Biomedical Test Laboratory. Crystalline silica samples were analyzed using NIOSH Method P&CAM 259 with the following modifications: 1) filters were dissolved in tetrahydrofuran rather than being ashed in a furnace, and 2) standards and samples were run concurrently and an external calibration curve was prepared from the integrated intensities rather than using the suggested normalization procedure. The total dust samples were determined by weighing the samples plus the filters on an electrobalance and subtracting the previously determined tare weights of the filters. Bulk material samples were analyzed for quartz and cristobalite using X-ray diffraction. Samples were passed through a ten micron precision sieve to obtain respirable dust for analysis. Two milligram portions of each sample were weighed onto FWSB filters in duplicate. NIOSH Method P&CAM 259 (modified), as previously described, was used to analyze the samples.

IV. CONTROL TECHNOLOGY

INTRODUCTION - PRINCIPLES OF CONTROL

Occupational exposures can be controlled by the application of a number of well-known principles, including engineering measures, work practices, personal protection, and monitoring. These principles may be applied at or near the hazard source, to the general workplace environment, or at the point of occupational exposure to individuals. Controls applied at the source of the hazard, including engineering measures (material substitution, process/equipment modification, isolation or automation, local ventilation) and work practices, are generally the preferred and most effective means of control both in terms of occupational and environmental concerns. Controls which may be applied to hazards that have escaped into the workplace environment include dilution ventilation, dust suppression, and housekeeping. Control measures may also be applied near individual workers, including the use of remote control rooms, isolation booths, supplied-air cabs, work practices, and personal protective equipment.

In general, a system comprised of the above control measures is required to provide worker protection under normal operating conditions as well as under conditions of process upset, failure and/or maintenance. Process and workplace monitoring devices, personal exposure monitoring, and medical monitoring are important mechanisms for providing feedback concerning effectiveness of the controls in use. Ongoing monitoring and maintenance of controls to ensure proper use and operating conditions, and the education and commitment of both workers and management to occupational health are also important ingredients of a complete, effective, and durable control system.

These principles of control apply to all situations, but their optimum application varies from case-to-case. The application of these principles at the crushing and grinding operation in this plant is discussed below.

The entire material particle size reduction process is completely automated from the time the pyrophyllite is dumped into the grizzly feeder until it is received in the main building storage bin. The grinding plant and pyrophyllite storage building are isolated from the main production building by about 350 feet and uses only two workers to perform the entire operation. The bulk storage area is separated from the grinding plant by a floor-to-ceiling wall with the exception of a small opening in one corner through which the coarse-crushed material passes. All material conveying systems are either trough or enclosed design to minimize potential dust emission. All 13 open material transfer points are equipped with local exhaust ventilation hoods. Makeup air is provided by louvered openings which open automatically when necessary. Housekeeping is maintained by the use of a central vacuum cleaning system. The pyrophyllite raw material is introduced into the crushing and grinding process by the use of an air-conditioned, cab-enclosed frontend loader. The company's industrial hygienist periodically monitors the dust levels in the grinding plant.

A. 1. Description of Process

The process evaluated involves all of the operations performed in the preparation of pyrophyllite for production use as described in Section II B and shown in Figure 1.

2. Description of Controls

At this plant, a combination of most of the above mentioned technologies is used to maintain dust exposures at a safe level, they include: containment of dust sources by enclosure and ventilation of potential dust sources; use of good work practices including housekeeping and maintenance of equipment and facilities; isolation of workers from dust sources (including control booth and enclosed, air-supplied cabs in vehicles), use of personal protective equipment; and medical and environmental monitoring programs. These systems will be described in the following sections. Qualitative and quantitative evaluation of these systems will be presented later in the report, in Section IV A-3.

a. Ventilation Control Systems (Figure 2)

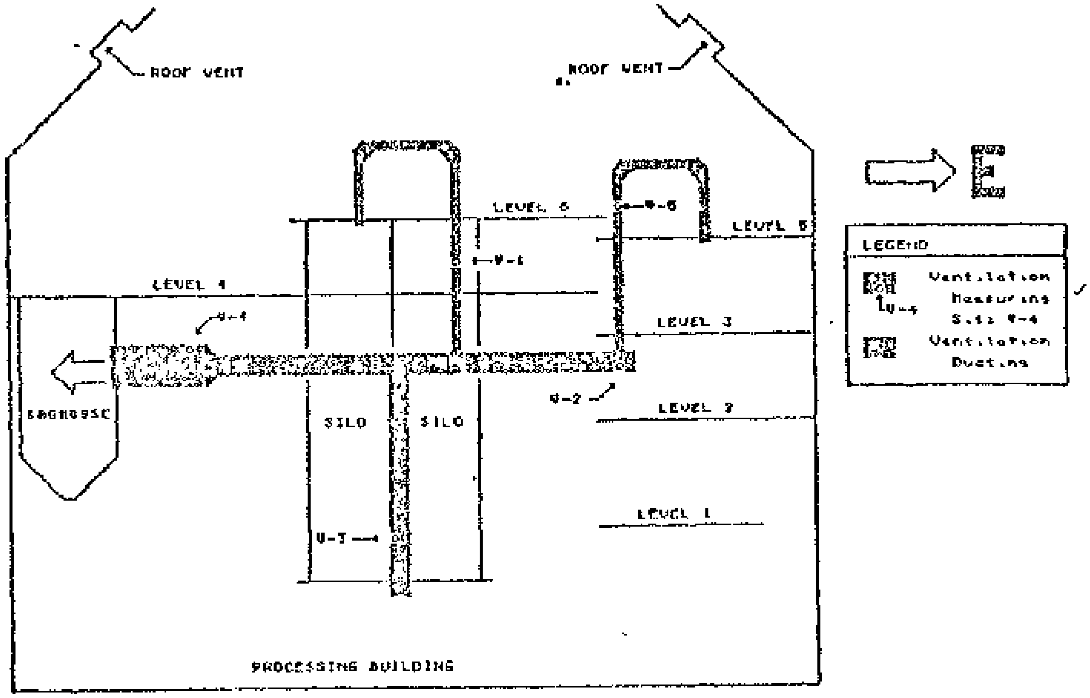
Local exhaust ventilation systems are used to capture and contain possible point sources of emitted dust such as conveyor/conveyor or conveyor/elevator transfer points. All material conveying systems are either of a trough or enclosed design to minimize dust emission. Thirteen (13) open material transfer points are provided with local exhaust ventilated hoods, as shown in Table 3A. In addition, exhaust ducts are connected to three (3) enclosed transfer points (Table 3B) and to three (3) enclosed processes (Table 3C) to prevent dust dispersion to the general work atmosphere.

Airborne dust, from these operational control points, is transported via ventilation ducts to a baghouse system, where the dust is separated from the airstream and returned to a main product storage bin. This baghouse system contains 120 12-foot polyester felt collecting tubes and is designed to operate at 15,000 CFM. Five of the major ducts, representative of the total duct system, were also evaluated for airflow and are listed in Table 3D.

Additional general room ventilation is provided to the Process Building (PB) by 6 roof fans. They are designed to move 40,000 CFM per fan or a total of 240,000 CFM (6 air changes per hour) in the Process Building.

b. Work Practices

Housekeeping, or clean up of spilled product, is accomplished by the use of a large, permanently mounted central air vacuum system. This unit is a centifuge exhauster and has 48" long legs, which attach to 40 1-1/2" inlet valves, strategically located throughout the plant. It was installed in December 1980. Operators and helpers are trained in the correct methods for cleaning up spills and dust accumulation as rapidly as possible.



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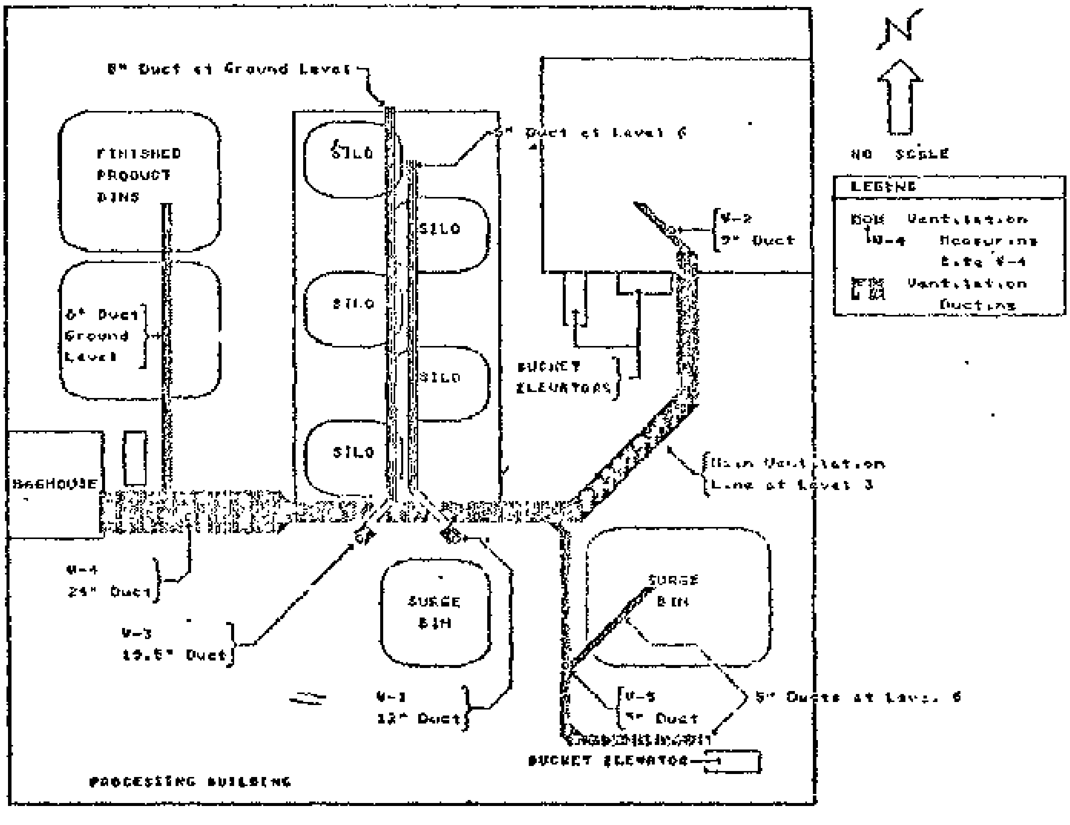


Overhead View

Figure 2. Ventilation System

Table 3. Ventilation Control System

	Operation/Location/Description	Floor Level(s)	Type Hood/Remarks
	A. LOCAL EXHAUST VENTILATION HOODS ON OPEN TRANSFER POINTS		
H-1	Jaw Crusher, open transfer from conveyor to elevator, RMSB	Sub Level	Lateral hood enclosure
H-2	CWF #1 feeder, PB	Ground	Lateral hood enclosure
H-3	CWF #2 feeder, PB	Ground	Lateral hood enclosure
H-4	CWF #3 feeder, PB	Ground	Lateral hood enclosure
H-5	CWF #4 feeder, PB	Ground	Lateral hood enclosure
H-6	CWF #5 feeder, PB	Ground	Lateral hood enclosure
H-7	Bucket elevator A, open transfer, elevator to conveyor	5	Lateral hood enclosure
H-8	Drier Surge Tank, transfer conveyor to surge bin entry	5	Lateral hood enclosure
H-9	Vibrating feeder, transfer to drier feeder	2	Lateral hood enclosure
H-10	Ball mill, surge tank discharge to vibrator feeder	1	Lateral hood enclosure
H-11	Troughing conveyor #3, transfer from Elevator C discharge	6	Lateral hood enclosure
H-12	Transfer to blending silo conveyor	6	Lateral hood enclosure
H-13	Shuttle conveyor to 5 silos	6	Lateral hood enclosure
	B. ENCLOSED TRANSFER POINTS		
14	Cone Crusher, bucket elevator B to crusher	2	Totally enclosed hood
15	Inclined screen, transfer to cone crusher	3	Totally enclosed hood
16	Inclined Screen, transfer to screen	4	Totally enclosed hood

Table 3. Ventilation Control System (Cont'd)

Operation/Location/Description	Floor Level(s)	Type Hood/Remarks
C. EXHAUST LINES TO EQUIPMENT		
17 Mill surge tank	4	Exhaust line to tank
18 Drier surge bin	5	Exhaust line to bin
19 Final product tank	Ground	Exhaust line to tank
D. MAJOR VENTILATION TRANSPORT DUCTS		
D-1 12"-Vertical, provides ventilation from all hoods above, Center of PB	6 to 2	Downward flow
D-2 9"-Horizontal, removes air from screen, NE corner PB	2	Horizontal flow
D-3 19.5" Vertical riser, removes air from 5 hoods on oscillator belt	1 to 2	Upward flow
D-4 24" Main duct to bag house, SW corner of PB	2	Horizontal flow
D-5 7" Vertical riser, removes air from Elevator B	5 to 6	Upward flow

c. Personal Protective Equipment

Head protection is required in the Process Building (PB) and the Raw Material Storage Building (RMSB). Other personal protective equipment, such as approved respirators, is provided on an "as needed" basis.

d. Environmental Monitoring

The division industrial hygienist conducts annual atmospheric dust sampling in the RMSB and the PB. The results of these analytical studies indicate good control of dust emissions.

e. Isolation of Dusty Areas

The bulk storage area (RSMB) is separated from the grinding plant (PB) by a floor-to-ceiling wall, with the exception of a small opening in one corner through which the damp, coarse, crushed material passes. The operator in the RSMB performs most of his duties in an enclosed, ventilated, front-end loader, which is used to move the bulk pyrophyllite from the in-plant storage pile to the coarse crushing circuit.

In the Processing Building (PB), the operator spends most of his work day in a ventilated control room (office). Thus, his exposure to dust is also minimized.

3. Discussion of Sampling Results and Control Effectiveness

In this discussion, we will discuss the effectiveness and the efficiency of the overall dust control systems and of the specific components of that system. In this report, "control effectiveness" may be defined as "the capability of the control systems to maintain exposures at or below a specific standard or design exposure level." Thus, it is a function both of the control system and of the hazard potential of the material being controlled. For example, a specific control system may be "effective" in controlling one type of dust (e.g. a low silica containing dust); but it may be "not effective" in controlling a second type of dust (e.g. a high silica dust or a toxic pesticide dust).

On the other hand, "control efficiency" of a system or component, may be defined as the fraction of the potentially emitted dust, which is removed from the environment by the control component. Our evaluations of efficiency, usually must be indirect and only approximate, since it is not feasible to measure the total amount of potential emission source, without major disruption of the control system. Thus, a control system may be highly efficient in controlling a dust source (i.e. 95% efficient); yet it may be, at the same time, "ineffective," if the 5% emission results in an environmental exposure above the PEL. Conversely, a system may be of low control efficiency (50-80%); yet, it could be "effective" if the dust is non-toxic or the potential emission rate is of a low magnitude.

a. Local Exhaust Hood Systems

The effectiveness of the hoods associated with the 13 open transfer points is a function of several characteristics of the hoods and the dust being controlled. These characteristics include:

1) The physical characteristics and rate of the material being transported through the system component (e.g. damp/dry, coarse/fine, high/low density, high/low transport rate, etc.).

2) The hazard rating of the material (high or low crystalline silica content).

3) The dimensions and degree of enclosure of the local exhaust hood.

4) The air velocity flow patterns; the average rate of airflow at the face of the hood; and its relationship to the point(s) of dust generation.

5) The "on-time" of the operation (duty cycle), which is creating the potential dust source, during the air sampling period. ✓

6) The respirable dust concentration of the air directly adjacent to the local exhaust hood.

7) The respirable dust concentration of the air in the general vicinity of the operation (background dust level).

Quantitative and qualitative evaluations were made of each of these parameters, and are shown in Table 4. Some of the values were directly measured or observed, such as hood face velocities (column(4)) and physical dimensions of the hood (column (3)); duty cycle (column (5)); dust concentrations at the hood and background (columns (6 and 7)) (see Figures 3, 4, 5, and 6) and silica content of the dust (column (2)).

Other values were derived from these direct measurements. The Permissible Exposure Limit (PEL) (column (9)) of the respirable dust was calculated from its silica content (column (2)) according to the formula:

$$\text{PEL} = \frac{10}{\%\ \text{Silica} + 2} \qquad \text{mg/m}^3.$$

The dust emitted from a potential source (column (8)) was estimated to be the difference between the dust level at the source (column (6)) and the dust level of the background atmosphere (column (7)). The effectiveness of the dust control system at each potential dust source (fraction of PEL (column

Table 4. Evaluation of local exhaust hoods.

Hood No.	Location/Operation (type of dust) (1)	Description of Hood (3)	Hood Velocity (4)	Silica Content of Dust (2)	PEL No. (9)	Run No.	Operating Time (5)	Resp'rable Dust Levels			Fraction of PEL (10)
								at hood (6)	back-ground (7)	(6)-(7) (8)	
H-1	Jaw crusher, sub-floor level, RMSR, transfer from belt to elevator hood S-1, background S-21 (damp, raw material	Lateral exhaust hood, 24" x 7", at transfer point	FPM	%	mg/m^3		hr.	mg/m^3	mg/m^3	mg/m^3	(6) ÷ (9)
			30			1	3.0	.86	.20	.66	1.72
			to			2	3.3	.28	.05	.23	.56
			420			3	5.0	.99	.08	.91	1.98
			Av.365	18	.50	Av.	3.8	.71	.11	.60	1.42
H-2	CWF #1 hood, ground level, center of PB, Hood S-2, background S-25, 26 (dry product)	Lateral exhaust hood, variable openings 24" x 7"	70			1	3.5	.43	.31	.12	.64
			to			2	4.0	.33	.05	.28	.49
			300			3	0	.10	(.11)	0	.15
			Av.154	13	.67	Av.	2.5	.29	.16	.13	.43
H-3	CWF #2 hood adjacent to CWF #1. Hood S-3 background S-25, 26 (dry product)	Same as CWF #1 hood	10			1	3.5	1.95	.31	1.64	2.91
			to			2	1.0	.16	.05	.11	.24
			240			3	0	.09	(.11)	0	.13
			Av.100	13	.67	Av.	1.5	.73	.16	.57	1.09
H-4	CWF #3 hood adjacent to CWF #2. Hood S-4 background S-25, 26 (dry product)	Same as CWF #1 hood	25			1	0	.50	.31	.19	.75
			to			2	0	.15	.05	.10	.22
			280	13	.67	3	0	.08	(.11)	0	.12
			Av.134			Av.	0	.24	.16	.10	.36
H-5	CWF #4 hood adjacent to CWF #3. Hood S-5 background S-26 (dry product)	"	15			1	0	.36	.15	.21	.54
			to			2	0	.11	.05	.06	.16
			280			3	0	.05	(.11)	0	.07
			Av.125	13	.67	Av.	0	.17	.10	.07	.25
H-6	CWF #5 hood adjacent to CWF #4. Hood S-6 background S-26 (dry product)	"	20			1	0	.21	.15	.06	.31
			to			2	0	.09	.05	.04	.13
			300			3	0	.16	.11	.05	.24
			Av.143	13	.67	Av.	0	.15	.10	.05	.22
H-7	Elevator A, transfer point, SE Corner PB level 5, Hood S-7 background S-19 (damp product)	12" x 4" Canopy hood with rubber skirt 80%	250			1	3.5	.13	(.27)	0	.22
			to			2	3.3	.15	.03	.12	.25
			400			3	5.0	.41	.17	.24	.69
			Av.330	15	.59	Av.	4.0	.23	.16	.12	.39
H-8	Elevator B, transfer point to drier surge bin, entry port, SE cover PB, level 5. background S-19 (damp product)	21 " X 22" side draft hood	90			1	3.5	.09	(.27)	0	.15
			to			2	3.3	.12	.03	.09	.20
			100			3	5.0	.23	.17	.06	.39
			Av. 97	15	.59	Av.	4.0	.15	.16	.05	.25

Table 4. Evaluation of local exhaust hoods. (Cont'd)

Hood No.	Location/Operation (type of dust) (1)	Description of Hood (3)	Hood Velocity (4)	Silica Content of Dust (2)	PEL No. (9)	Run No.	Operating Time (5)	Respirable Dust Levels			Fraction of PEL (10)
								at hood (6)	back-ground (7)	(6)-(7) (8)	
H-9	Drier surge bin, weigh scale, discharge port transfer point, SE corner, level 2 PB Hood S-9, background S-22 (damp product)	36.5" X 22" lateral hood	40			1	8.0	.37	.02	.35	52
			to			2	8.0	.09	.03	.06	.13
			100			3	0	.16	.05	.11	.23
			Av. 70	12	.71	Av	5.3	.21	.03	.18	.30
H-10	Hood before full mill surge tank discharge point, SE cover PB level 1 Hood S-10 background S-24 (dry product)	1/2" X 24' slot 2 openings 6" X 7"	650			1	8.0	.18	.18	0	25
			to			2	8.0	.09	.00	.09	.13
			850			3	0	.09	(.15)	0	.13
			Av.700	12	.71	Av	5 3	.12	.11	03	.17
H-11	Elevator C, discharge port transfer point, east side of belt, N central part PB, level 6. Hood S-11 background S-17 (dry product)	12" X 6" lateral hood, with rubber curtains	280			1	8.0	.24	24	0	.38
			to			2	0	.07	(.13)	0	.11
			410			3	0	.52	.13	.39	.83
			Av.310	14	.63	Av	2.7	.28	.17	.11	.44
H-12	Elevator C, transfer point to shuttle conveyor, west side of belt, Center of PB level 6 Hood S-12 background S-17 (dry product)	2-11' X 3' side slots; 10" X 17" side slot, 12" X 6" side hood	230			1	8.0	.35	.24	11	.52
			55			2	0	.14	.13	.01	.21
			110			3	0	10	(.13)	0	15
			to 450								
			Av.230	13	.67	Av	2.7	.20	.17	.03	.30
H-13	Shuttle conveyor discharge to blending silos, center of PB level 6. Hood S-13 background S-17 (dry product)	-	-			1	8.0	1.10	24	.86	1 64
						2	0	.26	.13	.13	.39
						3	0	.08	(.13)	0	12
				13	.67	Av	2 7	48	.17	.31	.72
P-1	8 hrs in process area	-	-			1	8.0	0			0
						2	8.0	.05			.07
						3	8.0	10			.10
				12	.71	Av	8.0	.05			.07
P-2	2 hrs in RMSB 6 hrs in PB					1	8 0	.32			.50
						2	8.0	23			.40
						3	8.0	.17			.30
				14	.63	Av	8.0	.24			.40

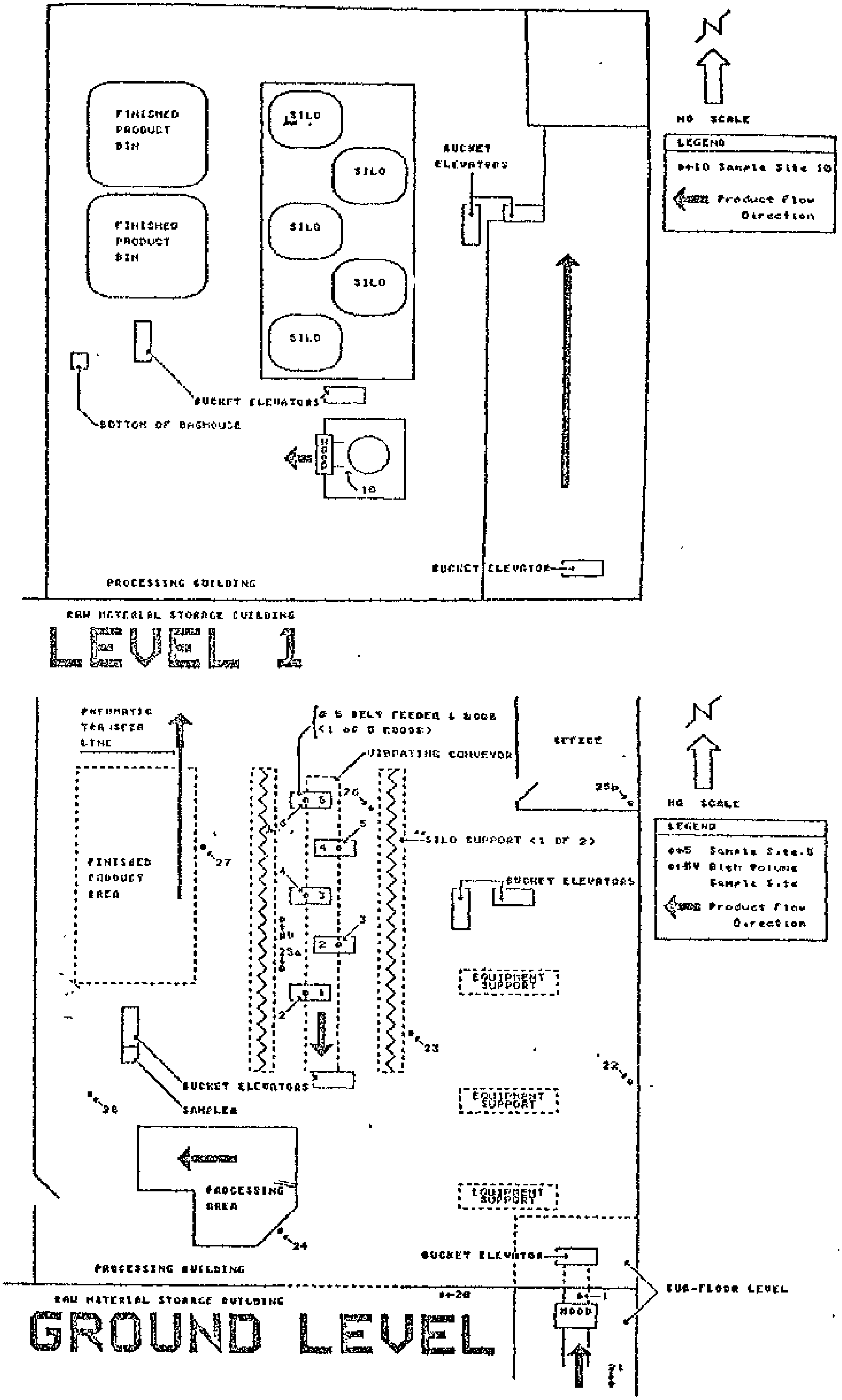
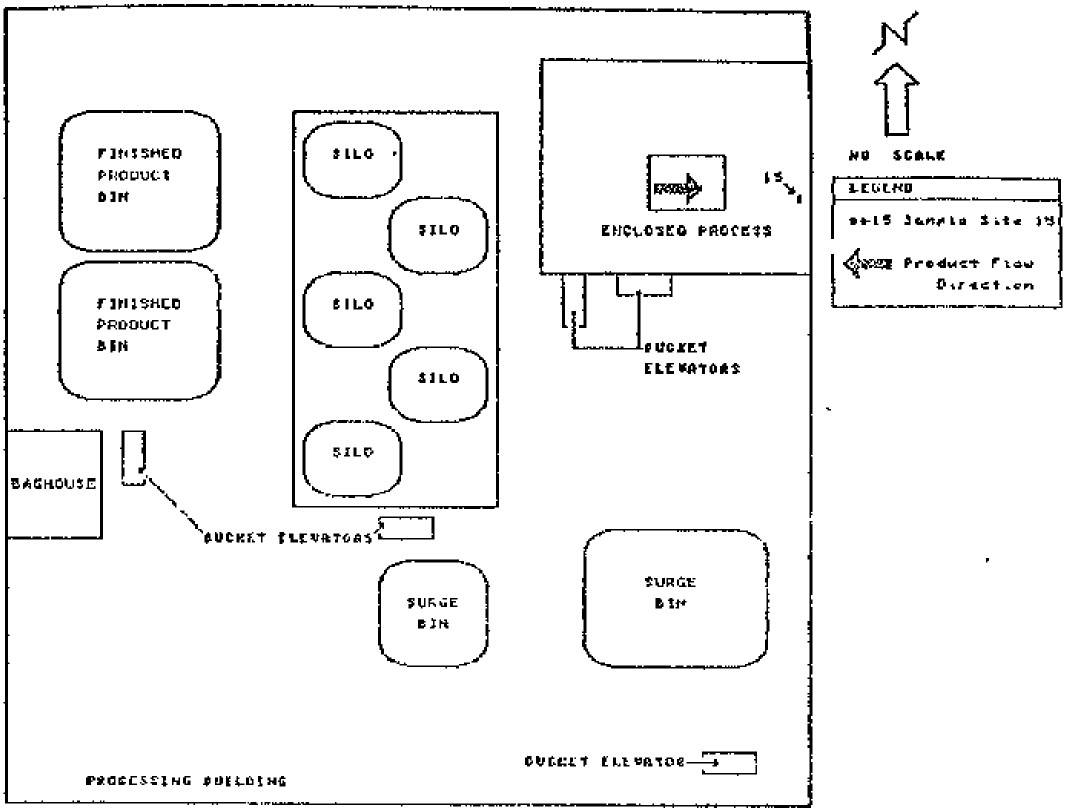


Figure 3. Dust Sampling Sites



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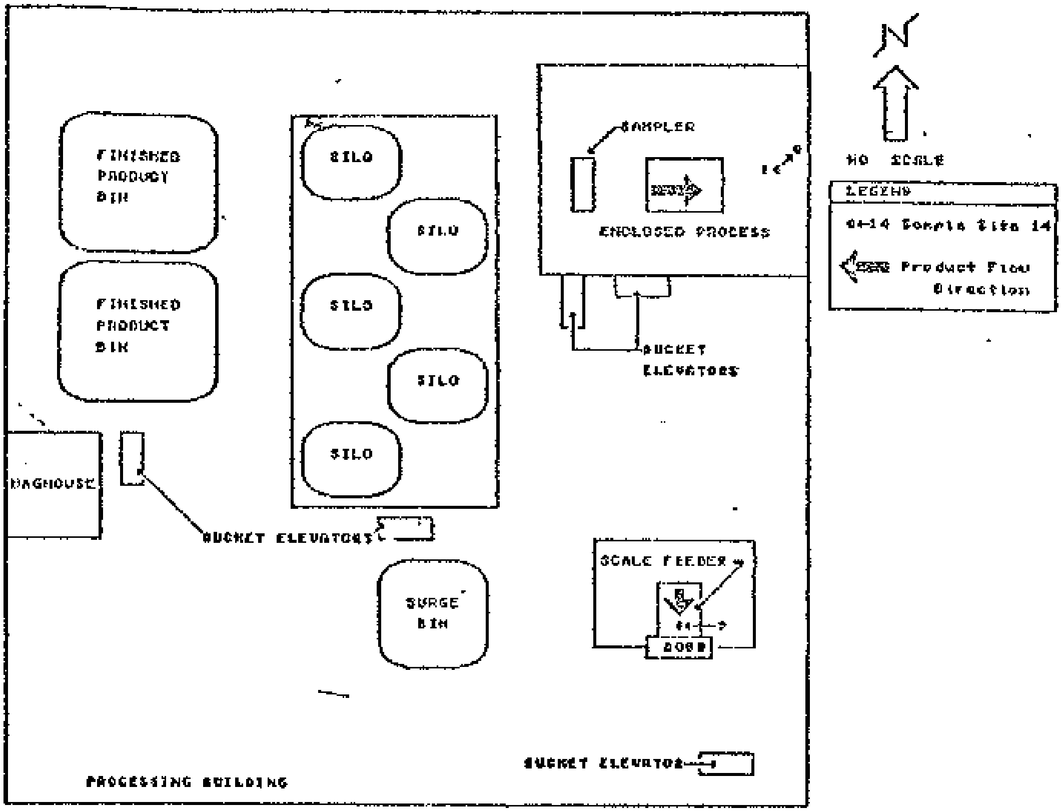

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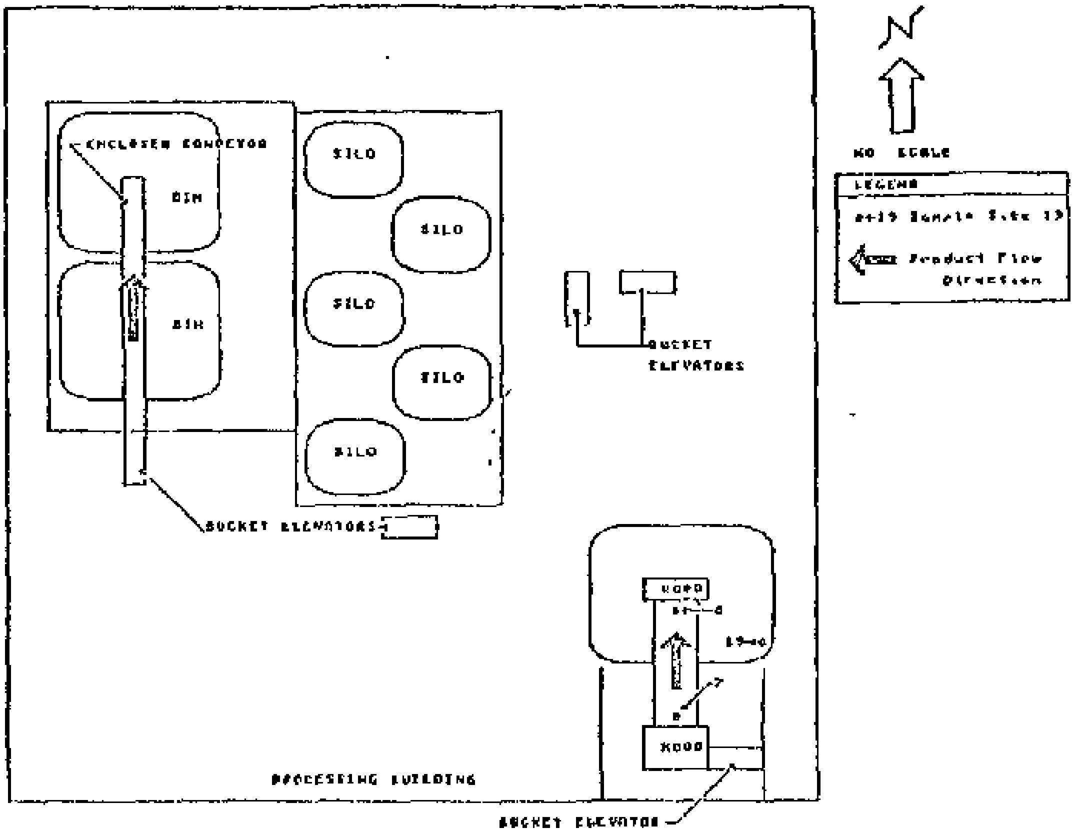
Figure 4. Dust Sampling Sites



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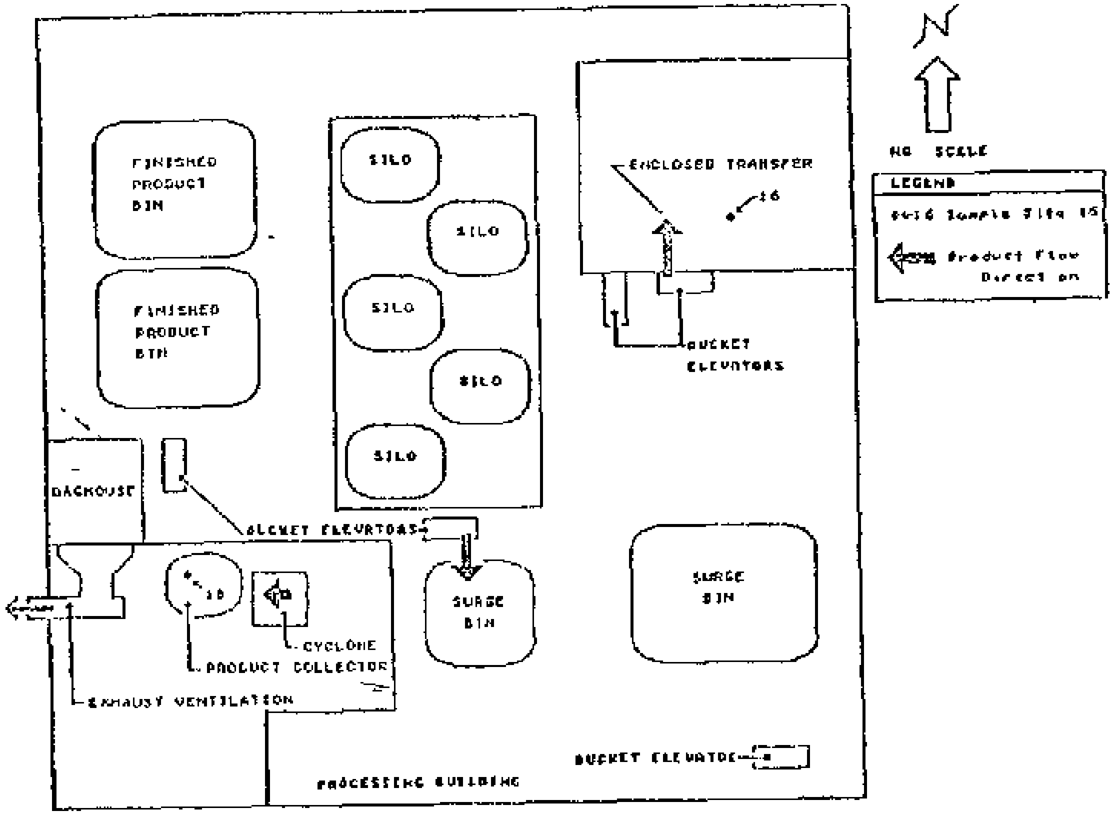

LEVEL 4

Figure 5. Dust Sampling Sites

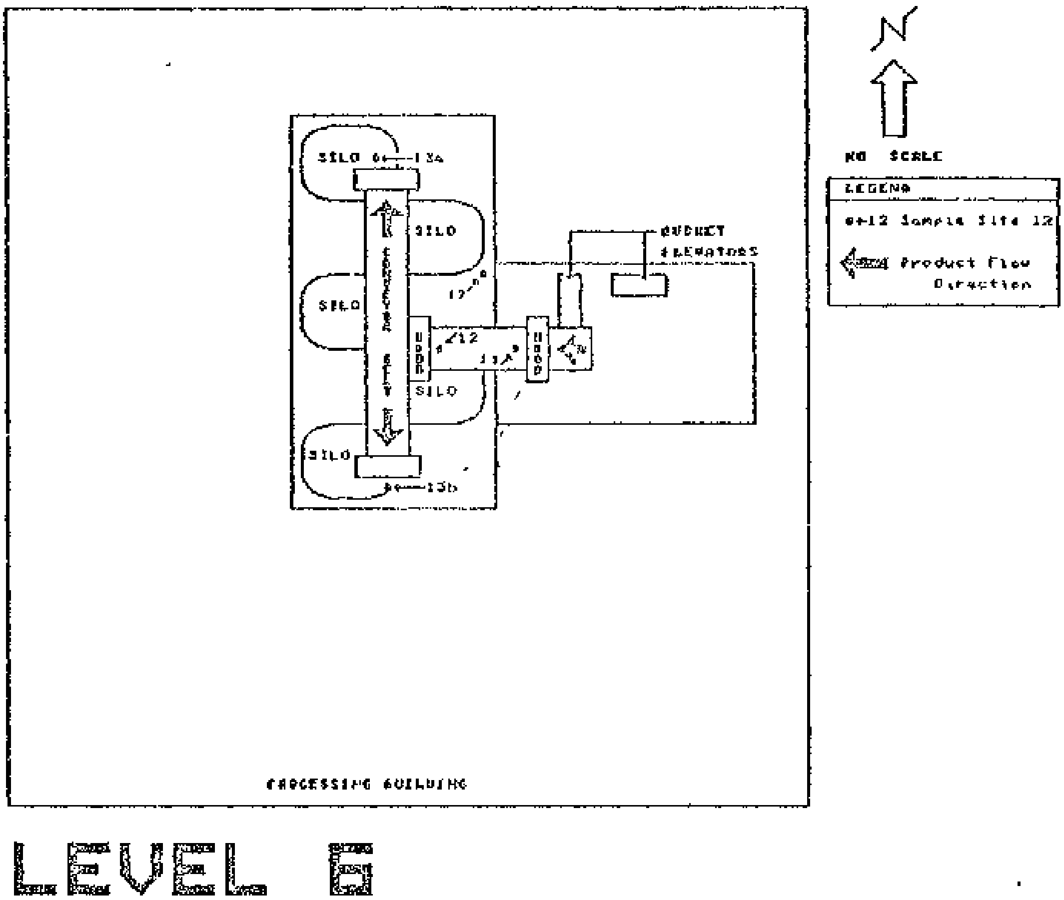

Figure 6. Dust Sampling Sites

(10)) was calculated as the ratio of the dust level at a source (column (6)) to the PEL (column (9)).

The general evaluation of the dust control systems indicates that the overall effectiveness of the controls was sufficient to maintain dust levels below their respective Permissible Exposure Limits. That is, personal exposures to the two operators evaluated were well below their PEL's of .71 mg/m^3 and .63 mg/m^3 respectively (Table 4). Operator 1, who spent most of his time in the Control Room of the Process Building, was exposed to an average of .05 mg/m^3 (PEL of .71 mg/m^3) or less than 10% of the PEL. The second operator who spent most of his time in the ventilated cab of the front end loader, whenever he was in the Raw Material Storage Building, was exposed to an average of .24 mg/m^3 (PEL of .63 mg/m^3) or approximately 38% of the PEL.

All of the control systems at the open transfer points were found to be "effective" in maintaining dust levels below their respective PEL's, based on the silica content of the analyzed dust samples. They were judged to be effective during this study, however, partially because some of the dust sources were not normal work stations; because many of the locations had a low on-time (duty cycle) during our three-day study period; but mainly, because the dust control systems were capable of maintaining dust levels below their respective PEL's, at all except one location, H-1, the Jaw Crusher transfer point, in the RMSB. At this emission source, average dust concentrations were approximately 40% above its calculated PEL. Since this point is not a normal work station, the dust source does not contribute significantly to the operator's overall dust exposure.

Excessive dust sources were observed at two additional locations, on the first day of the study, - at the hood of the Constant Weight Feeder, CWF, Number 2 (H-3) and at the Shuttle Conveyor discharge to the Blending Silos (H-13). These stations were in operation for 3.5 and 8 hours, respectively, on the first day of the study. They were approximately 3 times and 1.6 times their calculated PEL, during those sampling periods. Again, they did not contribute significantly to the operator's overall exposure, since they were not normal work stations.

1. Effect of Product Condition

✓

In general, two types of dust product were encountered in this plant: damp raw material (pre-drier) with a water content of 5%; and dry product (post-drier) with essentially no water content. Dry material was encountered in 27 (of the 39) samples and damp material in 12 samples, Table 5. Since dust exposure measurements are considered to be log normally distributed, the (log) average exposure to dry dust was approximately 24% of its PEL, whereas, the (log) average exposure to damp dust was approximately 29% of its PEL. The slightly higher level of exposure to damp dust was probably due to: (1) the slightly higher silica content (15% - PEL = .59 mg/m^3) of the damp product, compared to the silica content (13% - PEL = .67 mg/m^3) of the dry product; and (2) the relative ineffectiveness of the dust control at the Jaw Crusher (H-1) in the RMSB. The relatively higher silica content of the respirable portion of the damp (un-milled) material may be due to the generally observed situation that the milling of a mixture of two materials of unequal hardness (silica-quartz is harder than clay-silicate) causes a greater diminution of the softer material. As mentioned previously, the Jaw Crusher operation presents relatively more uncontrolled dust sources than the other open transfer points and milling operations in the Process Building.

2. Effects of Operational On-Time

The operational on time of the 13 open transfer, potential sources are also shown in Table 5.

Table 5. Effectiveness of dust control related to operating time and material condition.

Dry Material Operating Time						Damp Material Operating Time					
0 hours		1-5 hours		8 hours		0 hours		1-5 hours		8 hours	
Sample No.	Fraction of PEL	Sample No.	Fraction of PEL	Sample No.	Fraction of PEL	Sample No.	Fraction of PEL	Sample No.	Fraction of PEL	Sample No.	Fraction of PEL
2.3	.15	2.1	.64	10.1	.25	9.3	.23	1.1	1.72	9.1	.52
3.3	.13	2.2	.49	10.2	.13			1.2	.56	9.2	.13
4.1	.75	3.1	2.91	11.1	.38			1.3	1.98		
4.2	.22	3.2	.24	12.1	.52			7.1	.22		
4.3	.12			13.1	1.64			7.2	.25		
5.1	.54							7.3	.69		
5.2	.16							8.1	.15		
5.3	.07							8.2	.20		
6.1	.31							8.3	.39		
6.2	.13										
6.3	.24										
10.3	.13										
11.2	.11										
11.3	.83										
12.2	.21										
12.3	.15										
13.2	.39										
13.3	.12										
n = 18 range = .11-.75 arith.mean = .26 geo.mean = .20 med = .15		n = 4 range = .24-2.91 arith.mean = 1.07 geo.mean = .68 med = .57		n = 5 range = .13-1.64 arith.mean = .58 geo.mean =.40 med =.38		n = 1 range = .23 arith.mean.23 geo.mean =.23 med =.23		n = 9 range =.15-1.98 arith.mean =.68 geo.mean =.46 med =.39		n = 2 range = .13-.52 arith.mean =.33 geo.mean =.26 med =.33	

Analysis of all dry and damp samples

Dry samples		Damp samples	
n = 27		n = 12	
range	=.11 to 2.91	range	= .32 to 1.98
arth.mean	=.44	arith.mean	= .56
geo. mean	=.28	geo. mean	= .39

Of the 39 samples analyzed, (13 stations, for three shifts) nineteen (19) were collected during periods of no-activity, thirteen (13) were collected during activity periods of 1 to 5 hours per shift and seven (7) were collected during activity periods of 8-hours per shift (Table 5). Air concentrations around locations not in operation, showed average levels of approximately 18% of their PEL; operations of 1-5 hours per shift averaged approximately 43% of their PEL; and operations of 8-hours per shift activity averaged approximately 24% of their PEL. No correlation of "on-time" and "dust exposure levels" was apparent, since other factors apparently were more significant.

3. Effect of Air Velocity into Hoods

Hood velocity patterns were obtained at 12 of the 13 open transfer points. An attempt was made to correlate overall dust concentrations at these hoods with average hood face velocities. Since other factors, such as water content of the dust, operating time of the conveyor systems, and degree of enclosure of the potential dust sources were also important, significant correlations of all samples were poor.

For example, an evaluation of operations involving damp product only shows that, at the Jaw Crusher transfer point (H-1) in the RMSB (not a work station), dust concentrations were high-140% of PEL, even though the material was damp; air velocity patterns of the hood enclosure were high (average velocity 365 fpm); and the equipment was in operation only about 3 to 4 hours per shift, on the days of our study.

Excessive dust apparently was emitted from multiple sources around the transfer point. These probable uncontrolled sources included: the top of the hopper; the discharge from the hopper to the crusher feed belt; and the open feed belt to the crusher.

Conversely, at other transfer points handling damp material, such as H-7, H-8, and H-9, all dust sources were well controlled. Atmospheric dust levels ranged from 10 to 40% of their PEL's, even though average hood face velocities ranged from 70 to 330 fpm and on-time of the conveyor belts averaged approximately 4.5 hours per shift. The high degree of effectiveness of these systems was probably due to a combination of several factors, such as: dampness of the product, which may cause agglomeration of fine dust particles; high degree of enclosure of transfer points; and absence of other uncontrolled dust sources in the vicinity of the transfer points.

Where dry product is handled at open transfer points, however, better correlation of dust emission and hood face velocities was observed. Of the 27 air samples involving dry product at transfer points, (subsequent to the drier), 18 samples were collected when operation time was less than one hour per shift. The remaining nine samples were collected with on-time from 1 to 8 hours per shift. During 8 of these 9 sampling periods, hood face velocities were also measured. Figure 7 indicates a high degree of correlation (-.71) between excess dust generation (dust level at hood minus background dust level) and average hood face velocity.

This plot indicates that, at these dry product, open transfer points, an average hood face velocity of approximately 100 fpm is sufficient to maintain excess dust levels (level above background) at the PEL of .667 mg/m^3. Presumably, if a dust is being processed that contains a higher percentage of silica, for example, a dust with 50% silica and a PEL of .192 mg/m^3, the required hood velocity would be approximately 220 fpm. If pure silica material were being processed with a PEL of .1 mg/m^3, the required hood velocity would be approximately 300 fpm. These calculated control velocities are only estimates, of course, since other factors must be considered, such as particle size distribution, dust density, water content, quantity of product

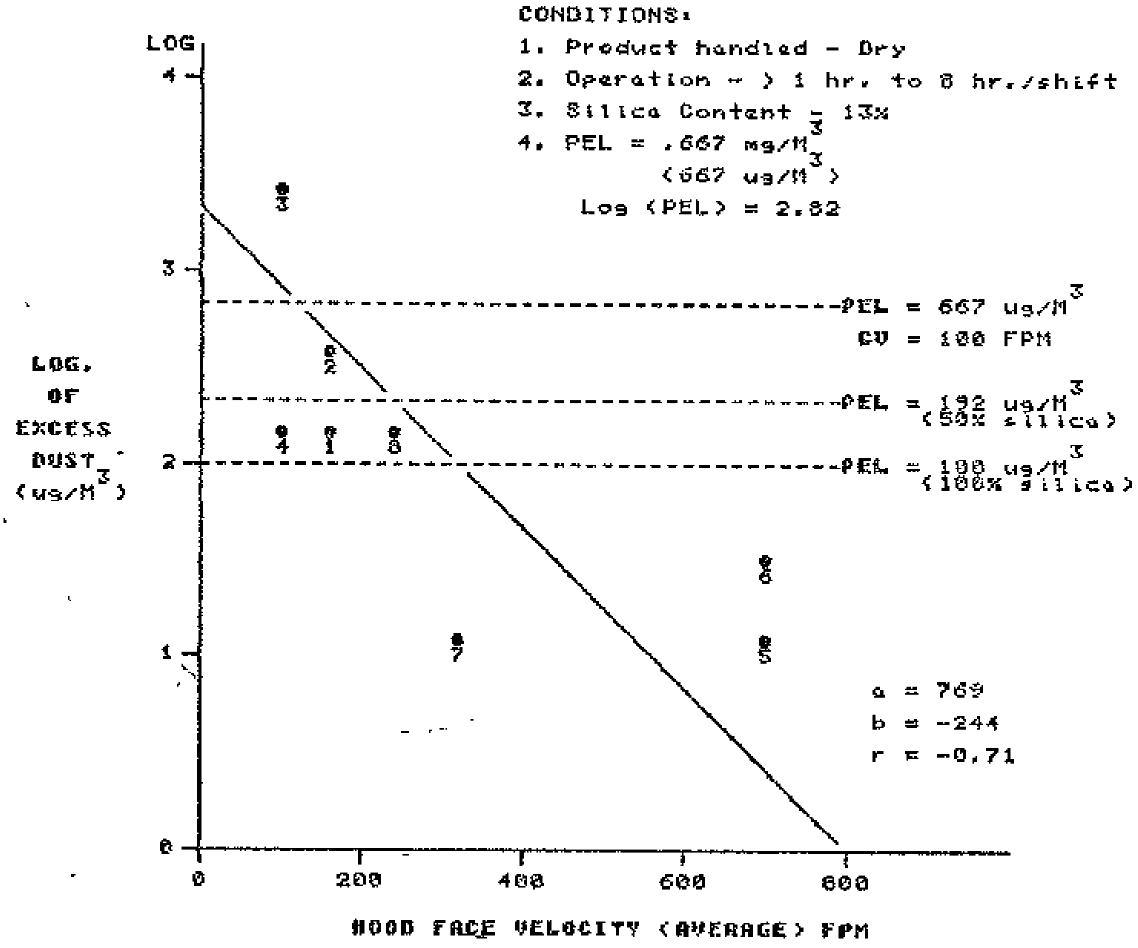

Figure 7. Correlation of Excess Dust from Hoods and Hood Face Velocities

transported per unit time, degree of enclosure of the hood over the dust source and the probable on-time of the conveyor belt.

The validity of these estimates, however, is shown by referring to samples taken with conveyor equipment in operation approximately 75% of the work shift. The hoods over the CW Feeders 1 and 2 had an average hood velocity of approximately 128 fpm and average excess dust levels of approximately .510 mg/m^3. Hoods number 10, 11, and 12 with an average hood velocity of approximately 410 fpm, maintained excess dust levels at approximately .075 mg/m^3.

b. Evaluation of Major Ventilation Ducts

As previously mentioned, total air flow through five major ventilation ducts were measured with a TSI Air Velocity Meter, Model 1650, which had been previously calibrated in our Industrial Hygiene Laboratory. The results of these evaluations are shown in Table 6.

According to the Industrial Ventilation Manual of the American Conference of Governmental Industrial Hygienists minimum velocities of 3500 to 4000 fpm are recommended to maintain transport of average industrial dusts, such as clay, granite and limestone through duct systems. This is particularly true for vertical risers and horizontal ducts. As shown in Table 6, minimally recommended velocities were measured in 3 of the 5 ducts (D-1, D-2, and D-5) while marginal transport velocities (ranging from 2400 to 3300 fpm) were measured in ducts D-3 and D-4. Of particular concern is duct D-3, the 19.5-inch vertical riser, which removes air from the five hoods on the oscillator belt. This minimal transfer velocity, averaging approximately 2775 fpm (range 2400 to 2900 fpm) may have been responsible for the relatively low face velocities at the CWF #2 hood (average 100 fpm) and its resultant high dust concentration (1.95 mg/m^3) on the first day of our study. Since low transport velocities may

Table 6. Evaluation of major ventilation ducts.

Duct No.	Location/description	Duct Spec		Air Movement		Comments
		Diameter in.	Area ft^2	Velocity (V) FPM*	Volume (Q) CFM	
D-1	Center of PB, vertical, from level 2-6, provides ventilation for all hoods above level 4.	12	0.785	3360	2640	Air moving down, good transfer velocity.
D-2	NE corner PB, horizontal, level 2, removes air from screen.	9	0.442	3530	1560	(V) range 1500-4900; nonuniform, but good velocity.
D-3	Center of PB, vertical riser, removes air from 5 hoods on oscillator belt, from level 1 - level 2.	19.5	2.074	2775	5755	(V) range 2400 to 2900; marginal velocity.
D-4	SW Corner of PB, horizontal, level 2, main duct to baghouse.	24	3.142	3067	9635	(V) range 2600 to 3300, minimally adequate velocity
D-5	SE Corner of PB, vertical riser, from levels 5-6, ventilates hood on elevator.	7	0.267	3271	875	(V) range 3200 to 3500, adequate transport velocity.
*Recommended design(1) transport velocity for average industrial dusts (granite, silica flour, clay, limestone, etc.)				3500-4000		

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(1)Industrial Ventilation - A Manual of Recommended Practice, 17th Edition. ACGIH, 1982.

result in partial plugging of ducts, these lines should be inspected for holes and plugs and measured for air flow on a scheduled basis.

OBSERVATIONS, CONCLUSIONS AND RECOMMENDATIONS

1. All material conveying systems are either of a trough or enclosed design to minimize dust emissions.

2. General evaluation of the dust control system indicated that the overall effectiveness of the controls was sufficient to maintain dust levels below their respective Permissible Exposure Limits.

3. Personal exposures to the two operators were well below their PEL's.

4. All of the control systems at the open transfer points were found to be effective in maintaining dust levels below their respective PEL's except the jaw crusher transfer point (not a normal work station) in the raw material storage building.

5. The open transfer point control systems were concluded to be effective, during this study, because some of the dust sources were not normal work stations; many of the locations had a low on-time duty cycle during the three-day study period; and mainly, the dust control systems were capable of maintaining dust levels below their respective PEL's.

6. The average respirable crystalline silica content of the wet or damp dust (predrier) was 15 per cent as compared to 13 per cent for the dry dust (postdrier).

7. There was no apparent correlation between the on-time duty cycle and dust exposure levels. Air concentrations around inactive sources averaged approximately 18 per cent of the PEL, at operations active 1-5 hours approximately 43 per cent, and at operations active 8-hours 24 per cent.

8. There was no apparent correlation between the average hood face velocity and excess damp or wet dust emissions.

9. A high degree of correlation was indicated between excess dry dust emissions and average hood face velocity.

10. The study indicated that excess (level above background) dry dust emissions from open transfer points can be effectively controlled with an average hood face velocity of 100 fpm (dust crystalline silica content of 13 per cent).

11. All ducts should be periodically inspected for holes and partial blockage and air flow measurements performed.

VI. APPENDIX

A. Detailed Sampling Data

Area/operation/ equipment	Sample Site No.	Day	% Quartz	PEL	TWA	% of PEL	Activity
Jaw Crusher -	1*	1	15	0.59	0.86	146	Crusher operated 3 hrs & 8 min
Sub-Ground		2	24	0.38	0.28	74	" " " 20 min
Level		3	16	0.56	0.99	177	" " 5 hrs
Mean			18	0.51	0.71	139	4 Ton Product Level
General Crusher	20	1	13	0.67	0.14	21	Area Sample - Adjacent to
Area-Ground		2	13	0.67	0.09	13	Site No. 1 Activity
Level		3	10	0.83	0.11	13	
Mean			12	0.72	0.11	15	
General Crusher	21	1	13	0.67	0.20	30	Area Sample - Adjacent to
Area-Ground		2	13	0.67	0.05	7	Site No. 1 Activity
Level		3	10	0.83	0.08	10	
Mean			12	0.72	0.11	15	
Blender No. 1 -	2*	1	16	0.56	0.43	77	Operated 3.5 hrs
Ground Level		2	16	0.56	0.33	59	" 4 hrs
Central		3	10	0.83	0.10	12	Inactive
Mean			14	0.65	0.29	45	
Blender No. 2 -	3*	1	14	0.63	1.95	3.10	Operated 3.5 hrs
Ground Level		2	13	0.67	0.16	24	Operated 1 hr
Central		3	10	0.83	0.09	11	Inactive
Mean			12	0.71	0.73	103	
Blender No. 3 -	4*	1	14	0.63	0.50	80	Inactive
Ground Level		2	13	0.67	0.15	22	Inactive
Central		3	10	0.83	0.08	10	Inactive
Mean			12	0.71	0.24	34	
Blender No. 4 -	5*	1	16	0.56	0.36	64	Inactive
Ground Level		2	13	0.67	0.11	16	Inactive
North Central		3	10	0.83	0.05	6	Inactive
Mean			13	0.69	0.17	25	
Blender No. 5 -	6*	1	27	0.34	0.21	62	Inactive
Ground Level		2	13	0.67	0.09	13	Inactive
North Central		3	10	0.83	0.16	19	Inactive
Mean			13	0.61	0.15	25	

Area/operation/ equipment	Sample Site No.	Day	% Quartz	PEL	TWA	% of PEL	Activity
Elevator A Discharge Port-Fifth Level S. East	7*	1	13	0.67	0.13	19	Operated 3.5 hrs
		2	13	0.67	0.15	22	Operated 3.3 hrs
		3	22	0.42	0.41	98	Operated 5 hrs
Mean			16	0.59	0.23	39	
Dryer Surge Bin Entry Port-Fifth Level S. East	8*	1	13	0.67	0.09	13	Operated 3.5 hrs
		2	13	0.67	0.12	18	Operated 3.3 hrs
		3	22	0.42	0.23	55	Operated 5 hrs
Mean			16	0.59	0.15	25	
Dryer Surge Bin Discharge Port (Vib. Feeder) Second Level S.East	9*	1	16	0.56	0.37	66	Operated 8 hrs
		2	13	0.67	0.09	13	Operated 8 hrs
		3	25	0.37	0.16	43	Inactive
Mean			18	0.53	0.21	40	
Ball Mill Surge Tank Discharge Port (Vib.Feeder) First Level S Central	10*	1	13	0.67	0.18	27	Operated 8 hrs
		2	13	0.67	0.09	13	Operated 8 hrs
		3	10	0.83	0.09	11	Inactive
Mean			12	0.72	0.12	17	
Elevator C Discharge Port Sixth Level N. Central	11*	1	20	0.45	0.24	53	Operated 8 hrs.
		2	13	0.67	0.07	10	Inactive
		3	17	0.53	0.52	98	Inactive
Mean			17	0.55	0.28	51	
Elevator C Conveyor Discharge to Shuttle Conveyors Sixth Level N. Central	12*	1	18	0.50	0.35	70	Operated 8 hrs
		2	13	0.67	0.14	21	Inactive
		3	10	0.83	0.10	12	Inactive
Mean			14	0.67	0.20	30	
Shuttle Conveyor Discharge to Blending Silos-Sixth Level N. Central	13*	1	15	0.59	1.10	186	Operated 8 hrs
		2	13	0.67	0.26	39	Inactive
		3	10	0.83	0.08	10	Inactive
Mean			13	0.70	0.48	69	
Cone Crusher - Second Level N. East	14	1	13	0.67	0.18	27	Operated 8 hrs) Area sample
		2	13	0.67	0.00	0	Inactive) Enclosed
		3	10	9.83	0.08	10	Inactive) Transfer Point
Mean			12	0.72	0.09	13	

Area/operation/ equipment	Sample Site No.	Day	% Quartz	PEL	TWA	% of PEL	Activity
Incline Screen –	15	1	13	0.67	0.19	28	Operated 8 hrs) Area sample
Third Level		2	13	0.67	0.14	21	Inactive) Enclosed
N. East		3	10	0.83	0.08	10	Inactive) Transfer Point
Mean			12	0.72	0.14	19	
Above Incline	16	1	13	0.67	0.18	27	Area Sample – No open Transfer
Screen – Fourth		2	13	0.67	0.01	1	Points or Other Activity
Level N. East		3	10	0.83	0.08	10	
Mean			12	0.72	0.09	13	
Top of Blending	17	1	13	0.67	0.24	36	Area Sample – Adjacent to Sites
Silos-Sixth Level		2	33	0.29	0.13	45	No. 11, 12 & 13 Activity
N. Central		3	10	0.83	0.13	16	
Mean			19	0.60	0.17	28	
Top of Bag House	18	1	13	0.67	0.28	42	Area Sample – No Open Transfer
Fourth Level		2	13	0.67	0.11	16	Points or Other Activity
S.W.		3	10	0.83	0.18	22	
Mean			12	0.72	0.19	26	
Top of Dryer	19	1	20	0.45	0.27	60	Area Sample – Adjacent to Sites
Surge Bin – Fifth		2	13	0.67	0.03	4	No. 7 & 8 Activity
Level S. East		3	10	0.83	0.17	20	
Mean			14	0.65	0.16	25	
Ground Level	22	1	13	0.67	0.02	3	Area Sample – No Open Transfer
East Central		2	13	0.67	0.03	4	Points or Other Activity
Wall		3	10	0.83	0.05	6	
Mean			12	0.72	0.03	4	
Top of Operators	23	1	13	0.67	0.13	19	Area Sample – No Open Transfer
Desk – Ground		2	13	0.67	0.03	4	Points or Other Activity
Floor East Central		3	10	0.83	0.04	5	
Mean			12	0.72	0.07	10	
Ground Level	24	1	13	0.67	0.18	27	Area Sample – No Open Transfer
South Central		2	13	0.67	0.00	0	Points or Other Activity
		3	10	0.83	0.15	18	
Mean			12	0.72	0.11	15	
Ground Level	25	1	13	0.67	0.31	46	Area Sample – Day 1 Adjacent to
Central Day 1		2	13	0.67	0.16	24	Sites No. 2, 3, 4, 5 & 6 Activity
Office Day 2 & 3		3	10	0.83	0.11	13	Days 2 & 3 – No open Transfer
Mean			12	0.72	0.19	26	Points or other Activity
Ground Level	26	1	13	0.67	0.15	22	Area Sample – Adjacent to Sites
North Central		2	13	0.67	0.05	7	No. 2, 3, 4, 5 & 6 Activity
		3	10	0.83	0.11	13	
Mean			12	0.72	0.10	14	

Area/operation/ equipment	Sample Site No.	Day	% Quartz	PEL	TWA	% of PEL	Activity
Ground Level North West	27	1	13	0.67	0.18	27	Area Sample - Enclosed Transfer Point - Finished Product Transfer Day 1 - 2 hrs & 50 mins., Day 2 & 3 - 4 hrs
		2	13	0.67	0.08	12	
		3	10	0.83	0.11	13	
Mean			12	0.72	0.12	17	
Ground Level South West	28	1	13	0.67	0.32	48	Area Sample - No Open Transfer Points or Other Activity
		2	13	0.67	0.08	12	
		3	10	0.83	0.11	13	
Mean			12	0.72	0.17	24	
Personal No. 1		1	13	0.67	0.00	0	Processing Operator - Essentially 8 hrs/day in Processing Area
		2	13	0.67	0.05	7	
		3	10	0.83	0.10	12	
Mean			12	0.72	0.05	7	
Personal No. 2		1	16	0.56	0.32	57	Processing Operator - Approx. 2 hrs/day in Raw Materials Storage Area Operating Frontend Loader - 6 hrs in Processing Area
		2	15	0.59	0.23	39	
		3	10	0.83	0.17	20	
Mean			14	0.66	0.24	36	

*Local Exhaust Ventilation