IN-DEPTH SURVEY REPORT

CONTROL TECHNOLOGY FOR THE CERAMIC INDUSTRY

AT

AMERICAN OLEAN TILE COMPANY
LEWISPORT, KENTUCKY

REPORT WRITTEN BY
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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 Lewisport, Kentucky 42351
SIC CODE:	3253 - Ceramic Wall and Floor Tile
SURVEY DATE:	November 15, 1982
SURVEY CONDUCTED BY:	Frank W. Godbey Robert D. Mahon Charleston C. K. Wang
EMPLOYER REPRESENTATIVES CONTACTED:	James Newton, Plant Superintendent, 502/295-3410 Donald Lacy, Personnel Director, 502/295-3410 Layman Hawkins, Safety Coordinator, 502/295-3410
EMPLOYEE REPRESENTATIVES CONTACTED:	No Employee Representatives
ANALYTICAL WORK PERFORMED BY:	Utah Biomedical Test Laboratory

I. INTRODUCTION

A. Background for Control Technology Studies

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.

B. Background for this Study

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.

C. Background for this Survey

The American Olean Tile Company, Lewisport Plant, was selected for an in-depth study because a walk-through survey indicated 1) the plant was performing extensive crushing and grinding of raw materials, 2) the plant was performing extensive grinding of the finished tile product, 3) the clay raw materials contained in excess of one percent (actual range 11 - 57%) crystalline silica to which employees were potentially exposed, and 4) potentially effective controls were being used to prevent harmful exposure.

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 clay raw materials and the grinding of the finished tile products. The specific objectives were:

1. To evaluate and document the effectiveness of the individual health hazard control technology methods in use.

2. To evaluate and document the operating parameters of the exhaust ventilation systems in use.

3. To make general observations, draw conclusions, and discuss the results of the above evaluations and their documentation.

II. PLANT AND PROCESS DESCRIPTION

A. Plant Description

The American Olean Tile Company is a subsidiary of the National Gypsum Company. The Lewisport Plant produces several million units per year of unglazed quarry tile in a variety of shades and colors. The Company's non-union workforce is 198 employees operating one shift per day, five days a week, with the exception of the clay preparation and grinding areas which operate two shifts. The clay preparation area and the grinding area employ approximately five and fifteen employees on each shift, respectively. Except for the brick front office - reception area building, all of the Lewisport operations are under one roof, an area of approximately 400,000 square feet. The production building is a one story, 1968 vintage, brick and sheet metal wall and concrete floor structure with open bays, metal trussed, and no basement. Isolated from the general production area are: the clay receiving and preparation area, offices, cafeteria, laboratory, warehouse, and shipping operations.

B. Process Description

Locally-mined ball clays and shale are brought to the plant by truck and dumped in raw material storage bins that are under roof and open to the outside on one side. These raw materials are transported from the storage bins by cab-enclosed front-end loaders and dumped into feed hoppers. They are fed from the hoppers onto conveyors in proportioned amounts to produce the desired shade of tile. The conveyors transport the blended raw material mixture to Clearfield dry pans for grinding to 35-mesh particle size. The ground material is discharged from the dry pan onto a conveyor for transport up to vibrating screens. The properly-sized particles pass through the screen to another conveyor and the oversized material returns to the dry pan for further size reduction. Other materials (barium carbonate to parcipitate naturally-occurring salts, calcium carbonate to lower the melting point, and manganese dioxide as a coloring agent) are fed from vibrating hoppers onto the conveyor for blending with the ground clay body material. The blended body material is transported by conveyor to storage hoppers in the mill area. The material is gravity-fed from the mill storage hoppers into a pugmill where it is mixed with water, blended, deaerated, and extruded in a continuous one-half inch thick ribbon. The ribbon is automatically cut into individual tiles that are placed onto trays in a batch-type dryer where they are dried for approximately 20 hours at 175-190°F temperature. The dried tile, containing one-half to one percent moisture, is placed on kiln cars and allowed to set in a preheating area for several hours. The preheated tile-laden kiln cars are placed in a tunnel kiln where they remain for four to four and one-half days at 1850-2050°F temperature for firing. The fired tile is removed from the kiln, allowed to cool, unloaded, manually knocked apart, inspected for shade and grade, and transported by forklift truck to the finish grinding area. The flat tile is manually placed onto a conveyor belt where it is transported through automatic grinders for sizing and finishing. The curved tile is manually fed into hand and corner grinder machines for sizing and finishing. The finished tile is inspected, sorted, packed, and stored or shipped by truck and rail to the consumer.

C. Potential Hazards

The raw material, Kentucky ball clays and shale, involved in the clay preparation area and the finish grinding operation contains a relatively high percentage of crystalline 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 total dust (respirable and non-respirable fraction) containing in excess of one percent crystalline silica, is determined by the equation:

$$PEL = \frac{30}{\%\ silica + 2}\ mg/m^3$$

The OSHA standard for respirable crystalline silica (quartz) is determined by the equation:

$$PEL = \frac{10}{\%\ silica + 2}\ (mg/m^3)$$

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. The NIOSH recommended level for respirable crystalline silica is 0.05 mg/m^3 or 50 ug/m.

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 1.

Table 1. Equipment Items Used in the Study

Item	Model	Used For
MSA Gravimetric Dust Sampler	G	Total Dust Sampling
DuPont Gravimetric Dust Sampler	P2500	Respirable Dust Sampling
High Volume Cyclone Dust Sampler	–	Bulk Dust Sampling
Kurz Air Velocity Meter	441	Hood Air Velocity
Dwyer Inclined Manometer		Duct Air Velocity
TSI Respirable Dust Monitor		Bulk Respirable Dust Measurement
Vista Scientific Automatic Psychrometer		Temperatures and Relative Humidity
Gastec Smoke Tubes		Air Flow Patterns

B. Measurement of Control Parameters

1. The volumetric flow rate through three major HVAC ductwork trunks and branches were measured by performing pitot traverses. Each point was measured by doing 10-point traverses, 90° apart, on three consecutive days, using a Dwyer Inclined Manometer with pitot tube.

2. Velocity measurements were made at local exhaust enclosure hoods at various locations in the grinding (both automatic and manual) and packing as well as crushing lines 23 and 24 on three consecutive days using a Kurz Air Velocity Meter. The instrument had been calibrated previously at the NIOSH Industrial Hygiene Maintenance and Calibration Laboratory.

3. Air movement measurements were made at various points in the vicinity of work stations, through doorways, and at other selected points using the aforementioned (Kurz Air Velocity Meter) instrument, on three consecutive days. The wet bulb, dry bulb temperatures, and relative humidity was also checked each day using a Vista Scientific Automatic Psychrometer.

4. Air flow patterns were observed at various points in the work areas (with and without general ventilation fans in operation), through the doorways, and between buildings, using Gastec smoke tester tubes.

C. Sampling Procedures

Personal samples were collected for respirable silica and total dust for the duration of the workshift on three consecutive days. Area samples were collected for total dust over the same period of time (Figures 1 and 2). Breathing zone samples for crystalline silica and total dust were collected on the dayshift workers in the crushing and grinding areas. These workers were in their respective areas except for occasional short breaks. All breathing zone samples were clipped to the collar, on the front side of the work shirt or blouse. 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 crushing and grinding areas. Eight of the area samples in the crushing area and thirteen of the area samples in the grinding area were positioned immediately above material transfer or grinding points

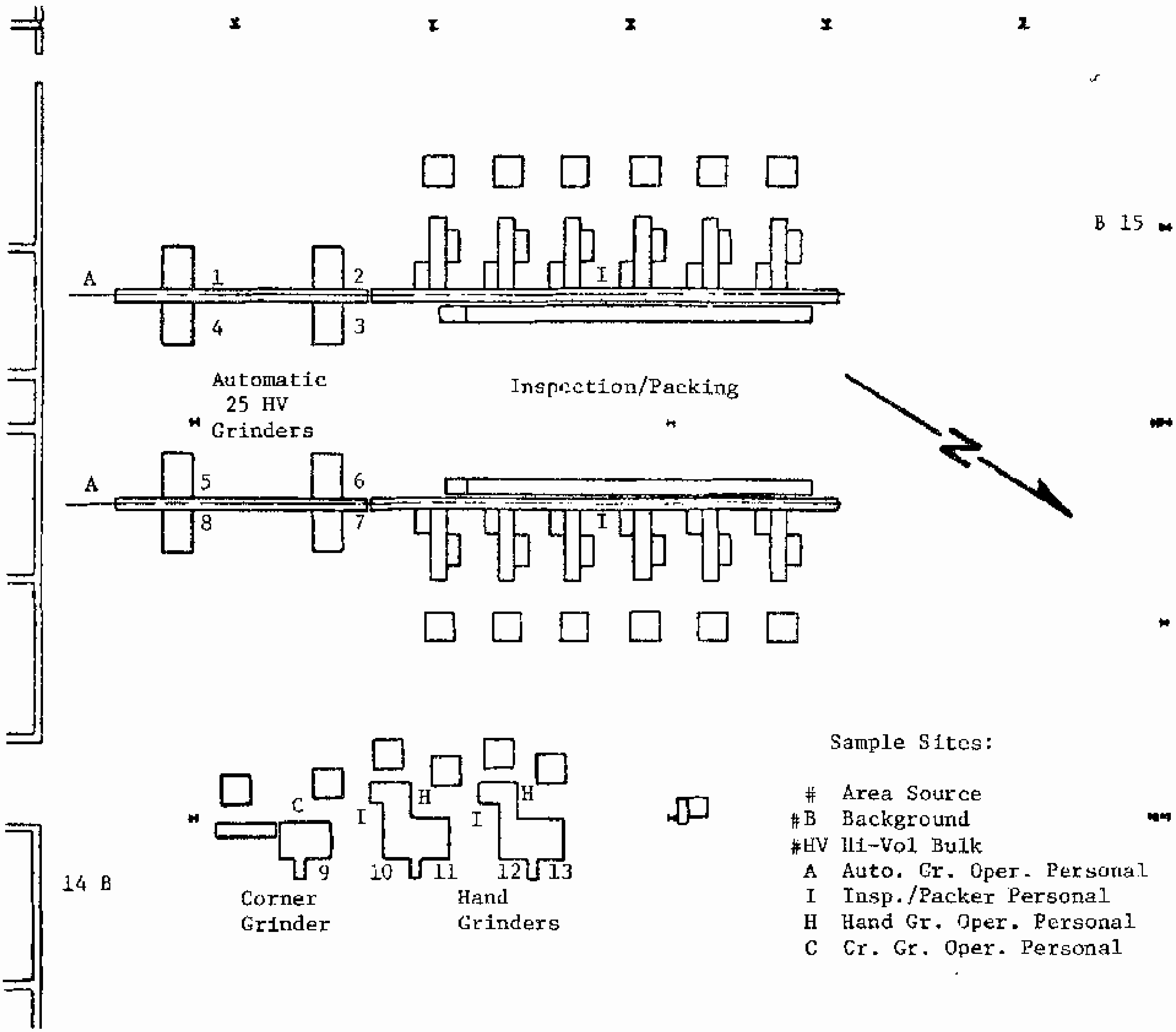


Figure 1 - Grinding and Packing

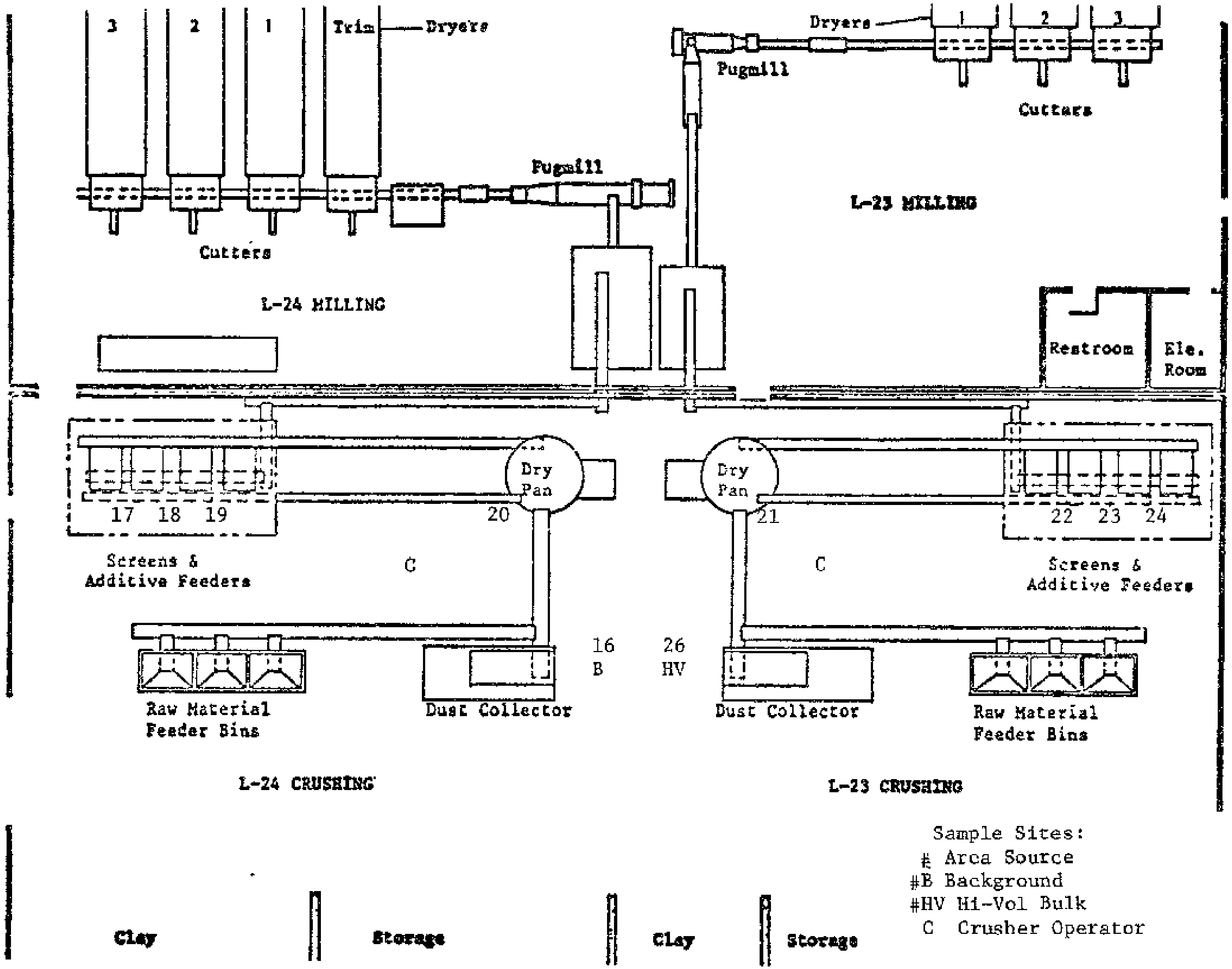


Figure 2 - Crushing Department

that were equipped with local exhaust ventilation hoods. The remainder (3) were positioned at strategic background locations in the crushing and grinding areas.

Personal and area samples were collected using closed-face, two-piece cassettes with preweighed 37 mm polyvinyl chloride membrane filters of five micron pore size. Personal samples for respirable crystalline silica were collected 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. Personal samples for total dust and area samples were collected at a flow rate of 2 liters of air per minute using MSA, Model G, gravimetric air samplers. 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.

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.

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 American Olean Tile Company's Lewisport Plant raw material preparation and finished product grinding operations is discussed below.

A. Use of Local Exhaust Ventilation for Controlling Dust Emissions from Hand and Corner Grinders

1. Description of Process

The Grinding and Packing Department is located in an open area of the plant adjacent to the storage and shipping areas. The hand and corner grinding operations are located on a north/south line near the east boundary of the Department. The operation consists of two hand grinders and one corner grinder. There are seven employees directly involved in the operation; two hand grinder operators, one corner grinder operator, and four inspector/packers. The inspector/packers rotate between the hand grinder and automatic grinder stations every two hours. Two inspector/packers are located in each area at any one time. Finished quarry tile is brought to the grinding area by forklift trucks and placed in stacks adjacent to the hand and corner grinders. Flat tile edges are ground on the hand grinders and curved tile on the corner grinder. The corner grinder operator manually loads a single tile into a shuttle and feeds the edge of the tile onto a single grinding wheel. The tile is withdrawn, rotated, and fed back into the grinder until all desired sides are finished ground. The ground tile is packed in boxes, sealed, and transported to the storage area.

The hand grinder operator manually loads a single tile into a shuttle and feeds the tile between two grinding wheels. The tile is withdrawn, rotated 90 degrees, and fed back into the machine for finish grinding of the other two sides. The ground tile is inspected by the inspector/packer (positioned on the right side of the operator), packed in boxes, sealed, and transported to the storage area.

2. Description of Controls

The corner grinder is equipped with an enclosure around the grinding wheel and shuttle at the point of operation. This enclosure exhausts into a 4" rectangular duct that is equipped with a cleanout opening. The 4" duct exhausts into a 6" vertical duct. There is an adjustable shield between the operator and the point of operation. The mean capture velocity measured 95 fpm at the enclosure opening and 40 fpm at the shield. These velocities are approximately three times higher when the grinding wheel is not operating. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends 200 fpm hood capture velocity for ceramic crushing and grinding.[3] A revision in the hood design should be investigated. A 21-inch overhead cooling fan (when operating) creates a tangential air flow at the work station which adversely affects the capture velocity. The two hand grinders are each equipped with an enclosure around the grinding wheels and shuttle at the point of operation (Figure 3 and Photo 1). These enclosures exhaust into 4" rectangular ducts that exhaust into a round 6" vertical duct. The 6" ducts converge and exhaust into a horizontal duct. There is an adjustable shield between the operator and the point of operation. With the grinding wheels in operation, the mean capture velocity measured 30 fpm at the enclosure openings and 25 fpm at the shield (ACGIH recommends 200 fpm [3]). A redesign of the hoods should also be investigated to see if the adverse effect on the capture velocity by the rotating wheels can be offset. The transition from the vertical ducts into the horizontal duct should be redesigned. The above-mentioned 21-inch fan only affects one of the hand grinder stations.

Measurements were taken in the 6-inch overhead exhaust duct 8 feet downstream from the corner grinder branch duct entrance and 6 feet upstream from Hand Grinder No. 1 branch duct entrance (Figure 4, Point A and Photo 2). The mean transport velocity at Point A was 1855 fpm. ACGIH recommends 3500 fpm duct transport velocity for ceramic crushing and grinding.[3] Additional measurements were taken in the 13-inch overhead exhaust duct approximately 20 feet downstream from the hand

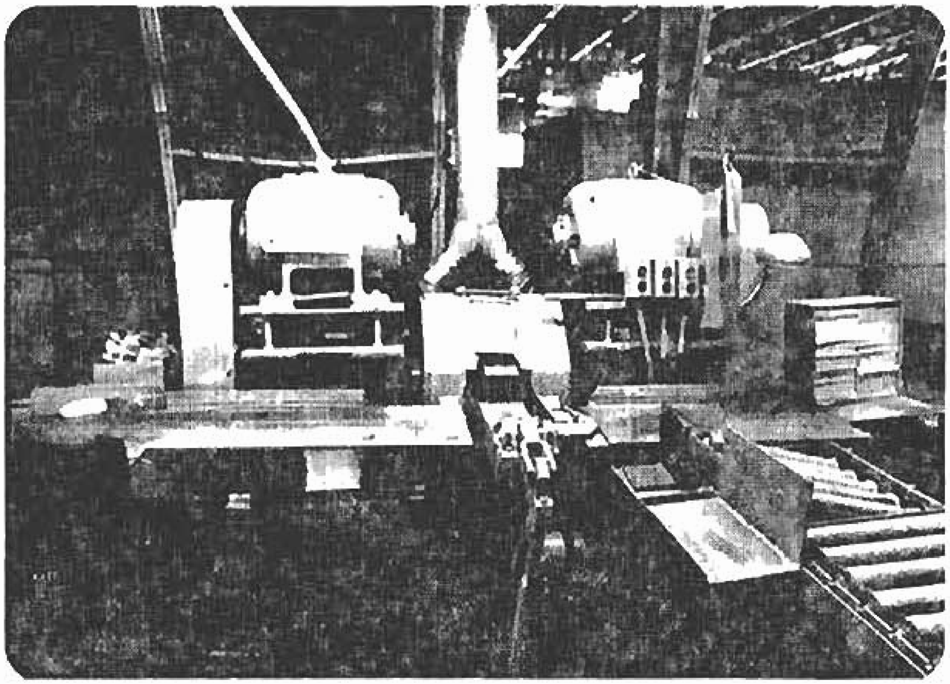
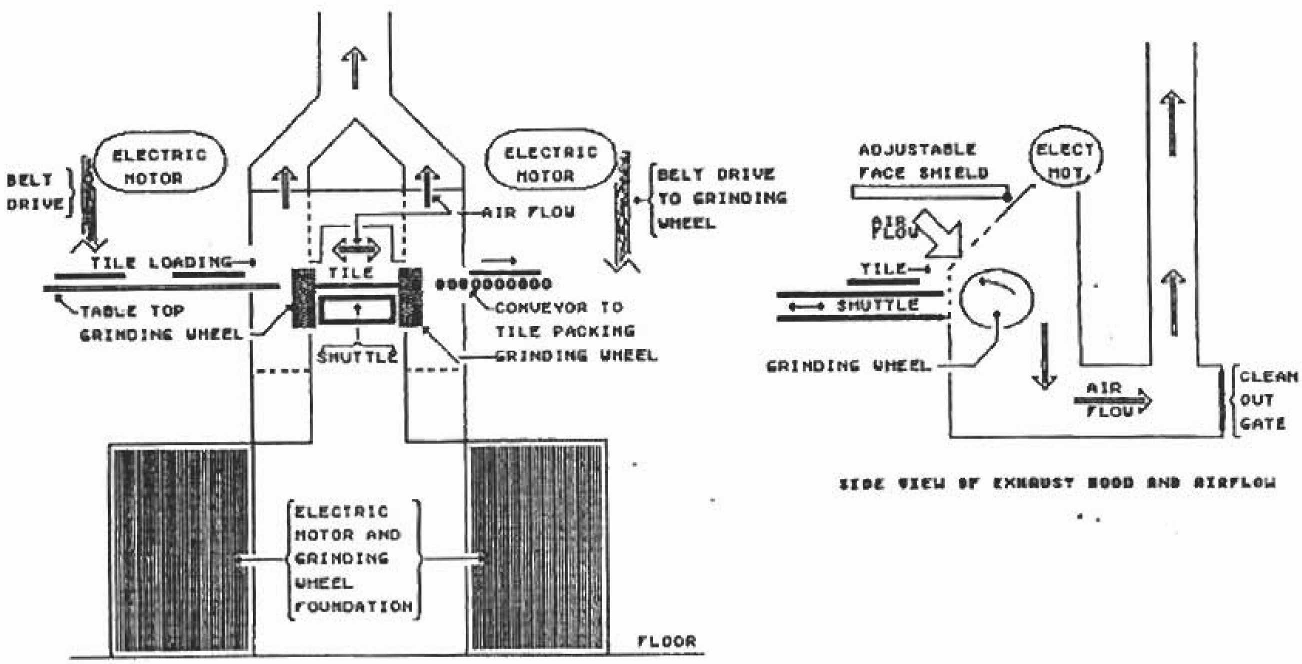


Photo 1 - Hand Grinder



HAND GRINDING STATION

Figure 3 - Hand and Corner Grinder Local Exhaust Hoods

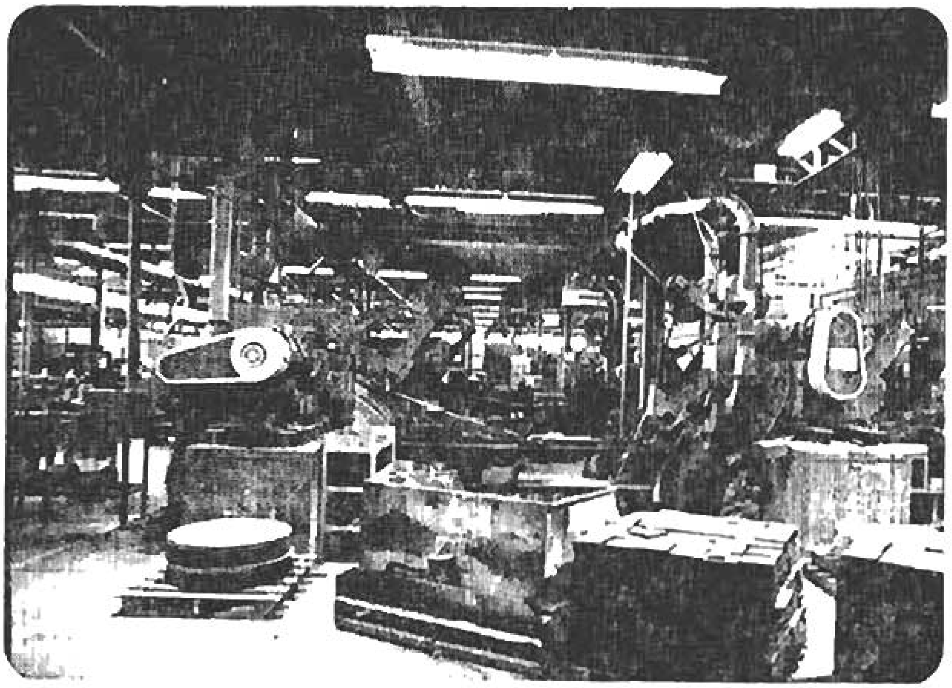


Photo 2 - Grinding Department

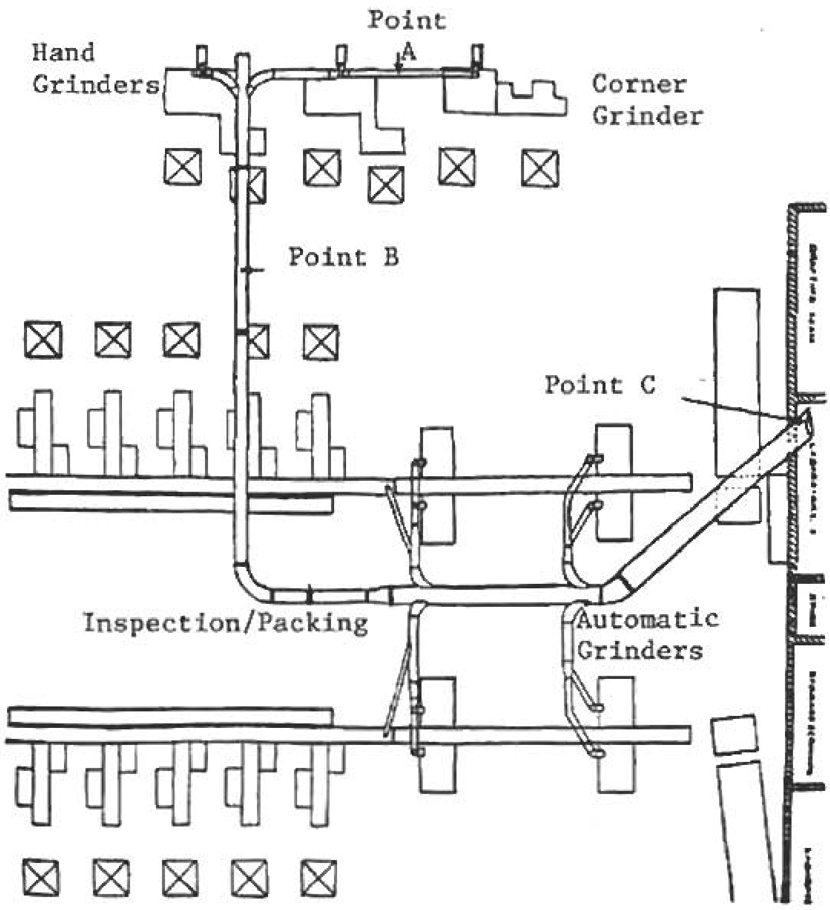


Figure 4 - Grinding Department Exhaust Ventilation System

grinder 6-inch branch duct entrance and approximately 40 feet upstream from the nearest automatic grinder branch duct entrance (Figure 4, Point B and Photo 2). The mean transport velocity at Point B was 1411 fpm (ACGIH recommends 3500 fpm[3]). This duct runs parallel to the floor and is not equipped with a cleanout door. There was approximately a one-inch deep deposit of dust in the bottom of the duct.

General air movement in the hand and corner grinder area was towards the heat source (kilns) at the time of this survey. Smoke tube checks indicate this movement to be approximately 25 fpm. Waste heat from the kilns is used to condition the inplant air during the heating season. The building is at atmospheric pressure and makeup air is supplied through wall openings. A single 10,000 cfm capacity Pangborn, bag-type self-cleaning dust collector (Figure 5) provides local exhaust ventilation at various operations throughout the grinding area. Ventilation for heat relief (comfort control) is supplied by two operator-controlled overhead axial flow, propellor-type fans that produce approximately 300 fpm air movement at breathing zone level. Overhead gas-fired unit heaters are available for use during cold weather.

3. Sampling Results

The mean time-weighted average (TWA) concentrations for respirable crystalline silica (SiO_2) and total particulates for personal and area samples were well below the PEL (see Table 2). Employees operating the hand grinders, corner grinder, and performing inspection and packing duties had an exposure level range of 42 to 51% of the PEL for respirable silica and 57 to 66% of the PEL for total particulates. Hand grinder operators and inspector/packers (positioned in front of the hand grinders) total particulate exposure levels were 154 and 178 percent of the hand grinder area concentration (measured above the local exhaust ventilation hood at the rear of the hand grinder). The

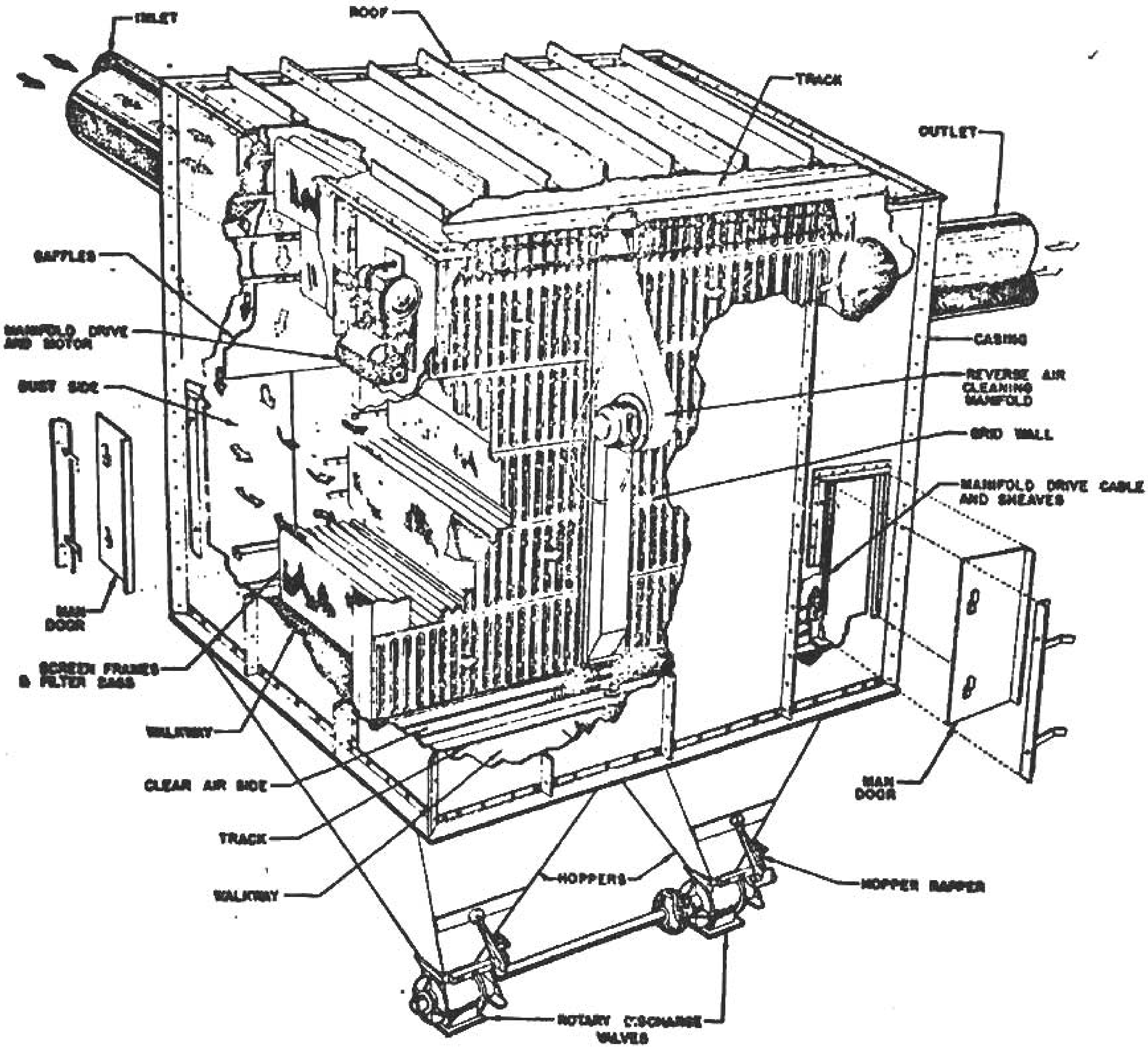


Figure 5 - Pangborn Dust Collector

total particulate area concentrations for the hand grinders, corner grinder, and general grinding area were essentially the same (35-37 percent of the PEL).

Table 2. Hand and Corner Grinding Mean TWA Personal and Area Concentrations

Grouping	Respirable SiO_2			Total Particulates		
	Number of Samples	% of PEL	Standard Deviation	Number of Samples	% of PEL	Standard Deviation
Hand Grinders	6	51	16	5	57	35
Hand Grinders Area	-	-	-	12	37	14
Corner Grinder	3	42	16	-	-	-
Corner Grinder Area	-	-	-	3	36	9
Inspectors/Packers	12	46	29	11	66	37
General Grinding Area	-	-	-	6	35	12

4. Discussion

While it is evident that the hand and corner grinder operations are significant sources of crystalline silica (20 percent of respirable fraction and 22 percent of total particulates - Appendix), the resultant worker exposure is reduced due to the excellent control of these emissions. Although there are some minor design and operational deficiencies affecting exposure levels, (e.g. overhead cooling fan position, duct transition, effects of grinding wheel rotation on capture velocity, dust deposit in duct) the local exhaust ventilation system effectively controls dust emissions from the hand and corner grinding operations.

B. Use of Local Exhaust Ventilation for Controlling Dust Emissions from Automatic Grinders

1. Description of Process

The automatic grinders are located in two parallel north/south lines near the west boundary of the Grinding and Packing Department. The operation consists of four automatic grinders, two in each line, operating in tandem. There are six employees directly involved in the operation; two automatic grinder feeders and four inspector/packers.

The inspector/packers rotate between the automatic grinder and hand grinder stations every two hours. Two inspector/packers are located in each area at any one time.

Finished quarry tile is brought to the Grinding Area on forklift trucks and placed in stacks at the head of each automatic grinder line. The automatic grinder feeder, positioned at the head of each line, manually loads the quarry tile into a chute that feeds by gravity onto a vertical ferris wheel. The tile passes between two 30-inch grinding wheels in the first grinder where two sides are ground. A belt holds the tile in place on the ferris wheel when it is being ground. It then drops onto a conveyor belt where it is rotated 90 degrees and transported between another set of tandem grinding wheels in the second grinder that grinds the other sides. The ground tile is transported by conveyor belt under a hooded air brush to the inspector/packer station where it is inspected, packed, and transported to the storage area.

2. Description of Controls

The largest particles from the tandem grinding wheels either drop into paper bags connected to the local exhaust enclosure hoods or into a pit beneath the grinders (Figure 6 and Photo 3). The smaller particles are drawn into 6- by 12-inch local exhaust hoods located on each side of the ferris wheels. The hoods discharge into 6-inch vertical ducts. The mean capture velocity measured 300 fpm at the hood openings when the wheels were operating (ACGIH recommends 200 fpm[3]). The hoods mean capture velocity was approximately three times (1000 fpm) greater when the ferris wheels and grinders were not operating. There is some dust emission from under the grinders when the ferris wheels are operating and the pits need cleaning. A considerable amount of dust is carried from the hoods on the hold-down

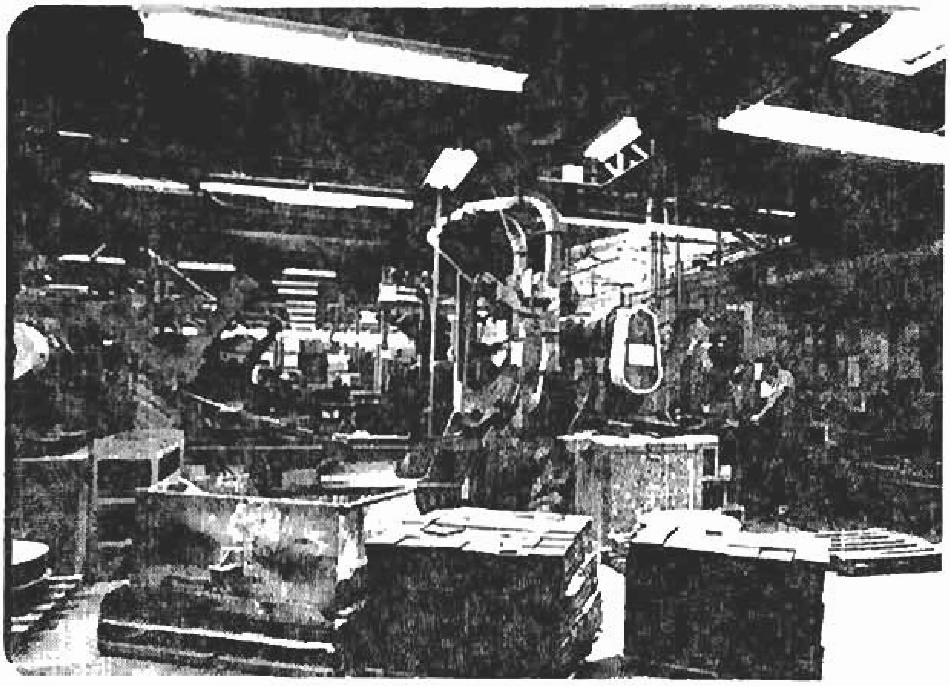


Photo 3 - Automatic Grinders

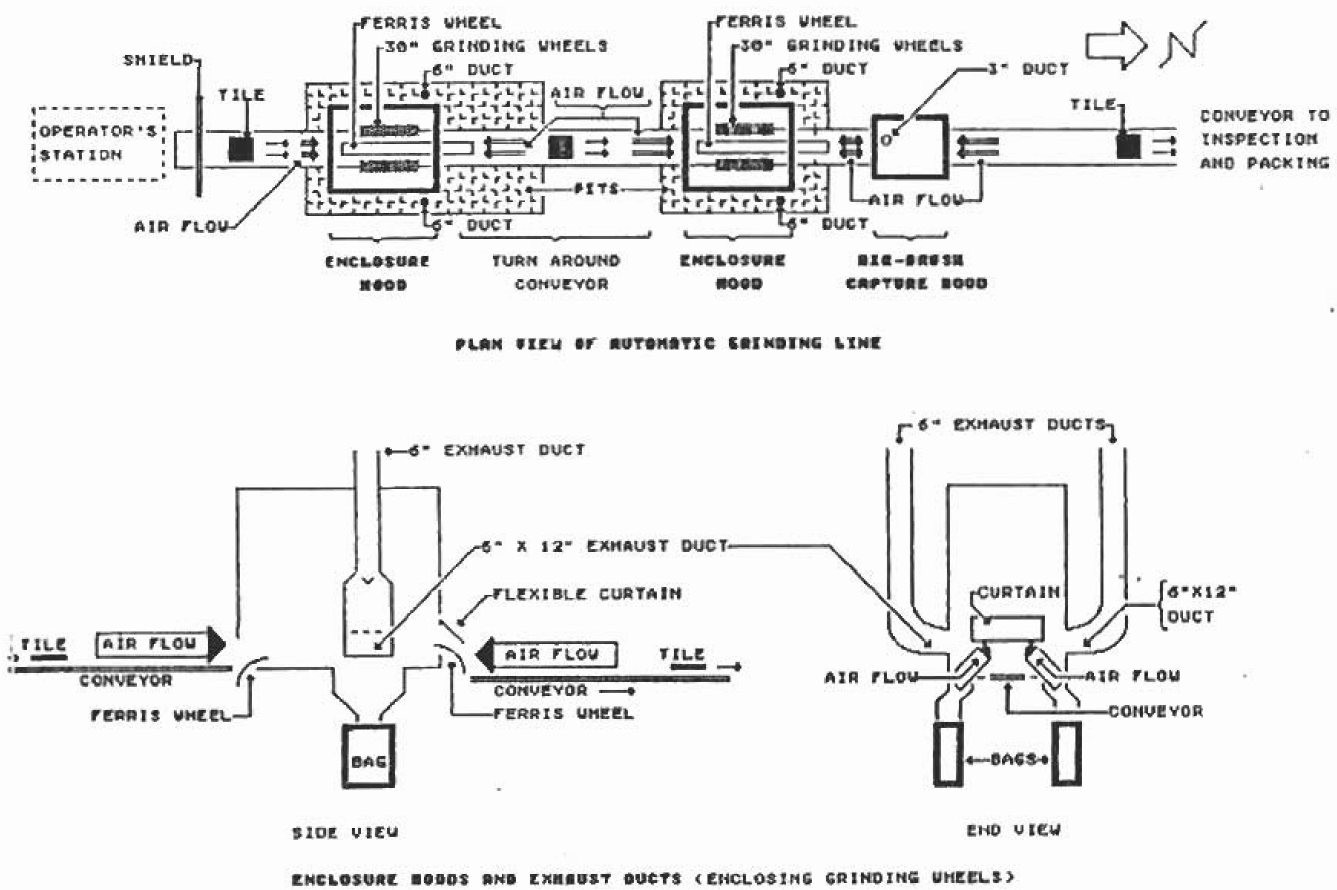


Figure 6 - Automatic Grinder Local Exhaust Hoods

belts. After the second ferris wheel on each line, there is a hooded air brush for brushing dust from the tiles that discharges into a 3-inch vertical duct. The mean capture velocity measured 100 fpm at the hood opening. A more effective system to remove the dust from the hold down belts needs to be installed.

Measurements were taken in the 24-inch overhead exhaust duct approximately 20 feet downstream from the nearest automatic grinder branch duct entrance and approximately 40 feet upstream from the dust collector (Figure 4, Point C and Photo 2). This duct runs at a 40^{o} incline from the floor. The mean transport velocity at Point C was 2223 fpm (ACGIH recommends 3500 fpm[3]). The dust collector for the Grinding and Packing Department was rated at 10,000 cfm at 8 inches Standard Pressure with an air-to-cloth ratio of 2.72. Dust collected from these operations is very abrasive. Consideration should be given to the installation of replaceable linings in outside duct sections at curves and bends.

General air movement in the automatic grinder area is toward the heat source (kilns) during the heating season. Smoke tube checks indicate this movement is at a rate of approximately 30 fpm. Waste heat from the kilns is used to condition the inplant air during the heating season. The building is at atmospheric pressure and makeup air is supplied through wall openings. Ventilation for heat relief (comfort control) is supplied by two operator-controlled overhead axial flow, propeller-type fans. Overhead gas-fired heaters are available for use during cold weather. The layout of the automatic grinder operators work station is not conducive to good general air movement.

3. Sampling Results

The mean time-weighted average (TWA) concentrations for respirable crystalline silica (SiO_2) and total particulates for personal samples were below the PEL (see Table 3). Employees operating the automatic grinders and performing inspection and packing duties had an exposure level range of 19 to 46% of the PEL for respirable silica and 26 to 78% of the PEL for total particulates. Automatic grinder No. 1 and 2 Feeder total particulate exposure level was 18% of automatic grinder No. 1 area concentration, 28% of automatic grinder No. 2 area concentration, and 74% of the general grinding area concentration. Automatic grinder No. 3 and 4 Feeder total particulate exposure level was 81% of automatic grinder No. 3 area concentration, 46% of automatic grinder No. 4 area concentration, and 223% of the general grinding area concentration. The inspector/packers (stationed at the automatic grinder lines and hand grinding stations) mean total particulate exposure levels were 55% of automatic grinder Nos. 1 and 2 line mean area concentration, 50% of automatic grinder Nos. 3 and 4 line mean area concentration, and 189% of the general grinding area concentration. Automatic grinder Nos. 1 and 2 mean area total particulate concentration level was 411% and 269% respectively of the general grinding area concentration. Automatic grinder Nos. 3 and 4 mean area total particulate concentration level was 274% and 480% respectively of the general grinding area concentration.

Table 3. Automatic Grinding Mean TWA
Personal and Area Concentrations

Grouping	Respirable SiO_2 Number of Samples	Respirable SiO_2 % of PEL	Respirable SiO_2 Standard Deviation	Total Particulates Number of Samples	Total Particulates % of PEL	Total Particulates Standard Deviation
Auto. Gr. 1 & 2 Feeder	2	19	19	3	26	35
Auto. Gr. 1 Area	-	-	-	6	144	64
Auto. Gr. 2 Area	-	-	-	6	94	50
Auto. Gr. 3 & 4 Feeder	3	26	19	3	78	36
Auto. Gr. 3 Area	-	-	-	6	96	69
Auto. Gr. 4 Area	-	-	-	6	168	115
Inspectors/Packers	12	46	29	11	66	37
Gen. Grinding Area	-	-	-	6	35	12

4. Discussion

While it is also evident that the automatic grinder operations are significant sources of crystalline silica (13 percent of respirable fraction and 21 percent of total particulates - Appendix), the resultant worker exposure is reduced due to the overall control of these emissions. Although there are some minor design and operational deficiencies affecting potential exposure levels, (e.g. effects of grinding wheel rotation on capture velocity, excess dust deposit in pits, excess dust carriage on conveyor belts, duct maintenance at outside curves and bends, and location of feeder station) the local exhaust ventilation system generally controls dust emissions from the automatic grinding operations.

C. Use of Local Exhaust Ventilation for Controlling Dust Emissions from Clay Crushing Processes

1. Description of Process

The Crushing Department is located in a separate building from the tile production area. It is open on one side and has large overhead doors on two sides. The operation has two crushing lines consisting of clay storage piles, raw material feeder bins, dry pans, vibrating screens, and additive feeders. There are two crusher operators involved in the operation, one on each line. The clay raw materials are stored and handled in an area open to and contiguous to both crushing lines. These materials are transported from storage piles by front-end loaders and dumped into feeder bins. The material is fed onto conveyor belts where it is transported to dry pans for crushing. It is conveyed to vibrating screens for classifying and additive feeders for the blending of manganese dioxide, barium carbonate, and calcium carbonate in predetermined amounts. The crusher operators manually break 50-pound bags of the additive material for blending into the crushed and sized clay to produce the desired tile body material. In addition, they maintain surveillance of the crushing equipment and perform various housekeeping duties.

2. Description of Controls

The crushed clay is ploughed from a belt conveyor into hoppers that discharge onto four vibrating screens on both Lines 23 and 24. The enclosed screens are equipped with two 5-inch exhaust ducts. If the screen local exhaust capture velocity is too high raw materials are wasted. Each line has three 7-inch diameter plain opening exhaust ducts above the screens and 7 feet above the balcony floor line. These 7-inch duct openings are equipped with blast gates. The mean exhaust duct inlet velocity on both lines was approximately 2500 fpm. The mean velocity at the operator breathing zone level was 28 fpm on Line 23 and 83 fpm on Line 24. Both operators wear dust masks when breaking bags and feeding blenders. The blender material discharge opening should be enclosed. The 7-inch plain opening exhaust ducts should be redesigned so they more effectively and efficiently exhaust the blending operations.

Measurements were taken in Line 23 overhead exhaust duct 10 feet upstream from the dust collector and 10 feet downstream from the nearest branch entrance (Figure 7, Point D and Photo 4). This duct measures 22 inches in diameter and runs parallel to the floor. The mean transport velocity at Point D was 2701 fpm (ACGIH recommends 3500 fpm[3]). The dust collector for Line 23 was rated at 10,000 cfm at 8-inch Standard Pressure with an air-to-cloth ratio of 2.72. Measurements were taken in Line 24 overhead exhaust duct 12 feet upstream from the dust collector and 10 feet downstream from the nearest branch entrance (Fiugure 7, Point E and Photo 4). This duct measures 22 inches in diameter and runs parallel to the floor. The mean transport velocity at Point E was 3797 fpm (ACGIH recommends 3500 fpm[3]). The dust collector for Line 24 was rated at 16,500 cfm at 8 inches Standard Pressure with an air-to-cloth ratio of 3.08. The collector discharge gate was one-third closed. A U-Tube manometer on the collector showed a 4-inch water pressure drop across the filters.

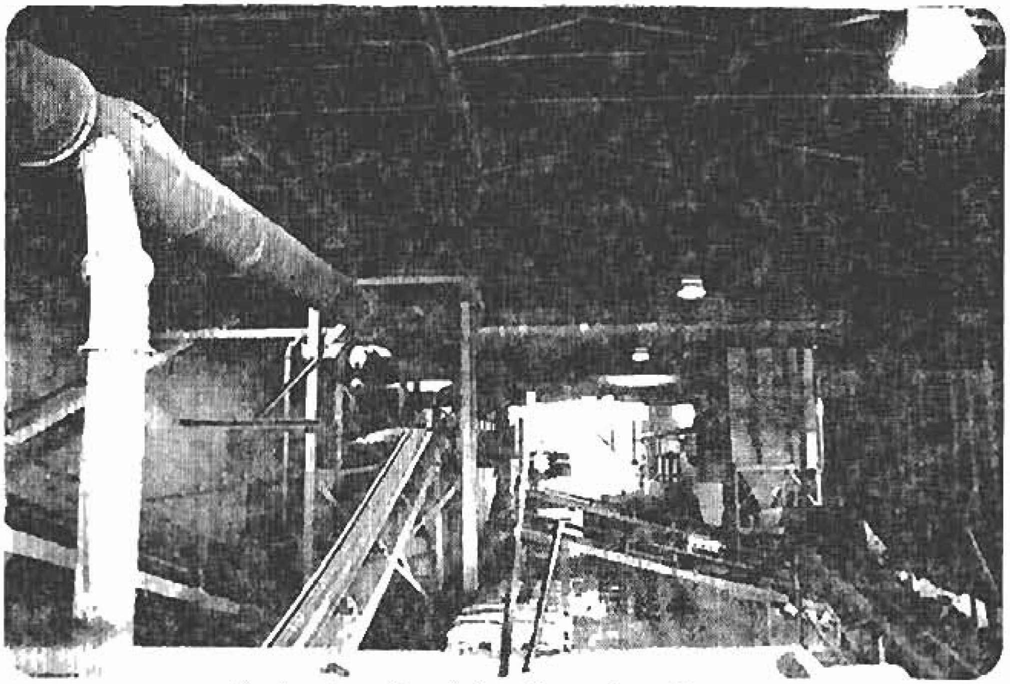


Photo 4 - Crushing Department

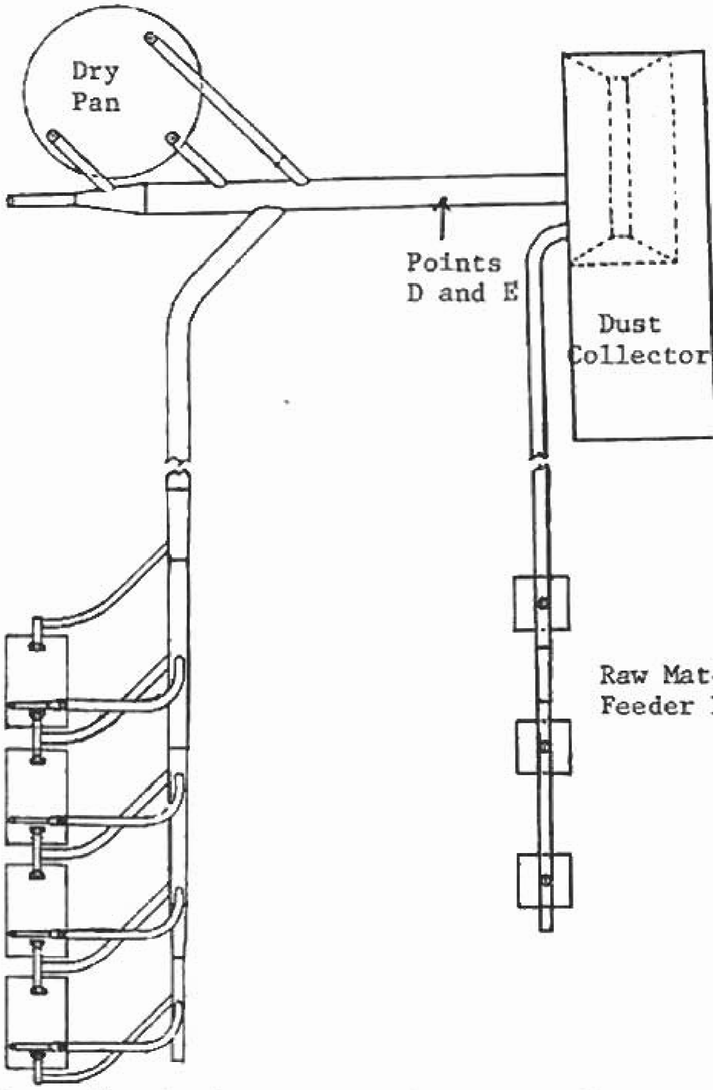


Figure 7 - Crushing Line Exhaust Ventilation System

The reason for partial closure of the discharge gate should be determined. General air movement in the crushing area is greatly influenced by climatic conditions as the operations are conducted in a separate building with one side open and large overhead doors on two sides. The fourth side is adjacent to the production building with two 6-feet by 6-feet, 8-inches interconnecting wall openings. Psychrometer readings taken between lines 23 and 24 indicated a temperature of 52°F dry bulb, 44°F wet bulb, and 55 percent relative humidity. Air movement from the production building into the crusher building measured approximately 150 fpm. Air movement through the West overhead door into the crusher building measured approximately 600 fpm. Consideration should be given to isolating the clay raw materials storage and front-end loading operations from the crushing area.

3. Sampling Results

The mean time-weighted average (TWA) concentrations for respirable crystalline silica (SiO_2) and total particulates for personal and area samples were at or above the PEL (see Table 4). Employees operating crusher Lines 23 and 24 had a mean respirable silica exposure level of 100% and 113% of the PEL and a mean total particulate exposure level of 438% and 292% of the PEL, respectively. Line 23 Crusher Operator total particulate exposure level was 220% of crusher Line 23 area concentration and 234% of the general crushing area concentration. Line 24 Crusher operator total particulate exposure level was 193% of crusher Line 24 area concentration and 156% of the general crushing area concentration.

Table 4. Crushing Mean TWA
Personal and Area Concentrations

Grouping	Respirable SiO_2 Number of Samples	% of PEL	Standard Deviation	Total Particulates Number of Samples	% of PEL	Standard Deviation
Crusher Oper. Line 23	3	100	13	3	438	72
Crusher Line 23 Area	–	–	–	8	199	121
Crusher Oper. Line 24	2	113	26	3	292	226
Crusher Line 24 Area	–	–	–	12	151	51
Gen. Crushing Area	–	–	–	3	187	47

4. Discussion

The crusher operations are significant sources of crystalline silica, 19 percent of respirable fraction and 24 percent of total particulates (Appendix). Although employee exposure levels for respirable crystalline silica (100% and 113% of the PEL) were reduced to a marginal level, total particulate exposure levels were well above the PEL (292% and 438%). This clearly indicates the ineffectiveness of the local exhaust ventilation system. This ineffectiveness appears to be principly due to the crushing area layout and design although duct design, blender discharge open transfer points, and collector discharge gate operation are potential contributors.

V. OBSERVATIONS, CONCLUSIONS, AND RECOMMENDATIONS

The local exhaust system in the grinding area is effectively controlling the dust from the grinding wheels. Since its' effectiveness is greatly affected by the wheels rotation a redesign of the exhaust hoods should be considered. If the particles which are now being carried around the wheels and discharged into the operator's breathing zone (and onto equipment bearing surfaces) were stripped off the wheel inside the exhaust hood its' effectiveness would be further enhanced.[1,2,3,4]

The automatic grinder ferris wheel hold down belts are carrying considerable amounts of ground particulate matter out of the exhaust enclosure hoods. A ventilation technique (combined with mechanical brushing) should be considered and should be worthwhile.

Due to the abrasiveness of the particulate matter in the high velocity airstream within the ventilation ductwork all directional changes result in a "sand blast" effect on the internal surfaces. The repair, replacement is costly and the systems effectiveness is adversely affected. In order to offset these conditions consideration should be given to inserting replaceable, lined, and prefabricated sections of ductwork where operating expense has shown maintenance to be most frequent.

The local exhaust system in the crusher area appears to be adequate to accomplish the desired task. If the raw materials handling operations (in the stockpiling area) could be physically isolated from the crushing, blending, and milling operations, it's effectiveness should be increased. Redesign of the exhaust duct pick-up hoods in the vicinity of the blenders and screens should be considered. The plain duct openings, as they are presently being used, are not effective. An improved design for the enclosure of the blender discharge chute should also reduce emissions.

Where there are long horizontal ductwork runs, such as that between the hand grinder and automatic grinder lines a clean out/inspection door is advisable. There was a deposit of approximately 1 inch in this run at the time of this study.

VI. REFERENCES

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2. ANSI, Inc. American National Standard for Ventilation Control of Grinding, Polishing, and Buffing Operations. ANSI Z43.1-1966. New York, 1966.

3. American Conference of Governmental Industrial Hygienists, Committee on Industrial Ventilation. Industrial Ventilation, A Manual of Recommended Practice. Edwards Brothers, Inc., Ann Arbor, 1980.

4. Crouch, K., O'Brien, D., Johnston, O. Development of Particulate Emission Controls for High Speed Snagging Grinders. NIOSH Unpublished Report, 1982.

VII. APPENDIX

A. Employee Exposure (mg/m^3)

		Respirable				Total Particulates			
Job Description	Day	% SiO_2	TWA	PEL	% PEL	% SiO_2	TWA	PEL	% PEL
Hand Grinder No. 1	1	20*	0.26	0.45	58	20*	0.05	1.36	4
	2	20*	0.07	0.45	16	25	1.19	1.11	107
	3	20*	0.28	0.45	62	18	0.53	1.50	35
Mean		20*	0.20	0.45	44	23	0.60	1.20	50
Hand Grinder No. 2	1	20*	0.16	0.45	36	-	-	-	-
	2	20*	0.38	0.45	36	20	1.00	1.36	74
	3	20*	0.23	0.45	51	23	0.72	1.20	60
Mean		20*	0.25	0.45	57	21	0.81	1.30	62
Inspector/Packer No. 1	1	20*	0.23	0.45	51	25	1.01	1.11	91
	2	20*	0.51	0.45	113	24	1.13	1.15	98
	3	20*	0.24	0.45	53	20	1.30	1.36	96
Mean		20*	0.33	0.45	73	22	1.15	1.25	92
Inspector/Packer No. 2	1	20*	0.00	0.45	0	20*	0.00	1.36	0
	2	20*	0.30	0.45	67	23	0.78	1.20	65
	3	20*	0.16	0.45	36	17	0.67	1.58	42
Mean		20*	0.16	0.45	35	20	0.49	1.36	36
Inspector/Packer No. 3	1	20*	0.00	0.45	0	27	1.00	1.03	97
	2	20*	0.29	0.45	64	22	1.03	1.25	82
	3	20*	0.23	0.45	51	24	1.42	1.15	123
Mean		20*	0.17	0.45	39	24	1.15	1.15	100
Inspector/Packer No. 4	1	20*	0.12	0.45	27	-	-	-	-
	2	20*	0.24	0.45	53	20*	0.09	1.36	7
	3	20*	0.23	0.45	51	18	0.89	1.50	59
Mean		20*	0.20	0.45	44	19	0.50	1.43	35
Corner Grinder	1	20*	0.14	0.45	31	-	-	-	-
	2	20*	0.30	0.45	67	-	-	-	-
	3	20*	0.15	0.45	33	-	-	-	-
Mean		20*	0.19	0.45	42	-	-	-	-
Automatic Grinder Feeder 1 & 2	1	20*	0.00	0.45	0	20*	0.00	1.36	0
	2	11	0.30	0.77	39	29	0.75	0.97	77
	3	-	-	-	-	20*	0.05	1.36	4
Mean		11	0.15	0.77	19	28	0.26	1.00	26

A. Employee Exposure (mg/m^3) (Cont'd)

Job Description	Day	Respirable				Total Particulates			
		% SiO_2	TWA	PEL	% PEL	% SiO_2	TWA	PEL	% PEL
Automatic Grinder	1	20*	0.00	0.45	0	16	0.93	1.67	56
Feeder 3 & 4	2	11	0.30	0.77	39	23	1.52	1.20	127
	3	20*	0.18	0.45	40	17	0.75	1.58	47
Mean		14	0.16	0.62	26	20	1.06	1.36	78
Crusher Operator	1	21	0.47	0.43	109	22*	6.38	1.25	510
No. 8113 - Line 23	2	14	0.51	0.63	81	22*	4.20	1.25	336
	3	22	0.46	0.42	110	28*	4.43	1.00	443
Mean		19	0.48	0.48	100	24	5.04	1.15	438
Crusher Operator	1	-	-	-	-	22*	0.37	1.25	30
No. 8707 - Line 24	2	16	0.46	0.56	82	22*	7.26	1.25	581
	3	22	0.56	0.42	133	28*	2.71	1.00	271
Mean		20	0.51	0.45	113	24	3.36	1.15	292

* Based on respirable bulk air sample.

B. Area Samples - Air Concentration (mg/m^3)

Area/Operation/Equipment	Sample Site No.	Day	% SiO_2	PEL	TWA	% of PEL
Automatic Grinder No. 1	1	1	28	1.00	1.94	194
West Side		2	26	1.07	1.22	114
		3	29	0.97	2.44	252
	Mean		28	1.00	1.88	188
East Side	4	1	32	0.88	0.84	95
		2	29	0.97	1.17	121
		3	28	1.00	0.64	64
	Mean		30	0.94	0.89	95
Mean			29	0.97	1.40	144
Automatic Grinder No. 2	2	1	30	0.94	0.85	90
West Side		2	29	0.97	1.09	112
		3	27	1.03	1.96	190
	Mean		28	1.00	1.33	133
East Side	3	1	27	1.03	0.70	68
		2	25	1.11	0.57	51
		3	29	0.97	0.41	42
	Mean		27	1.03	0.55	53
Mean			28	1.00	0.94	94
Automatic Grinder No. 3	5	1	28	1.00	1.49	149
West Side		2	18	1.50	1.27	85
		3	29	0.97	2.21	228
	Mean		26	1.07	1.66	155
East Side	8	1	23	1.20	0.45	38
		2	25	1.11	0.74	67
		3	24	1.15	0.33	29
	Mean		24	1.15	0.51	44
Mean			25	1.11	1.07	96
Automatic Grinder No. 4	6	1	27	1.03	3.10	301
West Side		2	13	2.00	6.11	306
		3	22	1.25	2.88	230
	Mean		19	1.43	4.07	285

B. Area Samples - Air Concentration (mg/m^3) (Cont'd)

Area/Operation/Equipment	Sample Site No.	Day	% SiO_2	PEL	TWA	% of PEL
East Side	7	1	26	1.07	0.60	56
		2	23	1.20	0.86	72
		3	29	0.97	0.34	35
	Mean		25	1.11	0.59	53
Mean			20	1.36	2.28	168
Automatic Grinder Grand Mean			24	1.15	1.42	123
Corner Grinder	9	1	27	1.03	0.48	47
		2	27	1.03	0.27	26
		3	25	1.11	0.44	40
	Mean		26	1.07	0.39	36
Hand Grinder No. 2	10	1	18	1.50	0.39	26
		2	20	1.36	0.75	55
		3	23	1.20	0.32	27
	Mean		20	1.36	0.49	36
	11	1	22	1.25	0.51	41
		2	24	1.15	0.75	65
		3	24	1.15	0.40	35
	Mean		24	1.15	0.55	48
Mean			22	1.25	0.52	42
Hand Grinder No. 1	12	1	32	0.88	0.35	40
		2	25	1.11	0.41	37
		3	24	1.15	0.26	23
	Mean		27	1.03	0.34	33
	13	1	26	1.07	0.30	28
		2	25	1.11	0.53	48
		3	27	1.03	0.15	15
	Mean		25	1.11	0.33	30
Mean			26	1.07	0.34	32

B. Area Samples - Air Concentration (mg/m^3) (Cont'd)

Area/Operation/Equipment	Sample Site No.	Day	% SiO_2	PEL	TWA	% of PEL
Hand & Corner Grinder Grand Mean			24	1.15	0.43	37
General Grinding Area	14	1	31	0.91	0.37	41
Southeast Corner		2	25	1.11	0.63	57
		3	22	1.25	0.28	22
	Mean		26	1.07	0.43	40
Northwest Corner	15	1	29	0.97	0.34	35
		2	23	1.20	0.44	37
		3	23	1.20	0.26	22
	Mean		24	1.15	0.35	30
Mean			25	1.11	0.39	35
Total Grinding Grand Mean			24	1.15	0.95	83
Crushing Line No. 23	21	1	40	0.71	0.50	70
		2	57	0.51	0.74	145
		3	38	0.75	1.33	177
	Mean		44	0.65	0.86	132
	22	1	22*	1.25	4.47	358
		2	22*	1.25	4.73	378
		3	-	-	-	-
	Mean		22	1.25	4.61	369
	23	1	38	0.75	1.52	203
		2	20	1.36	4.11	302
		3	-	-	-	-
	Mean		25	1.11	2.85	257
	24	1	-	-	-	-
		2	-	-	-	-
		3	28*	1.00	0.25	25
	Mean		28	1.00	0.25	25
Mean			26	1.07	2.13	199

B. Area Samples - Air Concentration (mg/m^3) (Cont'd)

Area/Operation/Equipment	Sample Site No.	Day	% SiO_2	PEL	TWA	% of PEL
Crushing Line No. 24	17	1	22*	1.25	2.31	185
		2	22*	1.25	2.22	178
		3	28*	1.00	0.53	53
	Mean		23	1.20	1.69	141
	18	1	30	0.94	1.76	187
		2	22	1.25	2.52	202
		3	32	0.88	0.69	78
	Mean		28	1.02	1.66	163
	19	1	16	1.67	3.53	211
		2	24	1.15	2.06	179
		3	39	0.73	0.68	93
	Mean		26	1.18	2.09	177
	20	1	27	1.03	1.35	131
		2	34	0.83	1.00	120
		3	51	0.57	1.06	186
	Mean		38	0.81	1.14	141
Mean			26	1.07	1.62	151
General Crushing Area	16	1	48	0.60	1.07	178
		2	38	0.75	1.01	135
		3	33	0.86	2.13	248
	Mean		38	0.75	1.40	187

* Based on respirable bulk air sample.