ASSESSMENT OF DUST CONTROL TECHNOLOGY

FOR

SELECTED CERAMIC PRODUCTION PROCESSES

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Personal exposure samples were collected on two automatic grinder feeders, two hand grinder operators, one corner grinder operator, and four inspector/packers for 8-hours each day for three consecutive days. As shown in Figure 12, the distribution of personal exposures appear to be normally distributed. The average exposure was 59% of the PEL.

Employees operating the automatic grinders had an exposure level range of 19 to 26 per cent of the PEL for Respirable Dust and 26 to 78 per cent of the PEL for Total Dust. Automatic Grinder Nos. 1 and 2 feeder, Total Dust exposure level was 18 per cent of Automatic Grinder No. 1 concentration, 28 per cent of Automatic Grinder No. 2 concentration, and 74 per cent of the general grinding area concentration. Automatic Grinder Nos. 3 and 4 feeder Total Dust exposure level was 81 per cent of Automatic Grinder No. 3 concentration, 46 per cent of Automatic Grinder No. 4 concentration, and 223 per cent of the general grinding area concentration.

Employees operating the hand and corner grinders had an exposure level range of 42 to 51 per cent of the PEL for Respirable Dust and 57 per cent of the PEL for Total Dust. The hand grinder operators Total Dust exposure level was 154 per cent of the hand grinder concentration and 163 per cent of the general grinding area concentration. Employees performing inspection/packing duties in the grinding area had an exposure level of 46 per cent of the PEL for Respirable Dust and 66 per cent of the PEL for Total Dust.

The inspector/packers (stationed at the automatic grinder lines and hand grinding stations) mean total particulate exposure levels were 55 per cent of Automatic Grinder Nos. 1 and 2 line mean concentration, 50 per cent of Automatic Grinder Nos. 3 and 4 line mean concentration, 178 per cent of the hand grinder mean concentration, and 189 per cent of the general grinding mean area concentration. The total particulate mean concentrations for the hand grinders, corner grinder,

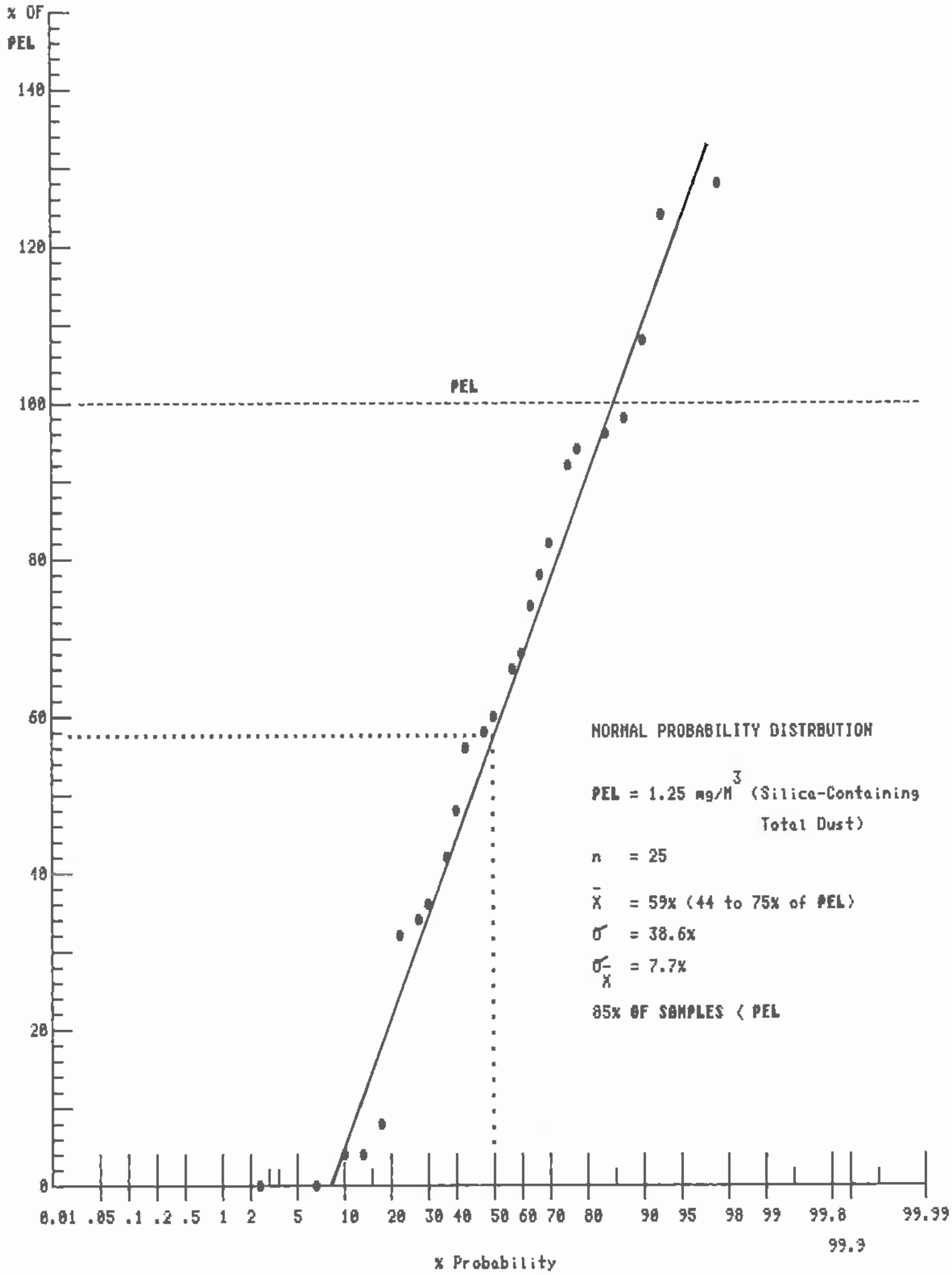


FIGURE 12 - PERSONAL EXPOSURES TO TOTAL DUST, SITE C - QUARRY TILE GRINDING

and general grinding area were essentially the same (35 - 37 per cent of the PEL).

Although some of the grinding area hood capture velocities and all of the duct transport velocities were generally low, the local exhaust ventilation system adequately controlled dust emissions below the OSHA Standard. The mean capture velocity measured 300 fpm at the automatic grinder hood openings when the wheels were operating (ACGIH recommends 200 fpm)[13] and 1000 fpm when the wheels were not operating. The mean capture velocity measured 30 fpm at the hand grinder hood openings (ACGIH recommends 200 fpm)[13] and 25 fpm at the shield. The mean capture velocity measured 95 fpm at the corner grinder hood opening (ACGIH recommends 200 fpm) and 40 fpm at the shield.

The mean transport velocity measured 1855 fpm (ACGIH recommends 3500 fpm)[13] at Point A 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 9). The mean transport velocity measured 1411 fpm (ACGIH recommends 3500 pm) at Point B in the 13-inch overhead exhaust duct 20 feet downstream from the hand grinder 6-inch branch duct entrance and 40 feet upstream from the nearest automatic grinder branch duct entrance (Figure 9). The mean transport velocity measured 2223 fpm (ACGIH recommends 3500 fpm) at Point C in the 24-inch overhead exhaust duct 20 feet downstream from the nearest automatic grinder branch duct entrance and 40 feet upstream from the dust collector (Figure 9).

D. Batching, Mixing and Packaging of Ceramic Materials in the Refractory Industry (Site D)[10]

1. Process Description

At the fourth site, various types of refractory products are produced, such as bricks, patches, ramming mixes, cements, castables and plastics.

Raw materials used in these products include: clay, zircon, alumina, chrome oxide, mullite, kyanite, liquid silicates and phosphate binders.

The operations of storage, batching, mixing, and packaging are carried out in a single story building (Figure 13), according to the process flow shown in Figure 14.

Receipt and Storage of Materials

Raw materials are received by truck and rail. Those in a solid state, which are generally transported in sacks or cardboard containers, are stored inside the building and moved to batching operations by fork truck. Liquid raw materials are pumped into large storage tanks inside the building.

Batching

Batching is performed at one of seven batching and packing stations. Raw materials are dumped into a series of skip hoist buckets. Sacks are normally cut open and shaken either directly into the skip hoist or indirectly through a vibrating screen. When the proper batch formulation is completed, the skip hoist bucket is elevated and dumped into a mixer. Empty sacks are hand carried by the operator to the incinerator located outside the building.

Mixing

Mixing operations may be either wet or dry. They are programmed to achieve a uniform mixture of the formulated raw materials. The nature of the mixing operation is dependent upon the desired characteristics of the final product being produced. Its consistency varies from a dry powdery mix, which is bagged; to a plastic mix, which is extruded and packaged; to a slurry, which is poured into pails or other types of closed containers.

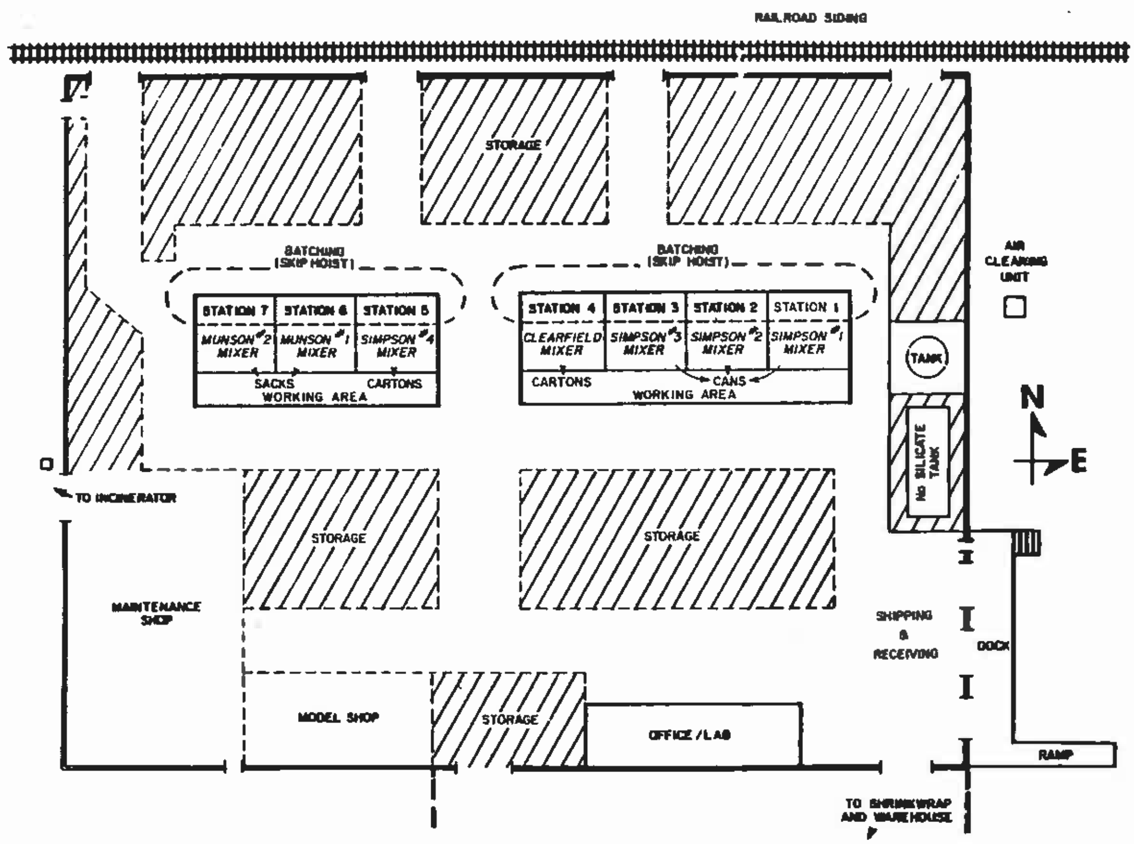


Figure 13 - Plant Layout

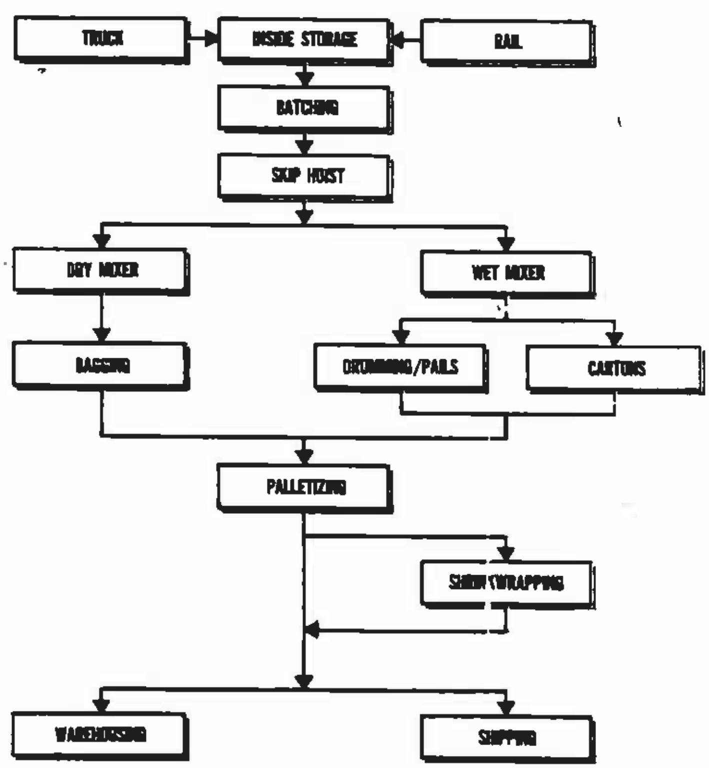


Figure 14 - Process Flow

Packaging

Packaging operations involve the filling of bags, drums, pails and cartons. Single spout bagging machines are used to fill pasted valve bags with dry granular finished products.

Highly plastic products, such as cements, ramming mixes, and patching mixes are fed by gravity into drums and pails. Cartons and/or individual wraps are used to package brick and other pressure formed (extruded) finished products.

2. Controls

Exposures to airborne dust during batching, mixing and packaging operations are maintained at levels below the OSHA Standard by a dust control program that includes:

- o Engineering controls - including plant layout, equipment designs, and the use of local exhaust and general ventilation systems.
- o Good work practices - including housekeeping procedures, the encouragement of safety awareness by incentive awards, and active safety committee work.
- o Use of personal protective equipment - including dust respirators, hard hats and clothing.

a. Engineering Controls

Plant Layout

Several factors for effective control of dust sources were incorporated into the design of this facility. The seven mixing/blending/packaging stations were aligned adjacent to each other so that a centralized local exhaust ventilation system could operate most efficiently.

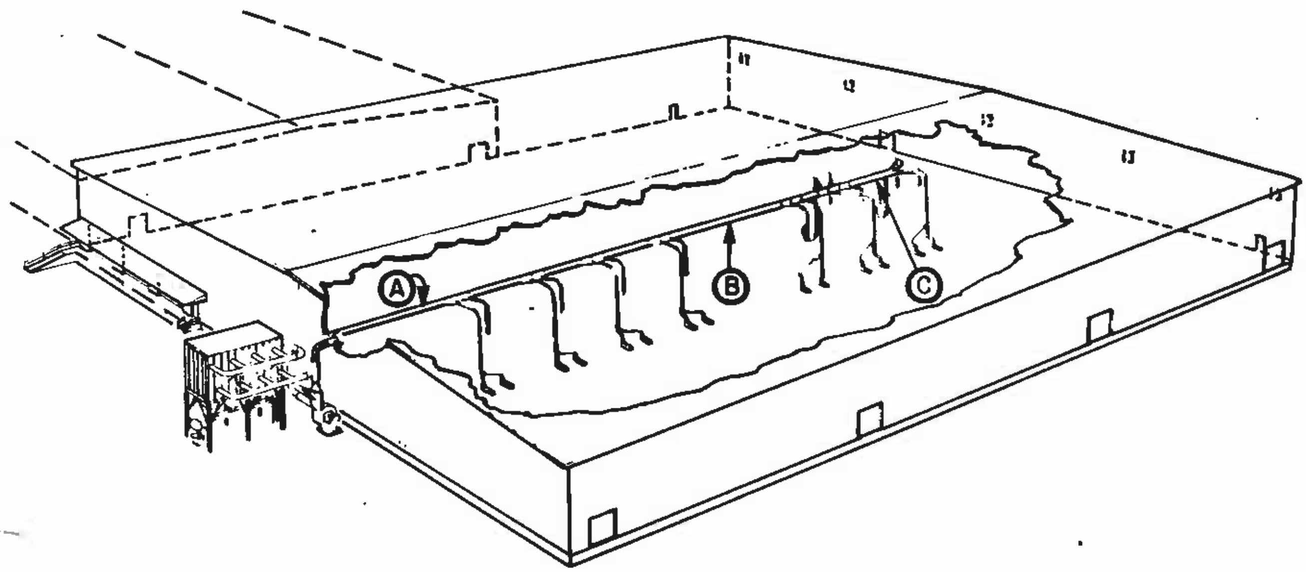
Equipment and facilities were designed so that effective end-of-shift washdown could be accomplished to minimize redispersion of spilled product into the atmosphere. The baghouse dust collector is located outside, on the downwind side of prevailing winds. This location minimizes recirculation of the baghouse effluent into the building.

Equipment Design

Major potential dust emission sources, such as skip hoist buckets and mixers, are enclosed and operate under negative pressure to reduce environmental dust dispersion. Manual and semi-automatic material handling systems are used to fill different sized drums and pails with various refractory products. Since these products are a wet slurry or plastic, and therefore, dust-free, no local exhaust ventilation is needed for container filling. Dry product, however, may be an atmospheric dust source during bag filling. Therefore, a special pasted valve bag is used in bag filling. Dust dispersion from filled bags is further reduced by shrink wrapping loaded pallets.

Local Exhaust Ventilation Systems

All major potential dust sources, which are not completely enclosed, are provided with local exhaust hoods. These hoods are connected to a central duct trunk by a series of branch ducts from each work station (Figure 15).



NOTE:

POSITION	A	- DUCTWORK	DIAMETER	33"	AVERAGE AIR FLOW	3782 FPM
	B	- "	"	23"	" " "	3075 "
	C	- "	"	16"	" " "	2792 "

Figure 15 - Exhaust System Ductwork

At each batching station, ventilation hoods are located on each side of the loading bucket (Figure 16). Additional exhaust ventilation moves air upward through the rear of the bucket elevator.

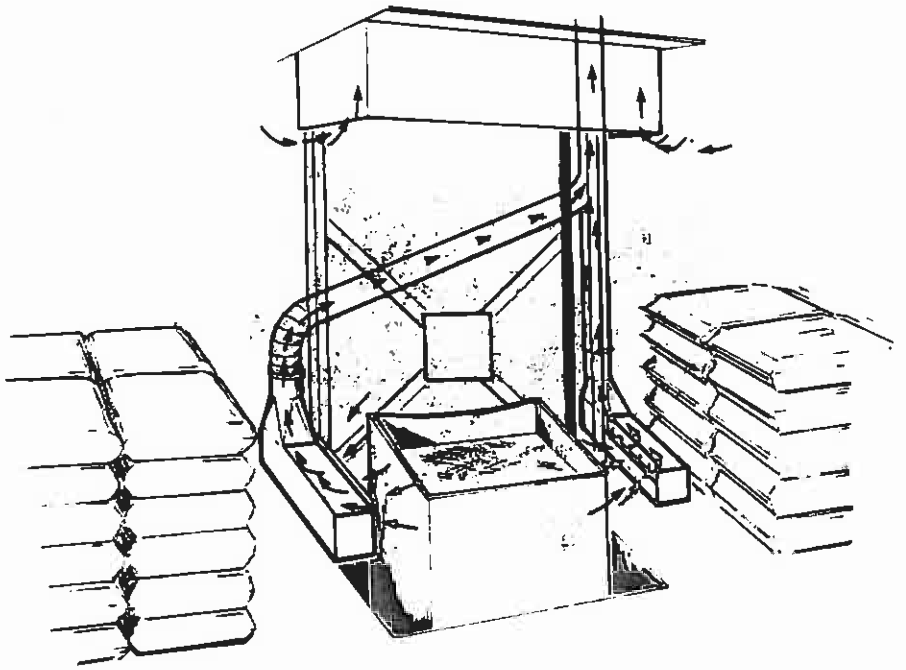


Figure 16 - Typical Batching Station Air Flow

Enclosed mixers, above the batching stations, are also exhausted or under negative pressure to insure dust control. The single spout bag packing machines are also provided with dust collection hoods (Figure 17), which are connected to the central dust collection system. Ventilation system efficiency on the batching stations, mixers, and bag packing machines could be improved by incorporation of design features illustrated in Section 5 of the Industrial Ventilation Manual.[15]

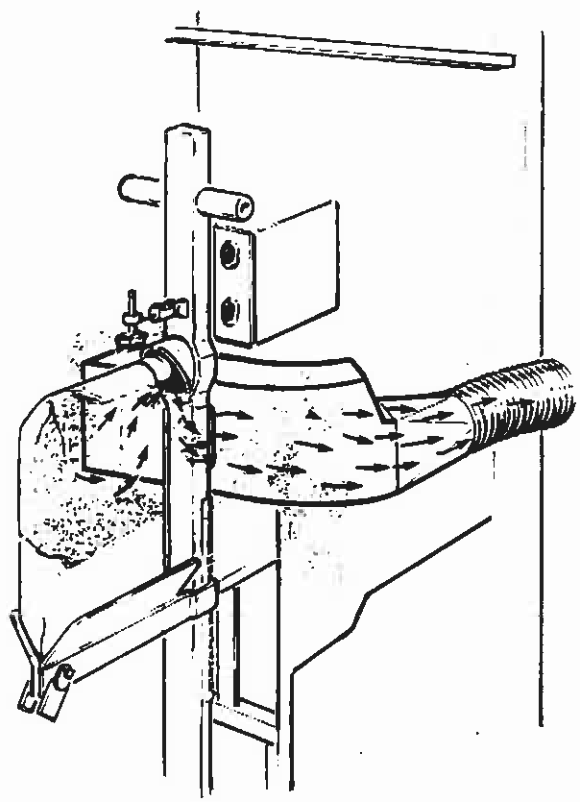


Figure 17 - Typical Bagging Station Air Flow

General Ventilation System

In addition to natural ventilation, developed by open doors and bays, general building ventilation is augmented by five axial-flow exhaust fans located at the west end of the building near the roof line. These fans, which may move approximately 25,400 cfm each (total of 127,000 cfm), provide approximately one air change per hour of outside air. The primary purpose of this system is to remove super-heated air from the building, particularly during hot summer weather.

b. Work practices

One of the very effective elements of this site's dust control program involves an excellent housekeeping program. Required end-of-shift wash down of all work stations greatly reduces the potential for re-entrainment of dust spilled during the day. A large, mobile, industrial vacuum sweeper is also used to clean aisles and warehouse area floors. Sweeping compound is readily available to help clean up spills.

Other good work practices, including good safety, health and housekeeping records, are rewarded with incentive awards. Gifts can be selected, based on the accumulation of "good work practice" points. Health and Safety surveys are made monthly by a union/management team, and "tail gate" type safety and health meetings are held with employees on an "as needed" basis.

c. Personal Protective Equipment Program

NIOSH/MSHA approved dust respirators are available and worn on selected jobs. Their use is mandatory at some locations and during the performance of some activities. Bump type hard hats, safety shoes, safety glasses and laundered work uniforms are also provided, at no cost, to all employees.

3. Sampling Results and Control Effectiveness

The dry raw materials and the finished products handled in this plant, such as clay, zircon, alumina, liquid silicates and phosphates, are generally considered to be "nuisance" dusts. Their toxicities, by inhalation, are determined by their crystalline silica (quartz) content. Bulk dust samples, collected from dust collector cleanouts, and rafter samples on ventilation ducts, contained an average of 6.7 per cent crystalline silica as quartz. The calculated PEL (Total Dust) for such material is 3.45 mg/m^3; the PEL (Respirable Dust) is 1.15 mg/m^3.

Overall Control Effectiveness

Dust control effectiveness in this plant is excellent when compared to the OSHA Standard as indicated by an evaluation of both personal and area exposure levels to atmospheric dust (See Tables 7 and 8).

Personal Exposures

Personal exposure samples were collected during three days of normal operation. As shown in Figure 18, 12 of the 14 samples in the can filling area appear to be normally distributed and average 28% of the PEL. However, two samples were significantly greater than the average and probably resulted from (observed) poor work practices. As shown in Figure 19, 5 of the 6 samples in the bag filling area appear to be normally distributed and average 85% of the PEL. However, one sample was significantly greater than the average and probably resulted from (observed) poor work practices. Personal exposure to Total Dust averaged 2.09 mg/m^3 (range of 0.67 to 3.7 mg/m^3) or approximately 65% of the PEL. Personal exposure to Respirable Dust averaged 0.61 mg/m^3 (range 0.14 to 1.94 mg/m^3) or approximately 55% of the PEL.

Table 7. Personal Dust Exposures in Refractory Products Plant - Site D

Location/Operation	Total Dust Conc. mg/m^3	Total Dust Fraction of PEL	Respirable Dust Conc. mg/m^3	Respirable Dust Fraction of PEL
1. Station #1 - Simpson Mixer	2.15	0.62	1.94	1.68
2. Station #2 - Simpson Mixer	2.37	0.69	0.30	.26
3. Station #3 - Simpson Mixer	0.78	0.23	0.14	0.12
4. Station #5 - Simpson Mixer	1.30	0.38	0.17	0.15
5. Station #6 Munson Mixer #1 St. Regis Bagger	3.7	1.43	0.62	0.72
6. Station #7 Munson Mixer #2 St. Regis Bagger	3.18	0.92	0.53	0.46
7. Gel Caster, Model Shop	0.67	0.20	0.17	0.15
8. Plant Clean-up	2.56	0.74	1.00	0.87
Average Exposure	2.09	0.65	0.61	0.55
PEL (based on 6.7% SiO_2)	3.45		1.15	

Table 8. Average Area/Source Dust Exposures in Refractory Products Plant - Site D

Operations/Location	Dust Concentrations - Total Dust						Remarks
	Conc. mg/m^3	Fract. of PEL*	Conc. mg/m^3	Fract. of PEL*	Conc. mg/m^3	Fract. of PEL*	
A. Batching (Source)	Left Side		Right Side		Eye Level		
1. Work Station #1	1.36	0.39	0.41	0.12	0.42	0.12	Prior to wet mix
2. Work Station #2	8.54	2.48	0.82	0.24	0.40	0.12	" " " "
3. Work Station #3	1.72	0.50	0.49	0.14	0.32	0.09	" " " "
4. Work Station #6	17.55	5.18	3.22	0.93	0.63	0.18	Prior to dry mix
5. Work Station #7	5.62	1.63	3.06	0.89	0.23	0.07	" " " "
Average	6.96	2.04	1.60	0.46	0.40	0.11	
B Mixer Level (Source)							
1. Work Station #1					0.31	0.09	Wet mixer
2. Work Station #2					0.31	0.09	Wet mixer
3. Work Station #3					0.22	0.09	Wet mixer
4. Work Station #6					1.12	0.32	Dry mixer
5. Work Station #7					0.61	0.18	Dry mixer
Average					0.51	0.15	
C. At Bagger/Can Loader Station (Source)							
1. Work Station #1 (average)					0.63	0.18	Pouring mix into cans
2. Work Station #2 (average)					2.52	0.73	Pouring mix into cans
3. Work Station #3 (average)					0.69	0.22	Pouring mix into cans
Average of 1,2,3					1.28	0.38	

Table 8. Cont'd

Operations/Location	Dust Concentrations - Total Dust						Remarks
	Conc. mg/m^3	Fract. of PEL*	Conc. mg/m^3	Fract. of PEL*	Conc. mg/m^3	Fract. of PEL*	
4. Work Station #6 (eye level)					1.71	0.50	Bagging dry product
5. Work Station #7 (eye level)					0.97	0.28	Bagging dry product
Average of 4 & 5					1.34	0.39	
D. General Plant Areas							
1. NE storage area					0.37	0.11	
2. N. center storage area					0.33	0.10	
3. NW storage area					0.19	0.06	
4. Center storage area					0.36	0.10	
5. Main plant background					0.31	0.09	
Average in plant					0.31	0.09	
E. Background							
6. Air cleaner discharge					0.05	0.02	
7. Incinerator					0.33	0.10	
8. General outside background					0.14	0.04	
Average background					0.17	0.05	

* PEL (based on 6.7% SiO_2) = 3.45 mg/m^3

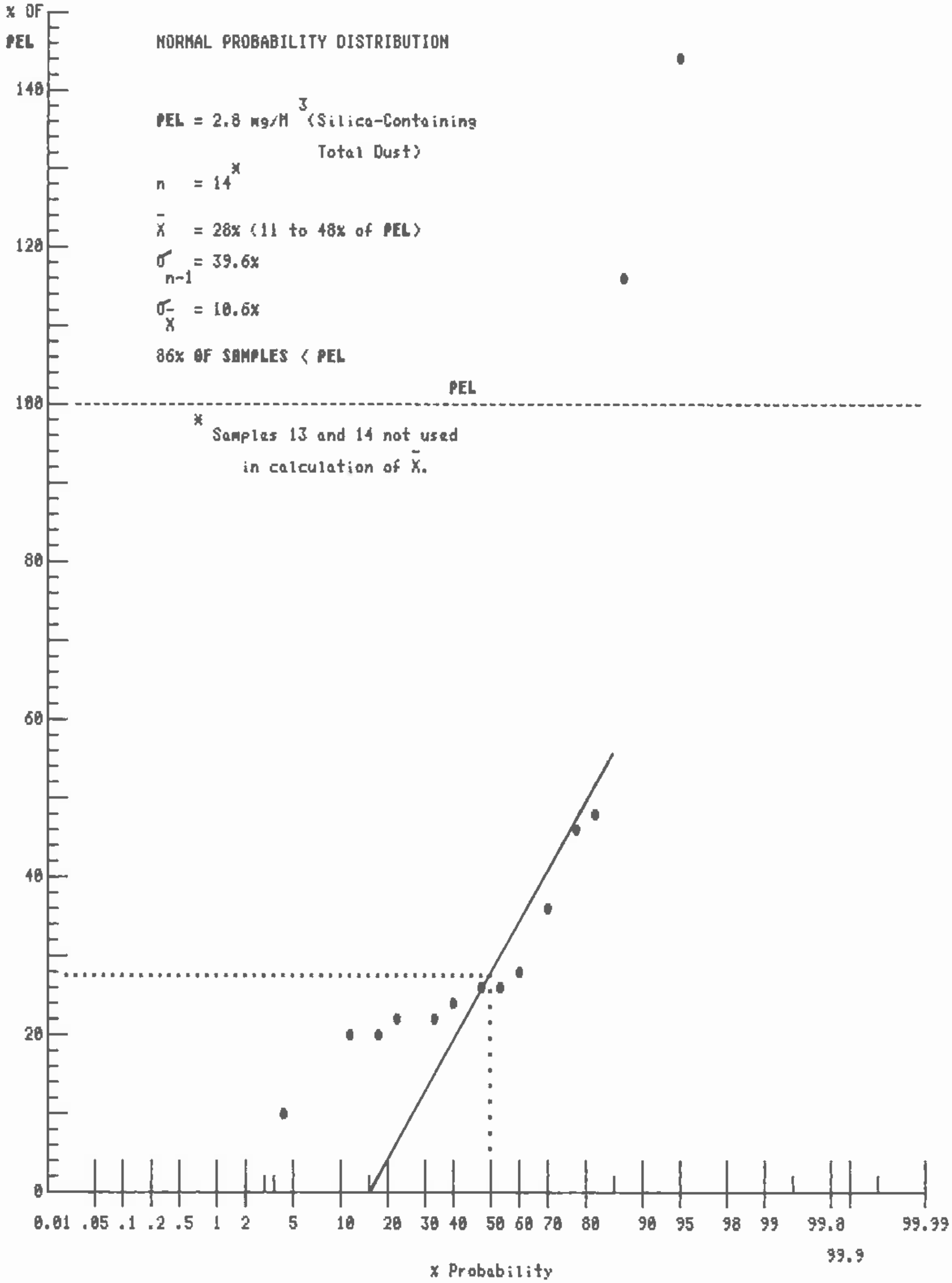


FIGURE 18: PERSONAL EXPOSURES TO TOTAL DUST, SITE D - FILLING CANS WITH SLURRY (REFRACTORY PRODUCT)

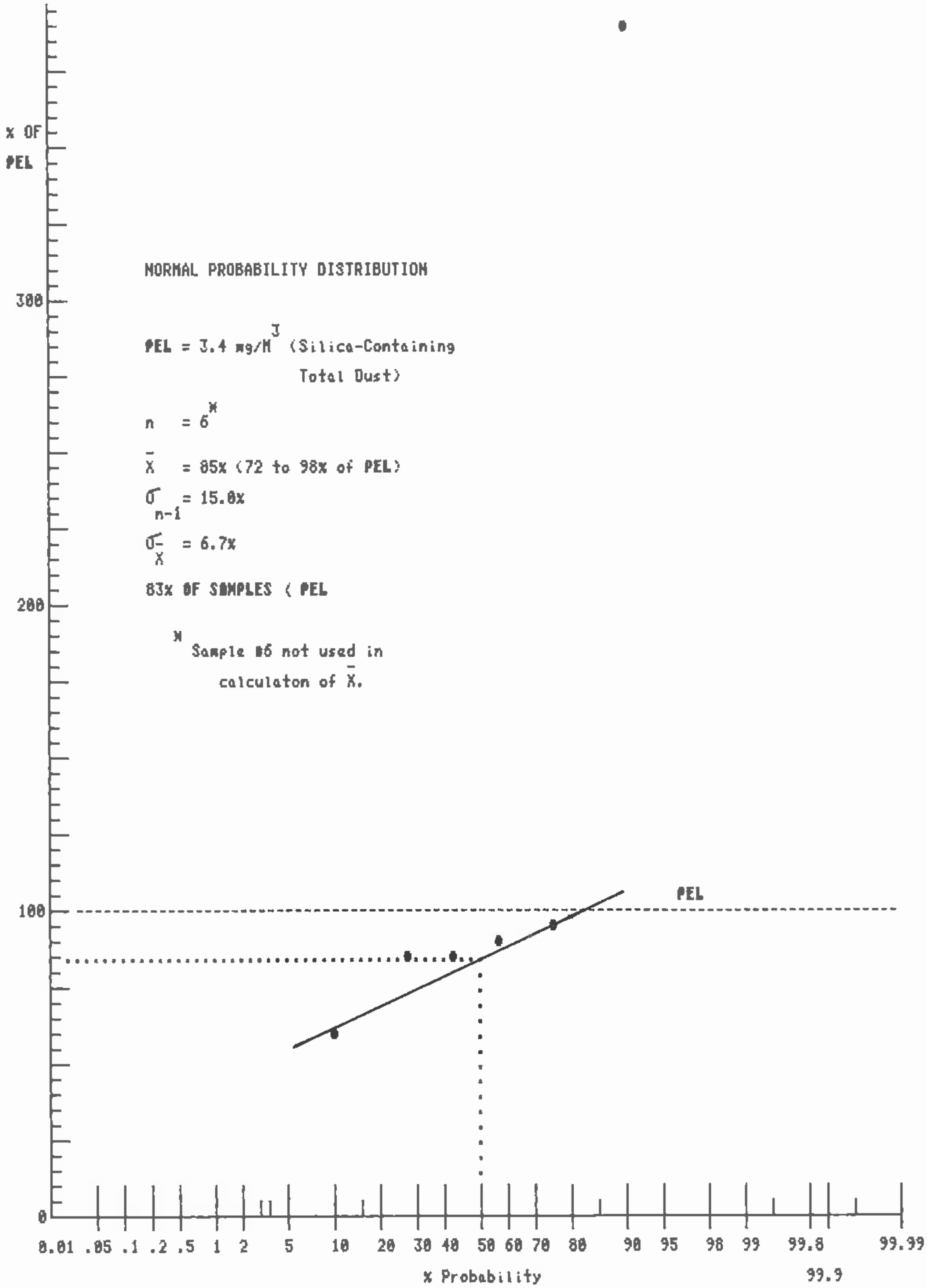


FIGURE 19: PERSONAL EXPOSURES TO TOTAL DUST, SITE D - FILLING BAGS WITH DRY POWDER (REFRACTORY PRODUCT)

During this study, 5 of 7 work stations were in operation. At the locations of these work stations, dust concentrations at the breathing zone (eye level) of the workers were well below the PEL (Table 8). However, dust levels were consistently higher on the left side of the batching stations (average 6.96 mg/m^3) than on the right side (average 1.6 mg/m^3). This situation probably was due to the manner in which bags were opened, dumped and stored prior to disposal.

At the mixer level, (Table 8) dust was well controlled (to an average of 0.51 mg/m^3 of Total Dust) at all five work stations by the enclosure and maintenance of negative pressure inside the mixers.

At the bag filling or can loading areas of the five operating work stations (Table 8), dust emissions were generally well controlled. At work station 2, excessive dust, from the batching station apparently caused higher dust levels to be developed at its can loading station. Similarly, excess dust during batching at working station 6 caused excessive dust at its bag loading station.

Dust levels in all general work areas of the plant were well below the PEL of 3.45 mg/m^3 for Total Dust (Table 8).

Effectiveness of Local Exhaust Hoods

General background levels in the plant were approximately .31 mg/m^3 (Table 9). In general, all dust levels at the worker's breathing zones: at the batching station (at eye level); at the skip hoist; at the mixer levels; and at the bag filling stations were well controlled. All dust concentrations were of the same order of magnitude as general background levels, indicating good control of potential dust sources. The two air samples, collected at the bag filling operations of work stations 6 and 7, were slightly above background (averaging 1.34 mg/m^3) but were still below the PEL. Control hoods were well designed (Figures 16 and 17) to capture generated dust.

Table 9. Effectiveness of Local Exhaust Ventilation Hoods - Site D

Work Station	Operation/Location vs. Total Dust Concentration											Remarks
	Batching station					Skip hoist		Mixer		Bag or pail filling		
	left side		right side		eye level							
	conc. mg/m^3	vel. fpm	conc. mg/m^3	vel. fpm	conc. mg/m^3	conc. mg/m^3	vel. fpm	Conc. mg/m^3	vel. fpm	Conc. mg/m^3	vel. fpm	
#1	1.36	2789	0.41	3806	0.42	0.42	60	-	3600	-	-	filling pails with slurry
#2	8.40	1814	0.82	2985	0.40	0.40	70	-	5467	-	-	filling pails with slurry
#3	1.72	1436	0.47	1527	0.32	0.32	90	-	5350	-	-	filling pails with slurry
#4	-	3252	-	2890	-	-	40	-	4333	-	-	not in operation
#5	-	2633	-	3514	-	-	20	-	4367	-	533	not in operation
#6	14.06	2057	3.22	1852	0.63	0.63	70	-	-	1.71	716	filling bags
#7	5.62	3195	3.06	3171	0.23	0.23	80	-	-	0.97	2000	" "
Average	6.23	2453	1.60	2820	0.40	0.40	60	-	4623	1.34	1083	
Background												
1.NE corner	-		-		0.31	0.31		0.31		0.31		

PEL (based on 6.7% SiO_2) = 3.45 mg/m^3

Major Ventilation Duct Effectiveness

The transport of mineral dusts, such as the zircon, alumina, clay, etc. (density approximately 2.8 mg/cc) through ventilation ducts requires air transport velocities of the order of 3500 to 4000 fpm. Velocities through three of the main ducts averaged approximately 3220 fpm (ranging from 2792 to 3782 fpm). Two of the ducts indicated sufficient transport velocity to move captured dust through the system (3075 and 3782 fpm). The third duct, however, operating at 2792 fpm, was significantly below the recommended minimum transport velocity of 3500 fpm. This lower velocity probably was the cause of the partial clogging of the duct, as the velocity probe could penetrate only 12-1/2 inches down into the 16-inch (I.D.) duct. This also may have been the cause of slightly higher dust levels at Work Station 6 compared to the other five operating stations. As was stated in Site A report, duct systems should be inspected on a regular basis to repair holes, discontinuities, and plugging and to measure air transport velocities.

IV. GENERAL OBSERVATIONS, CONCLUSIONS, AND RECOMMENDATIONS

A. General Observations

1. Control of dust exposures in all areas of the ceramics industry requires a combination of:

   a. Good engineering controls including:

      1) Proper plant layout and design, such as isolation of dusty operations that cannot otherwise be feasibly controlled, and construction for easy cleaning, maintenance and repair.

      2) Enclosure of major dust sources, such as processing and material transfer equipment.

      3) Local exhaust ventilation on dust-producing material transfer points.

   b. Good work practices including well-planned housekeeping and cleanup procedures; proper material handling techniques; and scheduled equipment and facilities maintenance.

   c. Effective monitoring programs including periodic environmental monitoring of personal, source and area dust exposures; and medical monitoring of employees for possible effects of overexposure to dust.

   d. Effective personal protective equipment programs including the provision and maintenance of respirators and quantitative fit testing of employees to respirators.

2. As dust emissions from point sources are reduced, it normally follows that levels of personal exposures to atmospheric dust also are proportionately reduced.

3. With relatively non-toxic dusts (eg. low silica dusts) hood design capture velocities of the order of 100 fpm, at the point of dust generation, may be sufficient to maintain dust levels at approximately the 0.7 mg/m^3 level (see Figure 3). However, more toxic dusts, such as high silica (quartz) dusts, require capture velocities of the order of 300 fpm or more. Factors to consider include: the density and particle size distribution of the dust; the toxicity of the material; the degree of agitation of the operation; the quantity of product being moved per unit time; and the inherent dustiness of the material.

4. All sites participating in this study demonstrated a firm commitment to the implementation and effective use of good environmental control and occupational health programs.

B. Conclusions

1. Dust control procedures and installations at three of the four sites studied were generally effective in maintaining dust exposures below the OSHA Standard. At the fourth site, controls in the crushing area were not effective. As shown in the normal probability distribution figures, most of the personal exposures appear to be normally distributed.

    a. At Site A, all six personal samples indicated exposures less than the PEL with average exposures at 22 per cent of the PEL.

    b. At Site B, five of six personal samples exceeded the PEL with average exposures at approximately 361 per cent of the PEL.

    c. At Site C, only three of 25 personal samples exceeded the PEL with average exposures at approximately 59 per cent of the PEL. Average personal exposure levels were approximately 51 per cent of the PEL in the hand and corner grinding area; 69 per cent of the PEL in the inspection/packing area; and 52 per cent of the PEL in the automatic grinder area.

d. At Site D, 17 of 20 personal samples indicated exposures less than the PEL. Average personal exposure levels were approximately 43 per cent of the PEL while packaging wet mix or slurries and 85 per cent of the PEL while packaging dry products.

2. The mineral dusts encountered in this study require minimum transport velocities of the order of 3500-4000 fpm. When velocities are much below this range dust settles out, causing clogging and reduced hood efficiency.

3. The use of plastic covers or wrapping (stretch or shrink) around pallet loads reduces bag breakage and dust dispersion during pallet handling and storage.

4. At Site A, a central vacuum cleaning system, with multiple outlets throughout the area, provided the means for rapid and effective cleanup of product spills.

5. Materials used in these ceramic industry processes contain significant amounts of crystalline silica.

6. State-of-the-art control technology exists to control silica-containing dust in the ceramic industry processes studied.

C. Recommendations

1. It is essential that all members of a company's staff including workers and management, implement and effectively use good environmental control and occupational health programs.

2. Dusty operations and potential dust sources, such as crushing and stockpiling of raw materials and air cleaning baghouses and scrubbers, should be physically isolated from other plant operations by solid walls or by location in separate buildings.

3. In dusty areas, workers should be provided the protection of a dust-free environment by filtered, air-conditioned vehicle cabs, filtered, air-conditioned control rooms, air curtains around work stations, or as a final measure, effective and comfortable respiratory protection.

4. Plants should be designed to permit regular washdown of equipment and facilities to remove accumulated dust.

5. All product-moving equipment, such as conveyors, elevators, feeders, screens, etc., should be enclosed as much as possible and operate under negative pressure to ensure that leaks in the system will not cause general environmental contamination.

6. Open material transfer points should be controlled with well-designed and well-maintained local exhaust ventilation hoods. Flow patterns around hoods should be designed to ensure maximum capture velocities at all potential dust emission points.

7. Ventilation ducts must be properly designed so that effective transport velocities are maintained at all times for transport of dust through ducts, particularly risers and horizontal ducts.

8. Product spills should be cleaned up immediately using wet sweeping or vacuum cleaning equipment to prevent redispersion of dust into the working environment.

9. Preventive and routine scheduled maintenance of equipment and facilities is essential for good dust control. The maintenance staff must be as well-trained as the production staff in methods and procedures affecting dust control.

10. Environmental and medical monitoring programs are essential for evaluation of the effectiveness of dust control programs. Environmental monitoring should be performed on a scheduled basis and

include atmospheric measurement of personal exposures for affected workers, potential dust sources, and general work area exposure levels. Medical monitoring should involve physical examinations including pulmonary function testing and chest x-rays to detect changes in the physiological condition of workers.

11. An effective respiratory protection program should be instituted to ensure proper fit, maintenance and use of respirators and to delineate work areas where respiratory protection may be needed.

12. The efficiency and effectiveness of local exhaust ventilation systems should be periodically checked as blast gate adjustments, slot openings, duct surfaces, and/or operations may change.

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APPENDIXES

APPENDIX A: CONTROL TECHNOLOGY DEFINITIONS

Control Technology, as related to industrial hygiene, refers to the application of science and engineering towards reducing or eliminating worker exposure to chemical or physical agents. The major elements of this concept are education, engineering controls, monitoring systems, work practices, and personal protective equipment. The control of occupational health hazards involves the application of one or more of these methods.

EDUCATION

Education should be considered indispensable to any strategy. Managers and engineers should be informed about what control methods are available and how to select the proper one(s) for a given hazard. Once the control methods have been instituted, the workers and their supervisors need to be educated about the nature of the hazards and the importance of the controls.

ENGINEERING CONTROLS

Controls which become a part of the production process are preferred over other measures. Unless intentionally circumvented, they function the entire time the process is operating. Included in this category are substitution, isolation, and ventilation.

Substitution can be applied at various levels. The most obvious is replacing the agent being used with one which is less hazardous but which will still do the job. Another approach is to install another piece of equipment which emits less of the hazardous agent. Finally, a different process all together may be implemented, such as using threaded fasteners instead of welding.

Isolation implies separation. Since it is usually not feasible to interpose sufficient distance, in most cases a physical barrier is inserted between the employees and the hazard. This may be a special storage facility for material, a shield or guard installed on a machine, or an enclosure built around an entire process. Devices worn by workers do effect isolation, but are treated separately since they can not actually be built into the system. (See section on personal protective equipment.)

Ventilation is the third method considered an engineering control. Although this has historically included general ventilation, this dilution approach is seldom satisfactory today. In currently accepted practice, local exhaust ventilation uses relatively small quantities of air to extract the contaminants close to the source before they come in contact with the worker. It is no longer cost-effective to condition (temperature, moisture, etc.) the large volumes of air required to dilute the concentration of a substance in the workplace atmosphere. In fact, filtering exhaust air for recirculation is becoming an area of great interest.

MONITORING SYSTEMS

Monitoring systems (environmental and medical) are not controls in themselves, but they are an important adjunct to a control system. They may simply record measured values of certain parameters. This data can then be used to document performance and perhaps show if control measures are needed. An alarm may be connected to the monitoring instrument to warn workers when the levels exceed certain thresholds, indicating the failure of a control device and the need for additional action. Sensors may also be incorporated into the control system, adjusting its operation according to the state of the occupational environment.

WORK PRACTICES

Work practices include job techniques, care of equipment, and housekeeping. Often, the manner in which a task is accomplished can be a factor in the generation of a hazard. Regularly scheduled inspection, maintenance, and calibration of equipment to assure proper operation contributes to a safe and healthful workplace. Likewise, proper housekeeping techniques can minimize the spread of contaminants through the facility.

PERSONAL PROTECTIVE EQUIPMENT

The majority of personal protective equipment (PPE) items are safety devices meant to protect the worker from accidents. They should be used to reduce worker exposure to chronic hazards primarily when engineering and administrative controls are insufficient, and then used in addition to those controls. In cases where engineering controls are not able to continually maintain levels below permissible exposure limits, using appropriate PPE when alerted by a monitoring system is one way of handling this situation.

All PPE items have one thing in common, their effectiveness depends on proper fit, correct use, and worker acceptance. Educating employees about the hazards in the workplace and the importance of wearing the protective devices can help; but, if the device is uncomfortable and interferes with doing the job, it is only natural that the worker won't want to wear it. In some cases where comfortable devices are available, such as safety spectacles or steel-toed foot wear, it is good practice to wear them all the time in most industrial situations.

APPENDIX B: DESCRIPTION OF AIR SAMPLING AND ANALYTICAL EQUIPMENT

1. Dupont Gravimetric Dust Sampler, Model P 2500, manufactured by E.I. DuPont Company. This sampling system was operated without a cyclone separator for Total Dust sampling or with a cyclone separator for Respirable Dust sampling. The sampler consists of: a) portable battery powered pump; b) a two-piece plastic filter holder cassette containing a 37 mm PVC filter-type M5, manufactured by Millipore Corporation, or an FWS B filter, manufactured by MSA Appliances Co.; and c) (for Respirable Dust) a 10 mm plastic cyclone separator to remove "non-respirable" dust. This sampler is operated at 1.7 liters per minute (lpm) the standard flow rate for collecting Respirable Dust and 2.0 lpm Total Dust samples.

2. Anderson High Volume Sampler manufactured by Anderson 1000, Inc. This sampler, with a 1/2-inch respirable cyclone separator, operates at 9 liters per minute and is used to collect bulk air samples for qualitative and quantitative analyses.

3. Crystalline silica (quartz) was analyzed at the UBTL with a Phillips automated powder diffractometer, Model ADP-3501. The "limit of detection" was 18 micrograms (ug) per sample. Dust weights were determined by measuring the difference between filter weights before and after sampling. The measurements were carried out with a Perkins-Elmer Electro balance, Model AD-2, with a "limit of detection" of 10 ug per sample. All samples were desiccated for 48 hours to obtain constant weight.

APPENDIX C: AIR VELOCITY MEASUREMENT INSTRUMENTS

1. Duct and hood air velocity measurements were made with:

   (a) Pitot-Static tube and Durablock$^{(R)}$ manometer. Range 0–9000 fpm (0-5 " H_2O), manufactured by Dwyer Instruments, Inc.

   (b) Digital Air Velocity Meter, Model 1400. Range 0-6000 fpm, manufactured by Kurz Instrument Co.

   (c) TSI Air Velocity Meter, Model 1650. Range 0-6000 fpm, manufactured by Thermo-Systems Inc.

2. Air flow patterns were evaluated with:

   (a) Bendix/Gastec smoke tubes manufactured by National Environmental Instruments, Inc.

   (b) Draeger Air Current Tubes, manufactured by National Draeger, Inc.

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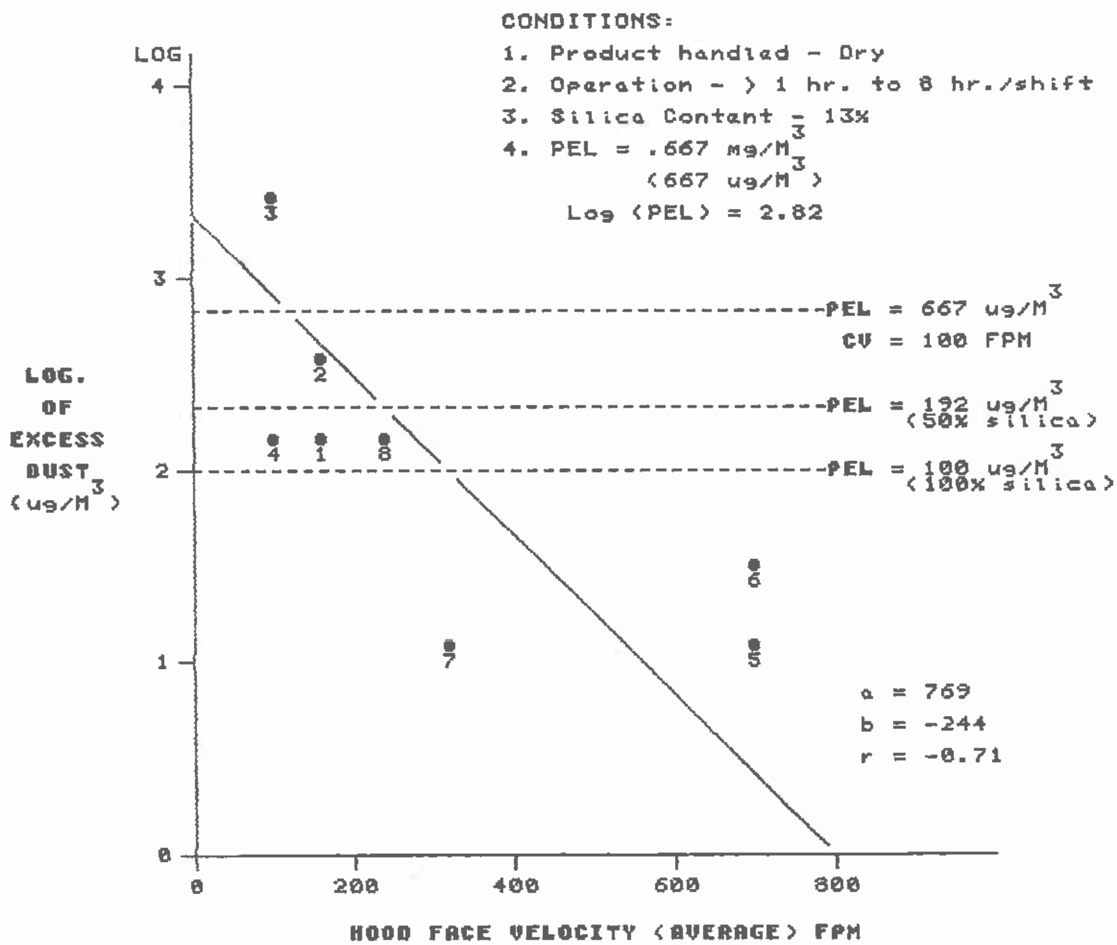


Figure 3. Correlation of Excess Dust from Hoods and Hood Face Velocities

III. CONTROL TECHNOLOGY EVALUATION

A. Crushing and Grinding of Pyrophyllite in the Ceramic Tile Industry (Site A)[9]

1. Process Description

At one site, ball clay, flint, and pyrophyllite are processed to make glazed floor and wall tiles. Pyrophyllite ore is crushed and ground in a grinding plant and transported pneumatically through a 6-inch pipe to a separate production building approximately 350 feet away.

The grinding plant is divided into two main buildings, a pyrophyllite raw materials storage building (RMSB) and a processing building (PB), which are physically separated by a wall (Figure 1).

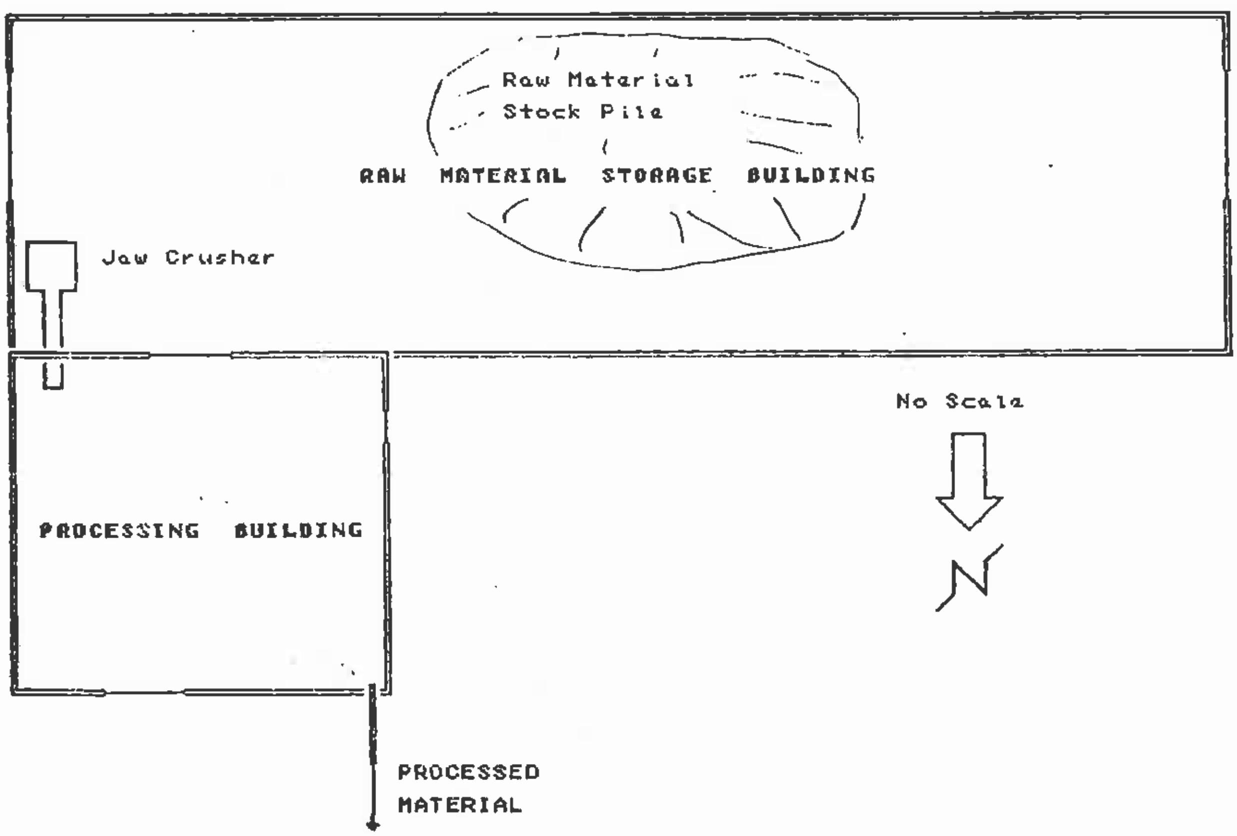


Figure 1. Storage and Processing Buildings

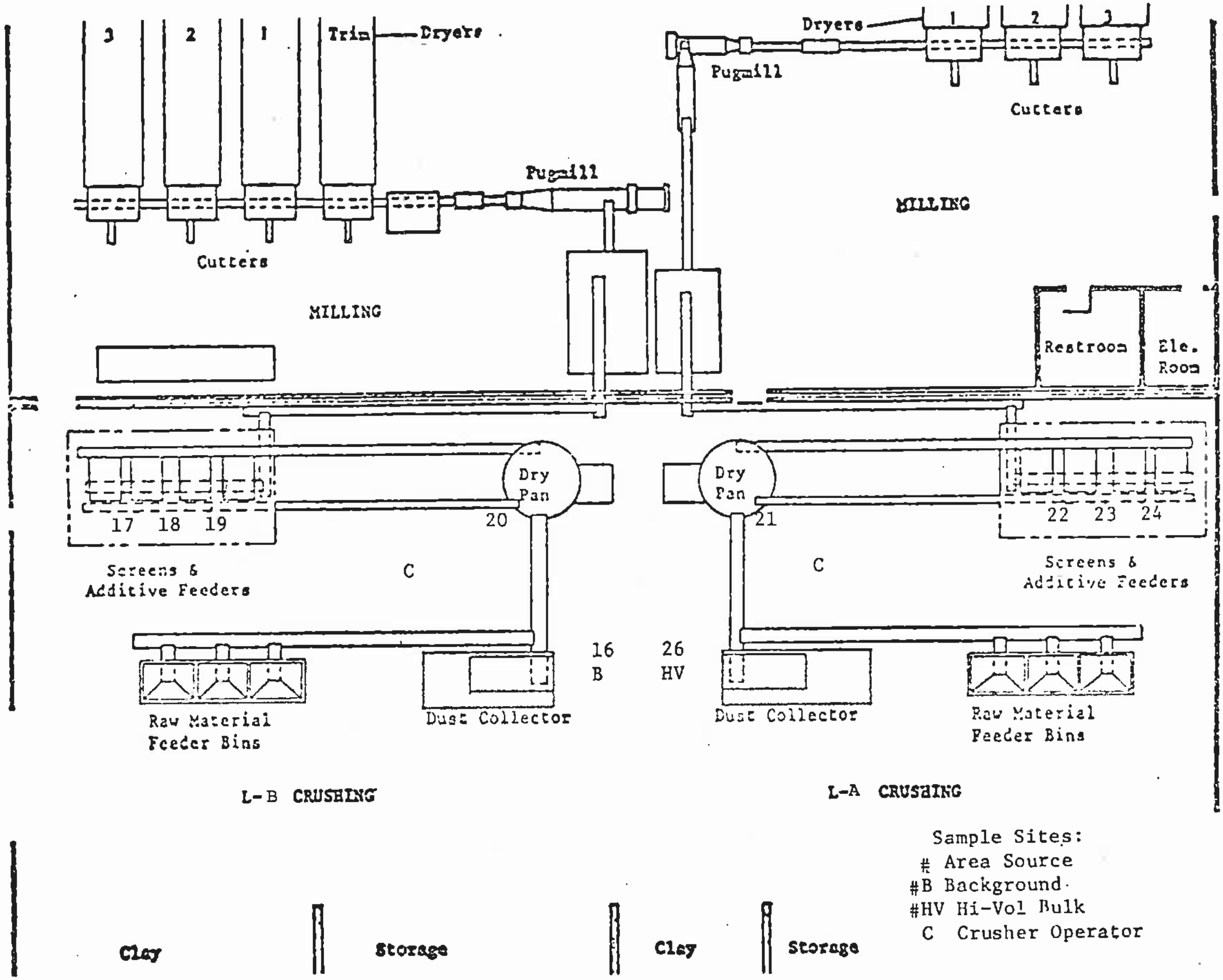


Figure 4 - Crushing Plant

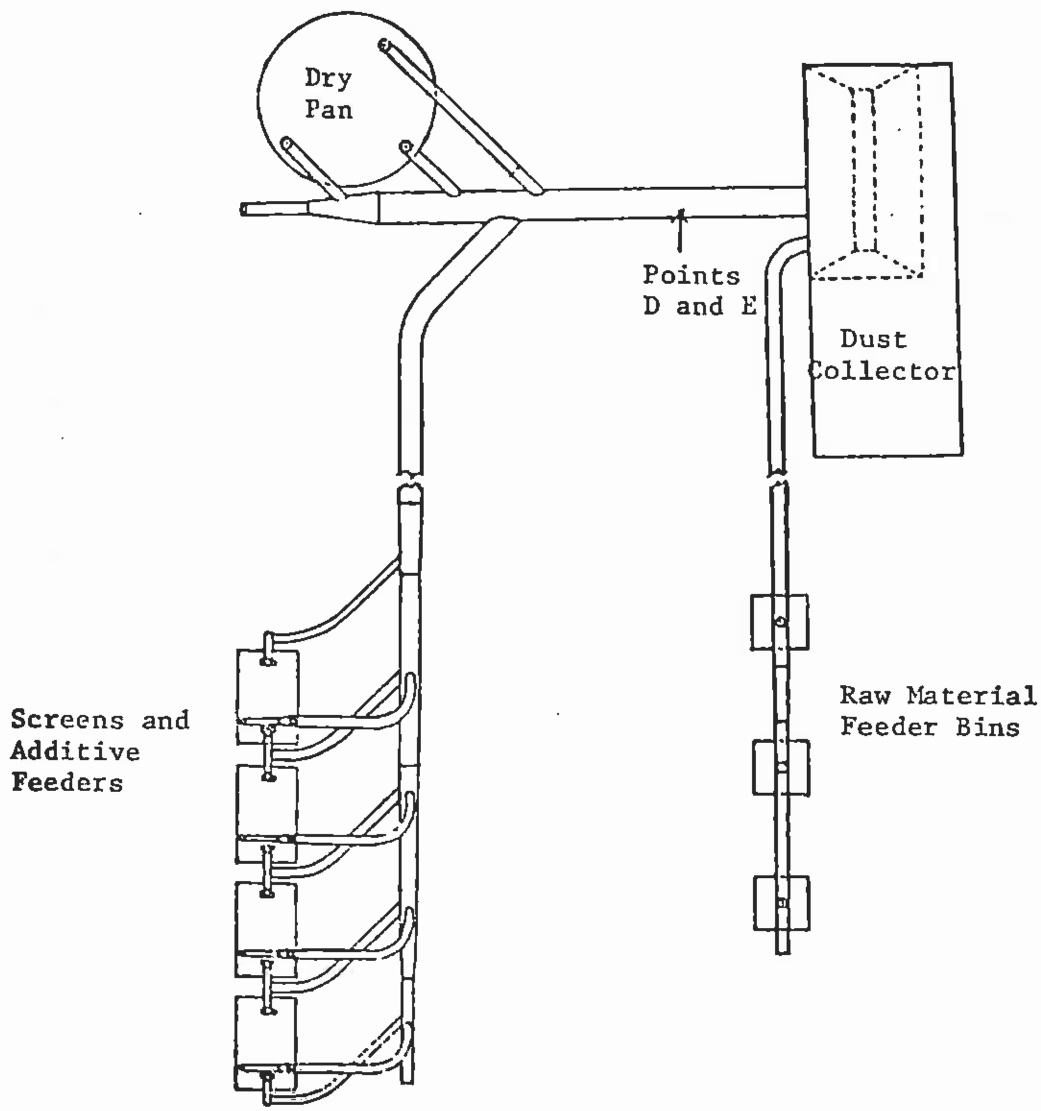


Figure 5 - Crushing Line Exhaust Ventilation System

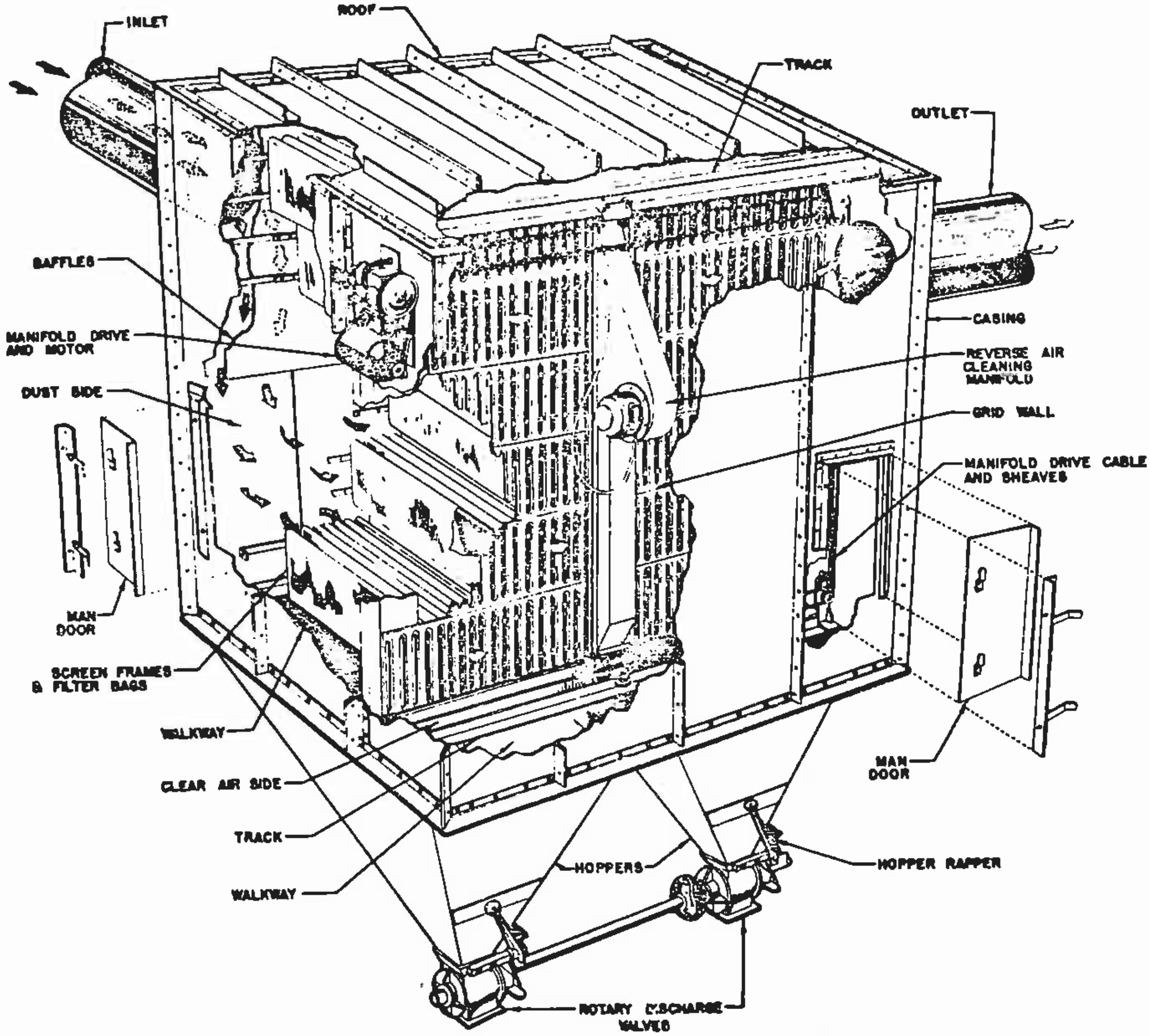


Figure 6 - Dust Collector

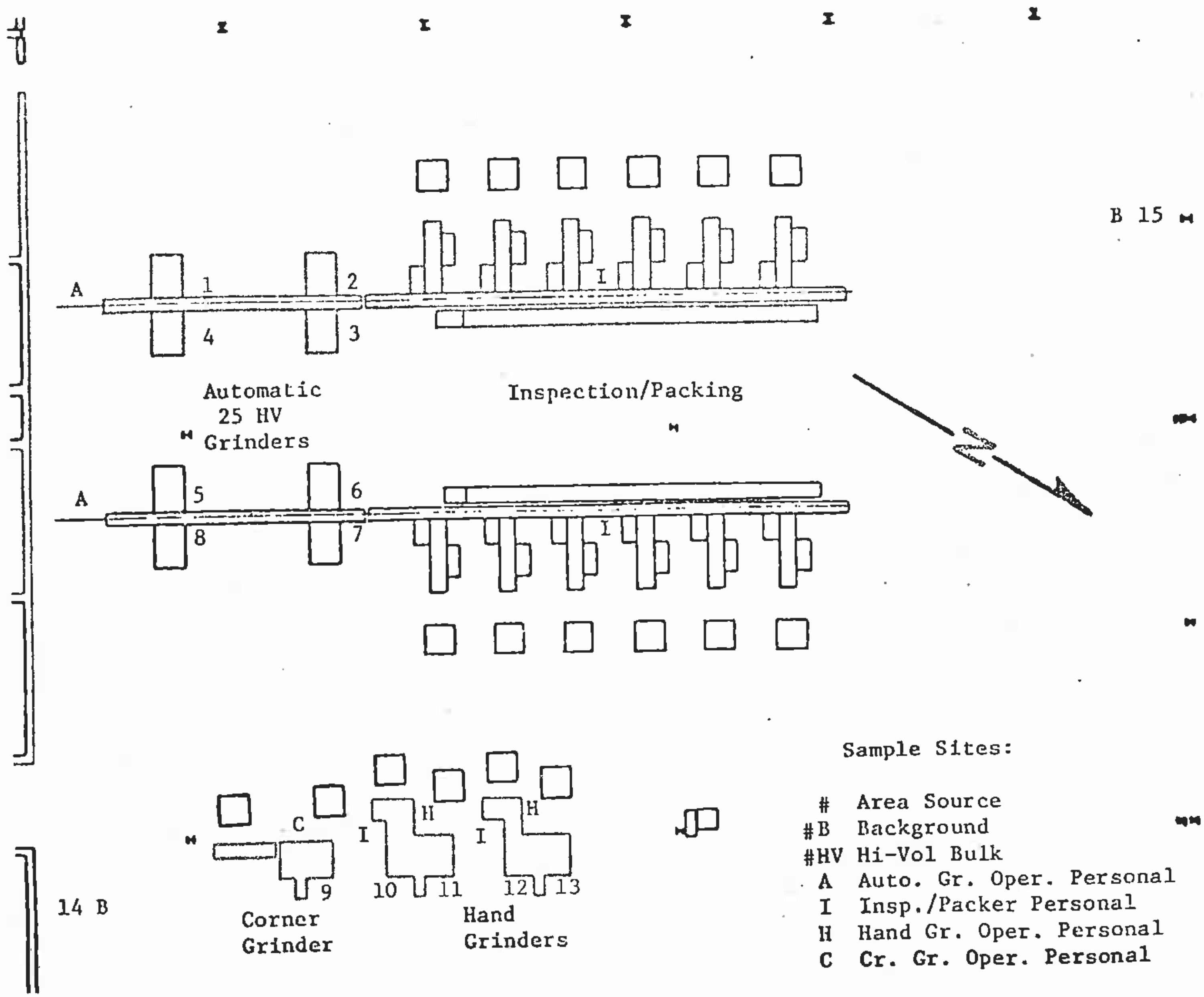


Figure 8 - Grinding and Packing Area

ducts to a baghouse, located outside the building, where the dust is separated from the airstream (Figure 5). The dust collector for the grinding area is designed to operate at 10,000 cfm at 8-inches Standard Pressure with an air-to-cloth ratio of 2.72 cfm per square foot.

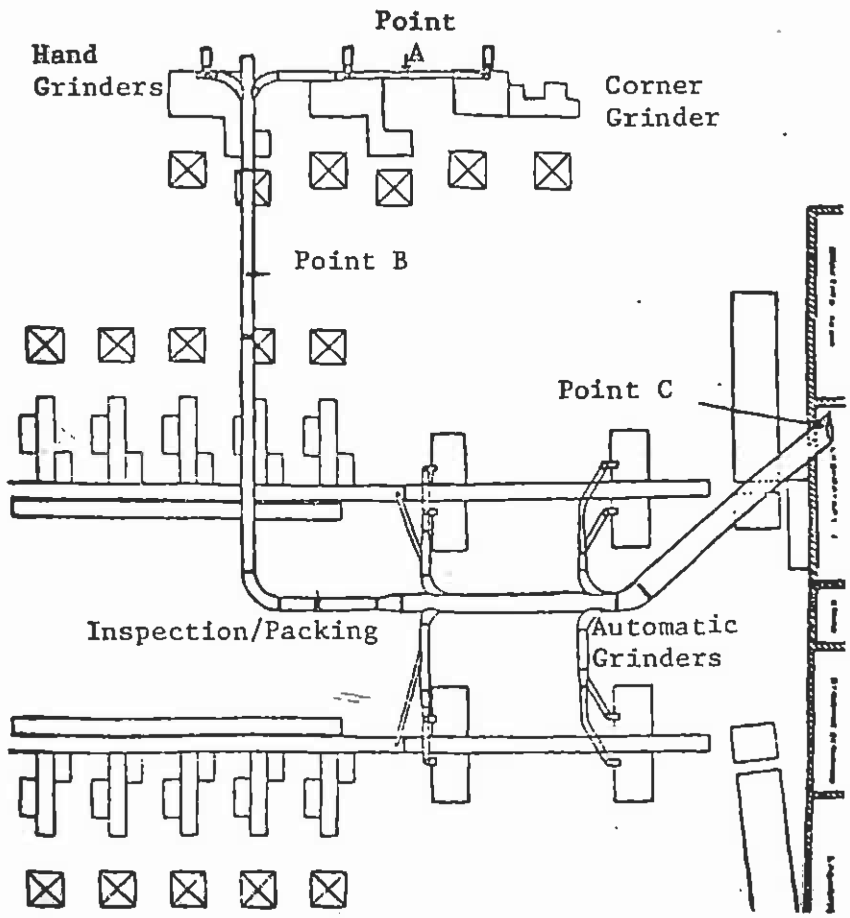


Figure 9 - Grinding Area Exhaust Ventilation System

b. Environmental/Medical Monitoring

Annually, the Company's industrial hygienist conducts atmospheric dust evaluations at strategic locations throughout the grinding area and personnel exposure evaluations among the grinding operators and inspector/ packers. Additionally, annual physical

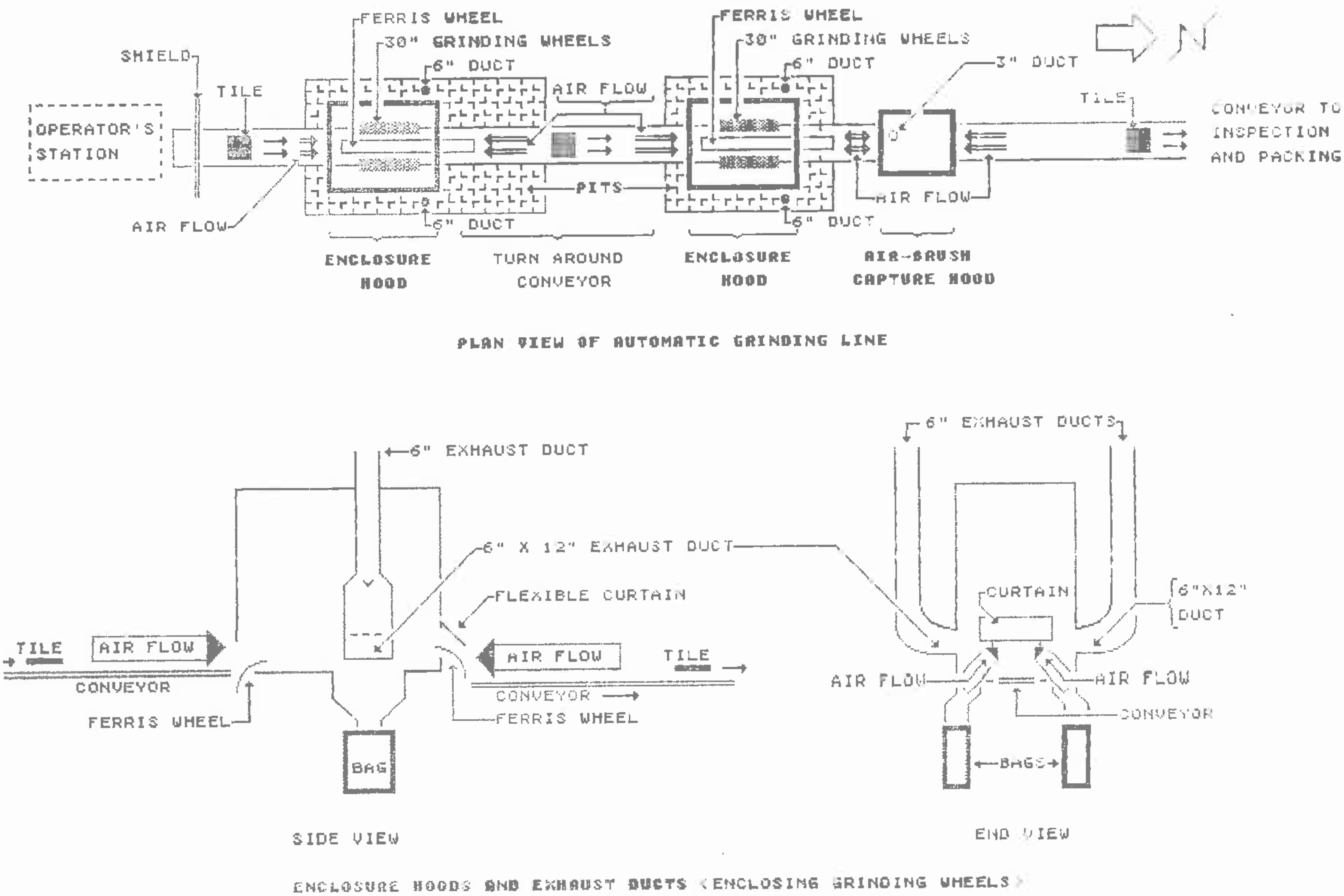


Figure 10 - Automatic Grinder Local Exhaust Hoods

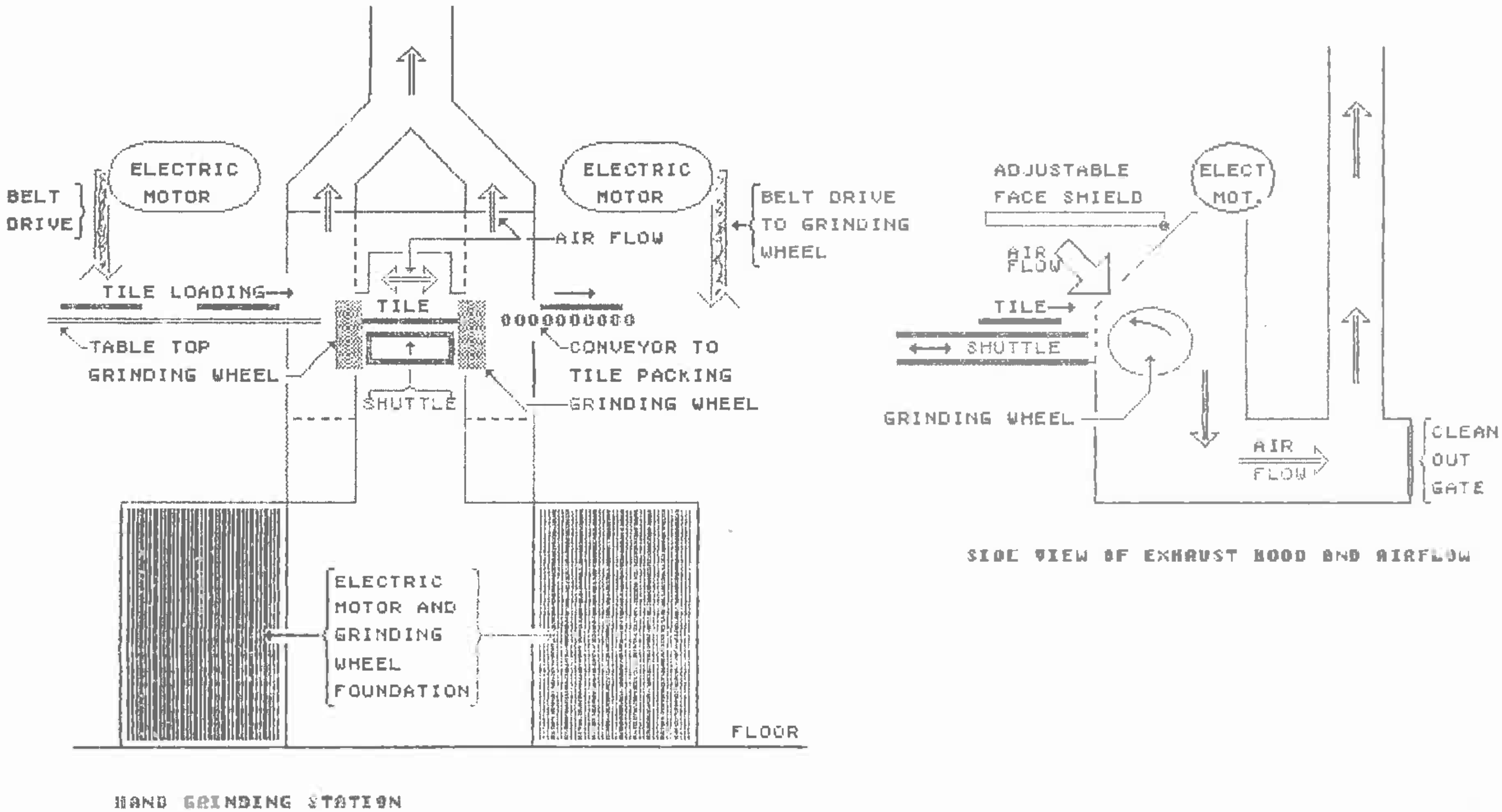


Figure 11 - Hand and Corner Grinder Local Exhaust Hoods

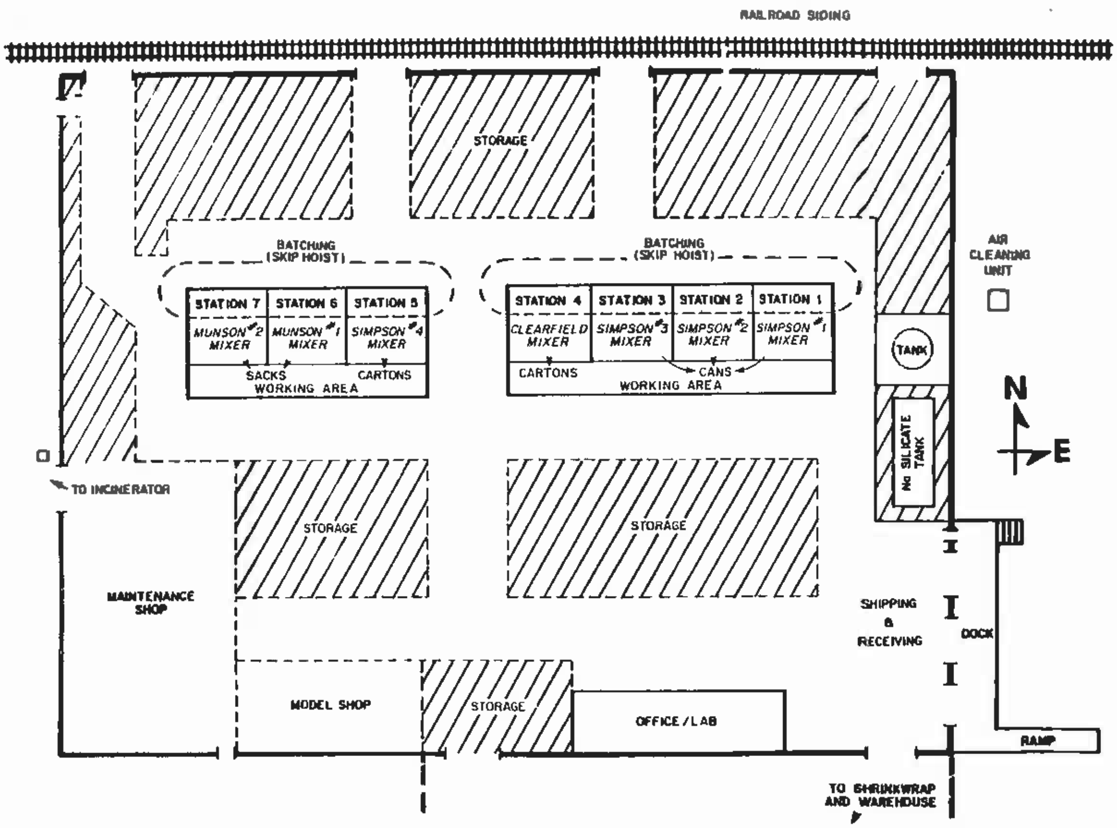


Figure 13 - Plant Layout

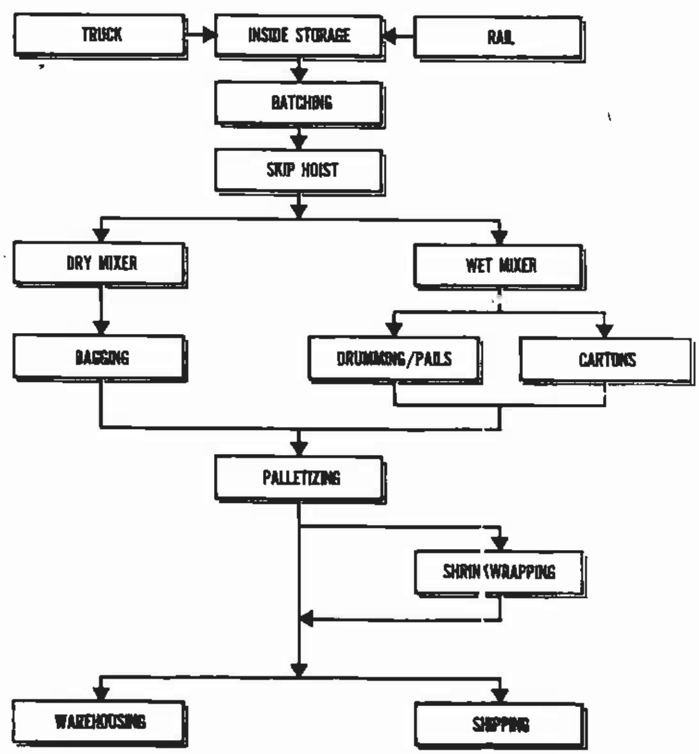
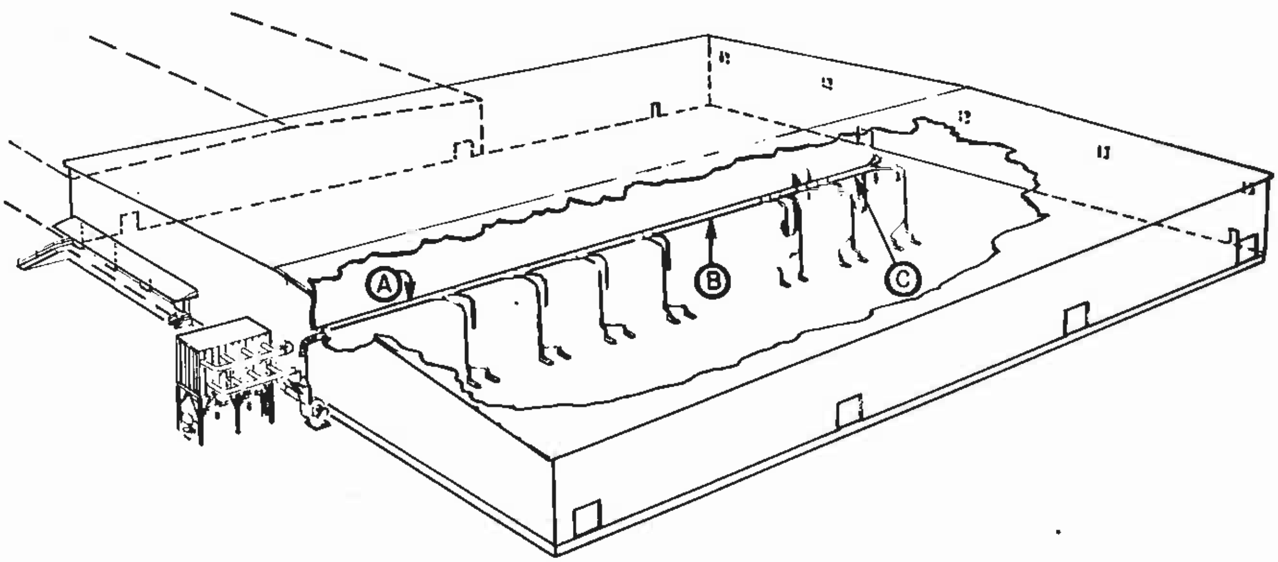


Figure 14 - Process Flow

Local Exhaust Ventilation Systems

All major potential dust sources, which are not completely enclosed, are provided with local exhaust hoods. These hoods are connected to a central duct trunk by a series of branch ducts from each work station (Figure 15).



NOTE:

POSITION A - DUCTWORK DIAMETER 33" AVERAGE AIR FLOW 3782 FPM
B - " " 23" " " " 3075 "
C - " " 16" " " " 2792 "

Figure 15 - Exhaust System Ductwork

At each batching station, ventilation hoods are located on each side of the loading bucket (Figure 16). Additional exhaust ventilation moves air upward through the rear of the bucket elevator.

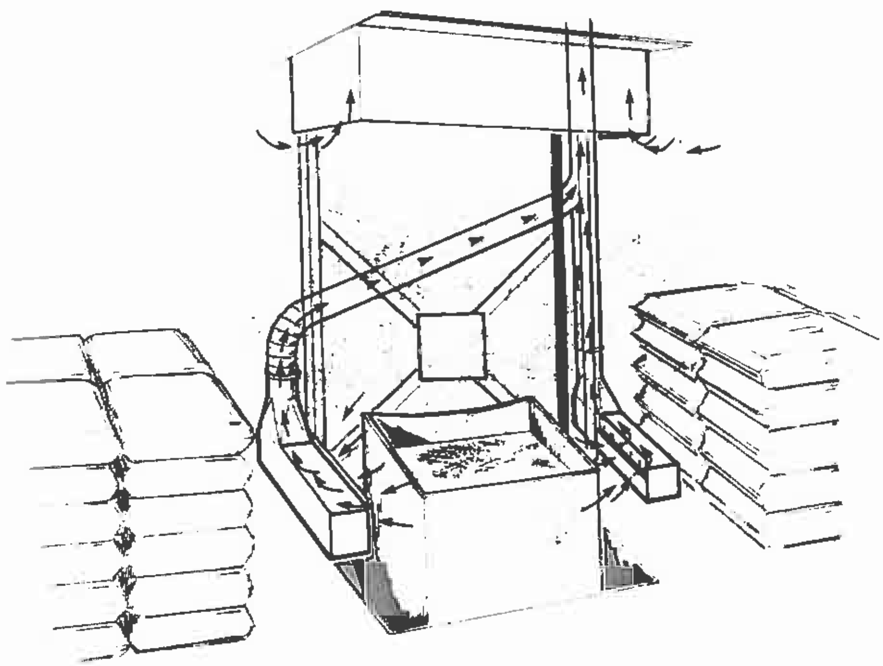


Figure 16 - Typical Batching Station Air Flow

Enclosed mixers, above the batching stations, are also exhausted or under negative pressure to insure dust control. The single spout bag packing machines are also provided with dust collection hoods (Figure 17), which are connected to the central dust collection system. Ventilation system efficiency on the batching stations, mixers, and bag packing machines could be improved by incorporation of design features illustrated in Section 5 of the Industrial Ventilation Manual.[15]

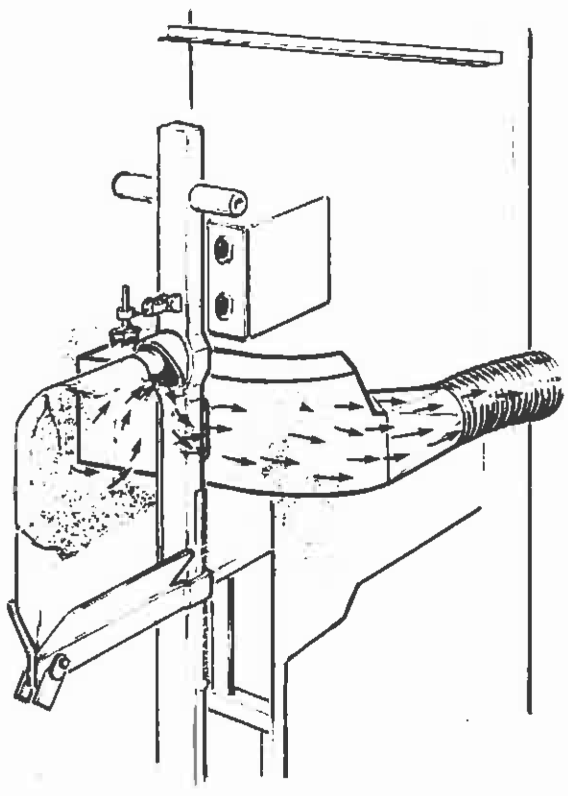


Figure 17 - Typical Bagging Station Air Flow