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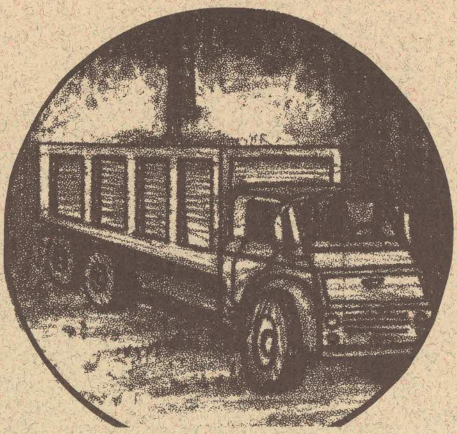
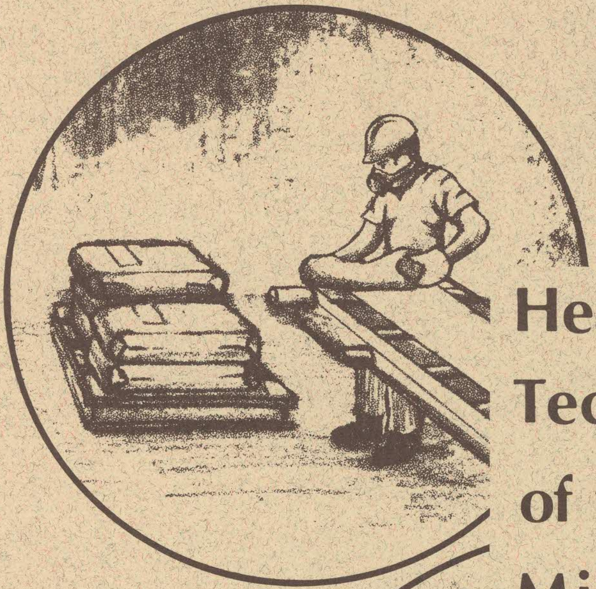
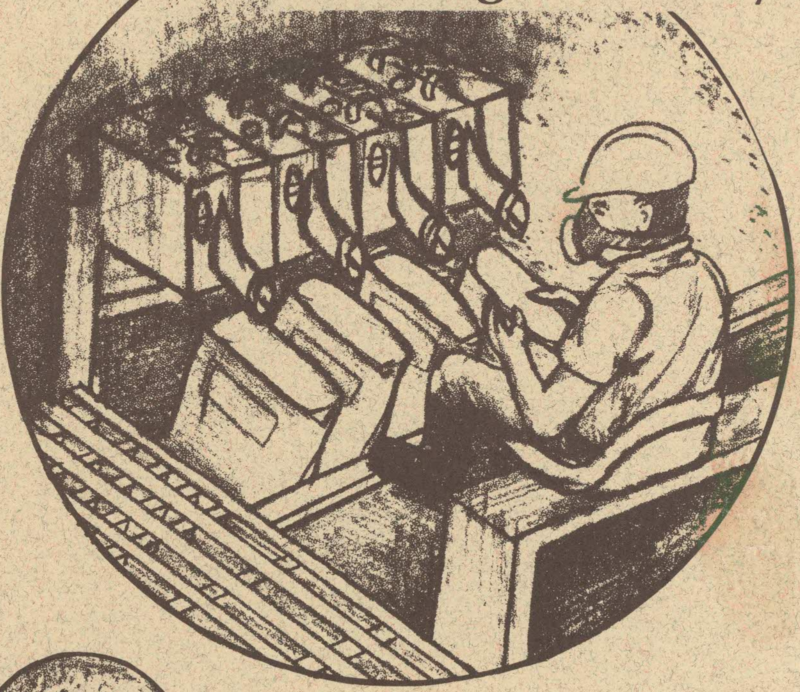




Health Hazard Control Technology Assessment of the Silica Flour Milling Industry



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health

HEALTH HAZARD CONTROL TECHNOLOGY ASSESSMENT OF THE SILICA FLOUR MILLING INDUSTRY

by

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ABSTRACT

A Health Hazard Control Technology Assessment of the silica flour milling industry was conducted by the National Institute for Occupational Safety and Health. Three silica flour mills were evaluated in depth. The primary operations investigated were bag packing, conveyor transfer of bags, palletizing, loading of bags in boxcars and trucks, and bulk loading of hopper cars and trucks. Several innovative dust control procedures were found to be effective. These included: 1) the injection of agglomerating agents such as water and Deter Micro Foam(R) into products; 2) water spraying of outer surfaces of product-filled bags during conveyance; and 3) bulk loading of silica flour into enclosed hopper trucks and railroad hopper cars under local exhaust ventilation control. Plant personnel have estimated that half of the environmental silica dust problems may be effectively controlled by good work practices and effective housekeeping procedures.

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ACKNOWLEDGEMENT

We gratefully acknowledge the cooperation and assistance of the management and workers at the plants participating in the field studies. Their willingness to contribute their experience and knowledge in the areas of silica processing and hazard control made this study possible. In particular, we wish to thank Mr. Charles Hawkins of the National Industrial Sand Association (NISA) and Mr. Arnold Alekna (deceased) and members of the NISA Committee who have produced excellent documents relating to the improvement of Occupational Health and Dust Control Programs in the silica production industry[1,2]. Dr. Aurel Goodwin, of the Mine Safety and Health Administration (MSHA) provided us with valuable environmental and production data.

We also are indebted to Drs. Charles Geraci, John Palassis, John Holtz and other members of the Measurement Support Branch, NIOSH and the staff of the Utah Biomedical Testing Laboratory (UBTL) for their analytical support. Illustrations were prepared by Mr. August Lauman. The manuscripts were patiently and ably typed by Ms. Myra D. Brooks.

I. INTRODUCTION

A. Background

Silica flour is produced by the crushing and milling of quartz sand or quartzite rock. It is commonly used in abrasive cleaners, autoclaved concrete blocks, foundries using lost wax investment casting, paints, and as inert fillers.[3] Silica flour consists of essentially pure crystalline silicon dioxide (quartz). Studies of the respirable dust fraction of silica flour show that over 98% (by weight) of all the particles are less than five micrometers in size, with a median particle diameter even smaller.[4,5,6] Thus, most of the silica flour dust is readily inhaled and retained in the lower portions of the respiratory tract. Silica flour has been implicated as a causative agent of a rapidly developing pneumoconiosis, called "acute silicosis" or "galloping silicosis." In 1956, Stokinger[7] described cases of silicosis in the scouring powder manufacturing industry, which developed after exposure to silica flour as short as 20 months. Recent NIOSH Health Hazard Evaluation/Epidemiology studies were conducted at two flour mills in Illinois, which have unique deposits of micro-crystalline quartz.[8,9,10] These studies have shown that exposures to silica flour dust can cause simple pneumoconiosis to develop in periods as short as one to two years. Progressive massive fibrosis can also develop, in periods as short as two to two and one-half years of high exposures to silica dust.

According to MSHA data[11], 28 active silica plants employing approximately 1400 workers, product silica sand. Some of these plants produce both silica flour and whole grain sand. The number of employees per plant ranges from 4 to about 200. Fourteen (small) plants employ from 4 to 30; eleven (medium) plants employ from 31 to 100; and three (large) plants employ from 101 to 200 employees. Most of the plants are located east of the Mississippi River while a few plants are located as far west as Texas, Oklahoma and Kansas (Figure A.).

B. Purpose of Study

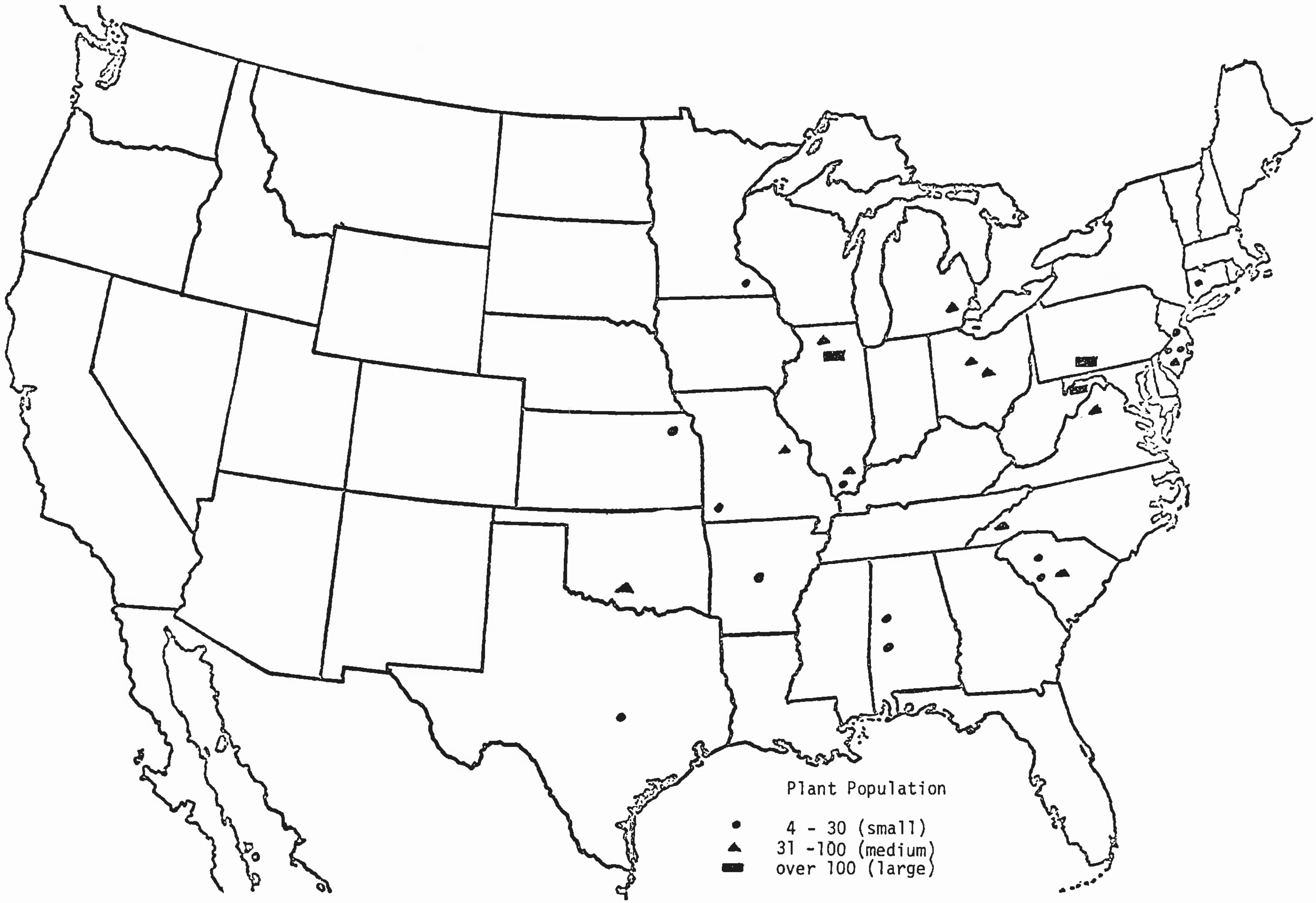
Because of the potential health hazard of exposure to this material, NIOSH conducted a Health Hazard Control Technology Assessment (CTA) of silica flour milling. This study was initiated at the request of MSHA and conducted in cooperation with NISA and the Bureau of Mines (BOM). The purpose of this study is to evaluate the effectiveness of the health hazard control procedures, which are presently being used and being developed for the bagging, handling, and shipping of silica flour. The spécific objectives are:

1) to evaluate the effectiveness of existing control technology procedures in silica flour milling operations.

2) to evaluate several new and innovative control strategies, which are, at present, experimental, and

Figure A.

Location of Silica Flour Plants



3) to identify gaps in existing control technology, which may be resolved by appropriate research and development programs.

C. Control Technology Elements

Hazard control technology consists of four elements. Two of these are equipment, process, and facilities oriented: engineering controls and environmental monitoring; and two of these are worker oriented: good work practices and the use of personal protective equipment.

II. STUDY PROTOCOL

A. Evaluation Criteria

The Threshold Limit Value (TLV)* for respirable crystalline silica (quartz), which is applicable in metal/non-metal mines and mills, is contained in 30 CFR (Code of Federal Regulations) Part 57.[12] This standard is determined by the free crystalline silica content of a dust and is calculated by the following equation:

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

For 100% respirable silica dust, this calculated TLV is approximately equivalent to 0.1 mg/m^3 or 100 micrograms per cubic meter (ug/m^3) of air.

NIOSH, in 1974;[13] recommended an Exposure Limit of 0.05 mg/m^3 for all forms of respirable, crystalline silica, including quartz. NIOSH reiterated this recommended standard of 0.05 mg/m^3 in its Current Intelligent Bulletin (CIB) on "Silica Flour - Silicosis" in 1981.[14] Nelson, et al [3], in 1978 recommended that the Threshold Limit Value (TLV) for silica flour dust be reduced to 0.05 mg/m^3 of respirable dust. The MSHA TLV and the recommended NIOSH Exposure Limit refer to daily (8 to 10 hours, time-weighted average) exposures to employees. In this report, the MSHA TLV and the NIOSH Exposure Limit are used as environmental criteria to evaluate the effectiveness of the control techniques under investigation.

*Threshold Limit Values (TLV's) are adopted yearly by the American Conference of Governmental Industrial Hygienists (ACGIH). They "refer to the airborne concentration of substances and represent conditions which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect." In 1977, MSHA promulgated the TLV for silica dust, which was recommended by the ACGIH in 1976.[12]

B. Industry Description

1. Process description

The following descriptions are limited to the production and dust control systems observed in this investigation. There may be other processes and procedures common to the silica flour industry which were not evaluated.

Mining

Sand ores vary from one mine to the next. The ore may be mined from a hard rock formation yielding quartzite or from a loosely cemented deposit, such as found in the St. Peter's Formation. The ores primarily consist of crystalline silicon dioxide (quartz) and may contain small amounts of impurities, e.g., iron and clay. Any overburden is removed and the ore is mined from an open pit or quarry. Some ore is also obtained from underground mines. However, this was not observed in this study. The deposit is usually drilled and blasted to loosen the material. Ore from hardrock deposits is loaded into trucks, transported to the primary crusher (usually located near the quarry) and reduced to minus 6-inch rock. For loosely cemented sand deposits, the material is hydraulically mined. The sand (mostly minus 1/8 inch) flows to a sump and is pump through a pipeline to the mill.

Milling

The mill may be located adjacent to or several miles from the quarry. The hardrock ores are transported either by an overhead bucket tramline or over a series of conveyor belts from the primary crusher to the secondary crusher. Usually, covered conveyor belts are used to move the ore through the remainder of the comminution processes. Secondary and, in some cases, tertiary crushers and rod mills are used to comminute the ore. The ore from the quarry is usually damp and remains damp through the crushing stages. Water is added during grinding in the rod mills.

The ore is then wet-screened to minus 1/8 inch as it comes from the rod mills or the quarry. It is dewatered and usually pumped as a slurry, through a pipeline or moved by covered conveyor belt to the next process. The next process may be either the stock-piling of "steel" grade sand; or vacuum filtering of the "steel" grade sand; or benefication of the sand ore (such as flotation to remove slimes) to upgrade it to a higher quality "glass" grade sand. The sand is dried and stored in silos or bins. Open conveyor belts are used to move the ore through the benefication processes. Usually, covered conveyor belts are used to transport the dried sand to the storage silos.

A portion of the "glass" grade sand is milled in pebble or tube mills. These mills are lined with silica blocks and use silica pebbles or ceramic plugs as the grinding media. The "glass" sand is dry ground to produce silica flour products ranging in size from 5 micrometers(µm) to 74 µm (minus 200 mesh). Solid particles are generally sized according to a screen mesh system, either the Tyler or the U.S. Sieve series, as shown in Table 1. The flour is sized and pneumatically transported to storage bins or silos. Most of the "Steel grade sand, "glass" grade sand, and silica flour is shipped by bulk. Closed and open trucks and closed railroad hopper cars are normally used to ship bulk whole grain sand and flour. The remaining sand and flour is bagged for shipping by truck or boxcar.

Table 1.

Equivalence of Screen Mesh to Particle Size, U.S. Sieve and Tyler Sieve Series (16)

Mesh size	Opening - um*	
	U.S. Sieve	Tyler
5	3962	3962
10	1981	1651
20	833	833
60	246	246
100	147	147
200	74	74
325	43	43
400	38	38

*um = micrometers

Packer machines vary in design and operation. The pneumatically operated, forced-flow, filling system is most commonly used, with one to four fill spouts. Auger feed is normally used to pack the smallest size particle flour (5 um) through a single-spout packer. Normally, each packer machine has its own exhaust ventilation system. Several machine ventilation systems are connected to one main system.

Manual or semi-automatic flour packing systems are used to fill multi-ply, valve-type paper bags. For the manual system, the bags are placed on the packer spouts, filled, removed and palletized. Packing and palletizing operations are located adjacent to each other.

For the semi-automatic system, the bags are manually placed on the packer spouts, filled, and either hand-tipped or automatically ejected onto a conveyor. They are then transported either to an intermediate loading (palletizing) point or directly into a truck or boxcar. The bags are then manually stacked in the shipping vehicle.

The bags are usually transported by belt, spring, gravity wheel, or other types of conveyors from the packing station to the loading or palletizing stations. These stations may be located on the same or different floor level. When bags are palletized at an intermediate loading point, a fork lift is used to transport the loaded pallets either into a truck, boxcar or to a storage area. When loaded pallets are placed in storage, they may be plastic wrapped (shrink or stretch) or covered with plastic bags. This reduces leakage and environmental contamination, and increases the weatherability of the pallet loads.

2. Dust control

Normally, minimal ventilation is required for dust control for the processes between quarrying and drying because the ore is either damp or being treated in a wet process. Extensive ventilation is required, however, to control dust dispersion after drying, especially in the flour processes of bagging, bag loading and bulk loading. These ventilation systems are usually connected to baghouses in which the captured dust is returned to product bins rather than exhausted into the atmosphere.

Other effective methods used to control dust, in addition to ventilation, include wet washing, mopping with kerosene emulsions, and vacuum cleaning.

C. Scope of Study

The potential for hazardous exposures to silica dust exists throughout the silica flour/sand industry. These exposures may occur during mining, sand and flour processing, and final product usage. The major emphasis of this assessment, however, was limited to exposure control during the packing, handling and shipping of the flour products. The four aspects of hazard control technology - engineering, environmental monitoring, work practices and use of personal protective equipment - were evaluated either quantitatively or qualitatively. The major emphasis in this study was directed toward the evaluation of engineering controls.

1. Study plan

Three silica flour plants, one medium and two large, were chosen for in-depth evaluation. Management at each of these plants has demonstrated a commitment to improved worker health through environmental and medical monitoring, hazard evaluation, and environmental control programs.

Furthermore, recent MSHA environmental data have indicated that dust exposures at these plants have been reduced by the development and implementation of good dust control procedures. Innovative dust control techniques were also being installed and evaluated at these plants.

The effectiveness of standard control methods, in use at several operations; was evaluated quantitatively. These operations included:

a) packing - main product, 74 to 43 um (minus 200 - 325 mesh) and fine product, 5 to 34 um; silica flour is packed into 3-ply, 50 and 100 pound bags, using 4-spout, 2-spout, and 1-spout packer systems.

b) conveying - filled bags are transported via conveyor belts from packing stations to pallet or truck/boxcar loading stations.

c) bag loading - filled bags are loaded on pallets or directly into boxcars or trucks (with or without pallets).

d) bulk loading - bulk flour is loaded into closed railroad or truck hopper cars, through ducts, using exhaust ventilation for dust control.

In addition, two experimental dust control procedures were evaluated. These were:

a) injection of agglomerating agents - at one plant, up to 1.5% by weight of water was added to silica flour during packing in 100 pound bags. At a second plant, the agglomerating agent,[15] Deter Micro Foam(R) was being tested for dust suppression in the transport of sand. Micro Foam(R) is now being tested for suppression of silica flour dust.

b) application of water sprays - at one plant, water is sprayed on filled bags of silica flour, through sonic water jets, at several strategic locations along its conveyance from packer to pallet loading. The water is used to agglomerate and to remove dust accumulated on the bags' outer surfaces.

2. Investigation procedures

a) Environmental dust measurements

Atmospheric dust concentrations were measured to evaluate the effectiveness of dust control procedures. Measurements were taken at potential sources of dust contamination and at general work areas. Additional atmospheric measurements were made upwind and downwind of the plants. Upwind samples were collected to estimate the contribution of background dust, unrelated to plant operations. Downwind samples were collected to estimate the contribution of in-plant dust sources to the ambient environment. Bulk samples (rafter, product and high volume air samples) were collected to determine the chemical composition and particle size distribution of product and airborne dust. Four types of dust samples were collected and analyzed.

1) Integrated air samples (several hours in duration) were collected with MSA Gravimetric Dust Samplers with attached cyclone separators. They were analyzed quantitatively (by weight) for "respirable dust" and "respirable silica dust".

2) Short-term, direct reading atmospheric measurements of "respirable dust" (several minutes in duration) were made with the TSI Respirable Aerosol Mass Monitor, Model 3500, to identify potential dust emission sources.

3) Air samples were collected with the Del High Volume Electrostatic Precipitator (ESP) sampler with an attached cyclone separator. The purpose of this sampler was to collect sufficiently large airborne samples for accurate identification of the airborne dust, both in silica content and in particle size distribution.

4) Bulk rafter and product samples were also collected and analyzed for silica content and particle size distribution. These results were compared with ESP sampler results.

All samples were analyzed either at UBTL or at NIOSH's Measurements Support Branch Laboratory. Descriptions of sampling and analytical procedures and methods are presented in Appendix A.

b) Ventilation control measurements

Ventilation and air flow pattern measurements were evaluated to determine the effectiveness of the local exhaust ventilation systems. Velocity measurements were made with a Kurz Air Velocity meter (Model 441) and air flow patterns were evaluated with Gastec Smoke Tester tubes.

III. RESULTS AND DISCUSSION

A. Workplace Environmental Conditions

Packing

Table 2 and Figure B present the atmospheric concentrations of silica dust where local exhaust ventilation systems have been installed as the primary method of dust control. Both effective and partially effective dust controls were observed at these plants. For example, at all three plants, where main product flour (-200 to 325 mesh) is packed on 4 spout St. Regis packers (Photo 1-3), dust exposures were controlled to below the MSHA limit and above the NIOSH recommended limit. Average respirable silica dust concentrations were approximately 84 $\mu g/m^3$, Table 2.2. At two locations, however, where packing and palletizing of fine product flour (<38 μm) were performed intermittently, respirable silica dust concentrations averaged 451 $\mu g/m^3$, Table 2.3. Additional improvement of these dust control systems is necessary.

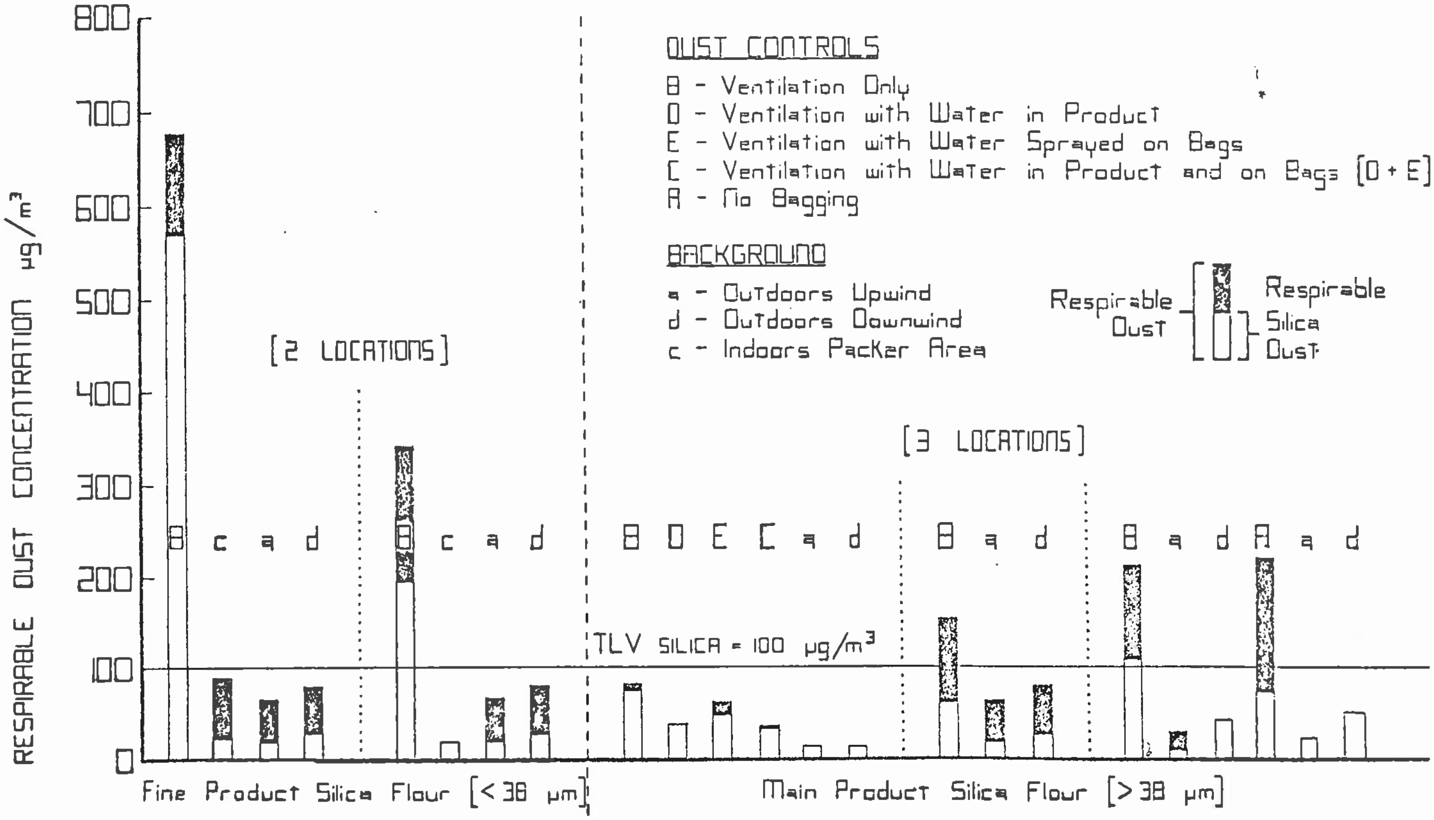
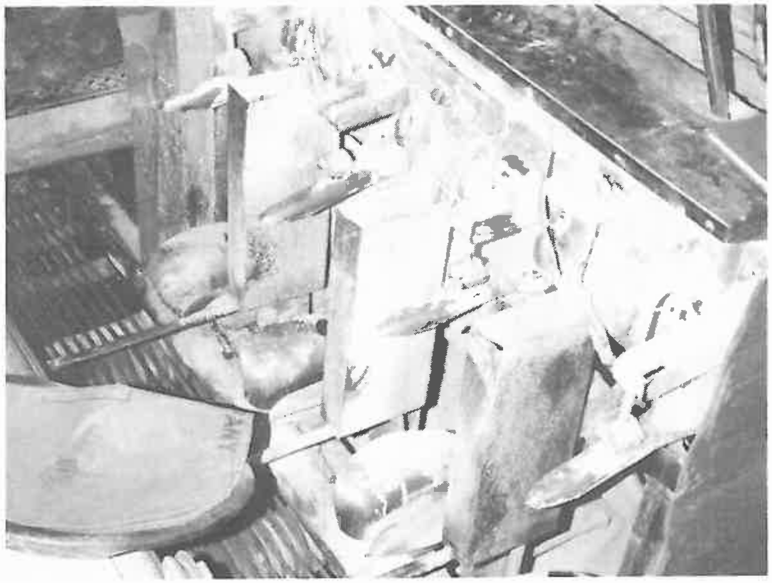
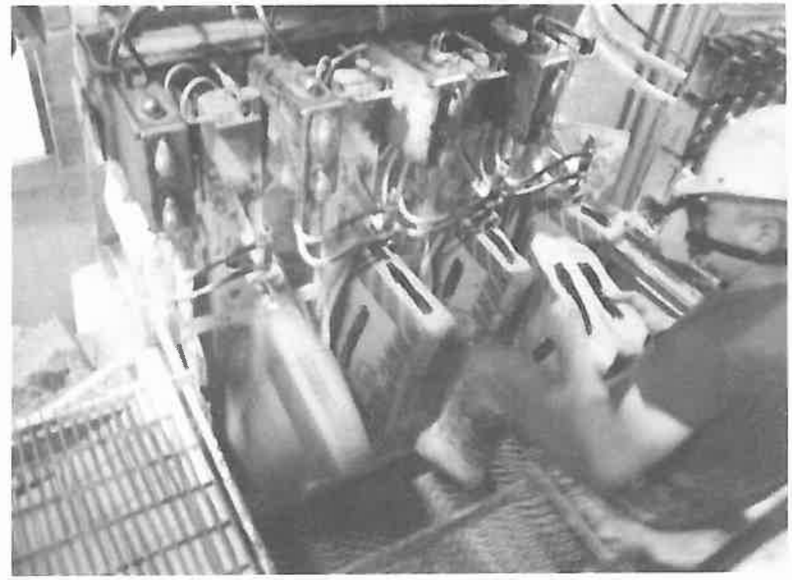
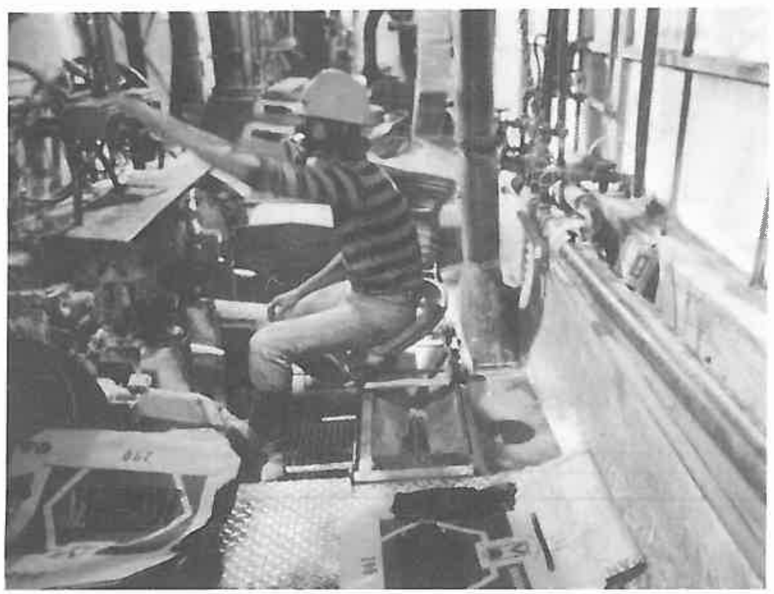


Figure B: DUST CONCENTRATION AT PACKERS

Packing in 100 lb Bags







1. Packing of 4-spout packer; Water spray, nozzles at fill-spouts

2. Packing at 4-spout packer, automatic bag ejector; Use of respirator, down-draft grill

3. Packing at 4-spout packer; 2 exhaust systems, use of respirator

Table 2.

Respirable Silica Dust Concentration at Three Flour Mills (Ventilation Control only)

Operation/Location	Respirable silica dust concentrations µg/m³	Average concentration µg/m³	Average silica content %	Type Sample
1. Background (3 plants)				
a) Upwind of mills	<11, <13, <13, <16, <25, 34	<19	32	area
b) Downwind of mills	<13, <13, <16, 35,	<23	64	
c) Between buildings	38, 41, 46, 51	46	75	
d) Truck loading dock	122	122	49	
2. Packing-main product flour on 4-spout packers (3 locations)	96, <69, 61, 112	84	56	work area
3. Packing and palletizing fine product (2 locations)	199, 451, 704	451	76	source
4. Conveyor transport of bags (1 location)	165	165	100	source
5. Transfer between conveyors (2 locations)				
a) Automatic transfer	64, 66	65	68	source
b) Manually assisted transfer	247, 332, 456	345	87	
6. Bag handling				
a) Pallet loading from conveyor (upwind)	59, 63, 68, 84, 105, 139	86	40	source
b) Pallot loading from conveyor (downwind)	244, 256	250	67	source
c) Boxcar loading from conveyor	1417, 1625	1521	80	work area
d) Truck loading from conveyor	264	264	80	work area
7. Bulk loding of hopper railroad car, semi-automatic	34, 34, 172	80	94	source

µg/m³ - micrograms per cubic meter
< - less than

Bag transfer between conveyors

Transfer of bags between conveyors may also be a major source of atmospheric dust (Figure C). This source can be controlled as shown in Table 2.5a. At one location (Photo 4) where transfer is automatic and drop distance between conveyors is minimal, the average respirable silica dust level was 65 $\mu g/m^3$. At a second location, however, where bags were manually assisted in transfer between conveyors (Photo 5), respirable silica dust levels averaged 345 $\mu g/m^3$. Additional dust control is necessary at this dust emission source.

Pallet loading

Dust dispersion, during palletizing of bags from conveyors, is another major source of dust (Figure C). This source can be reduced by a combination of good engineering controls and good work practices. These include proper bag handling to minimize bag breakage, and prompt cleanup of spills through a down-draft grill (Photos 6 and 7). Table 2.6a and b indicate that unequal dust emissions occur around the pallet loading area. An average concentration of respirable silica dust of 86 $\mu g/m^3$ was measured on three sides (the upwind side) of the conveyor, whereas the downwind concentration was 250 $\mu g/m^3$. This may be caused by excessive draft from nearby open doors.

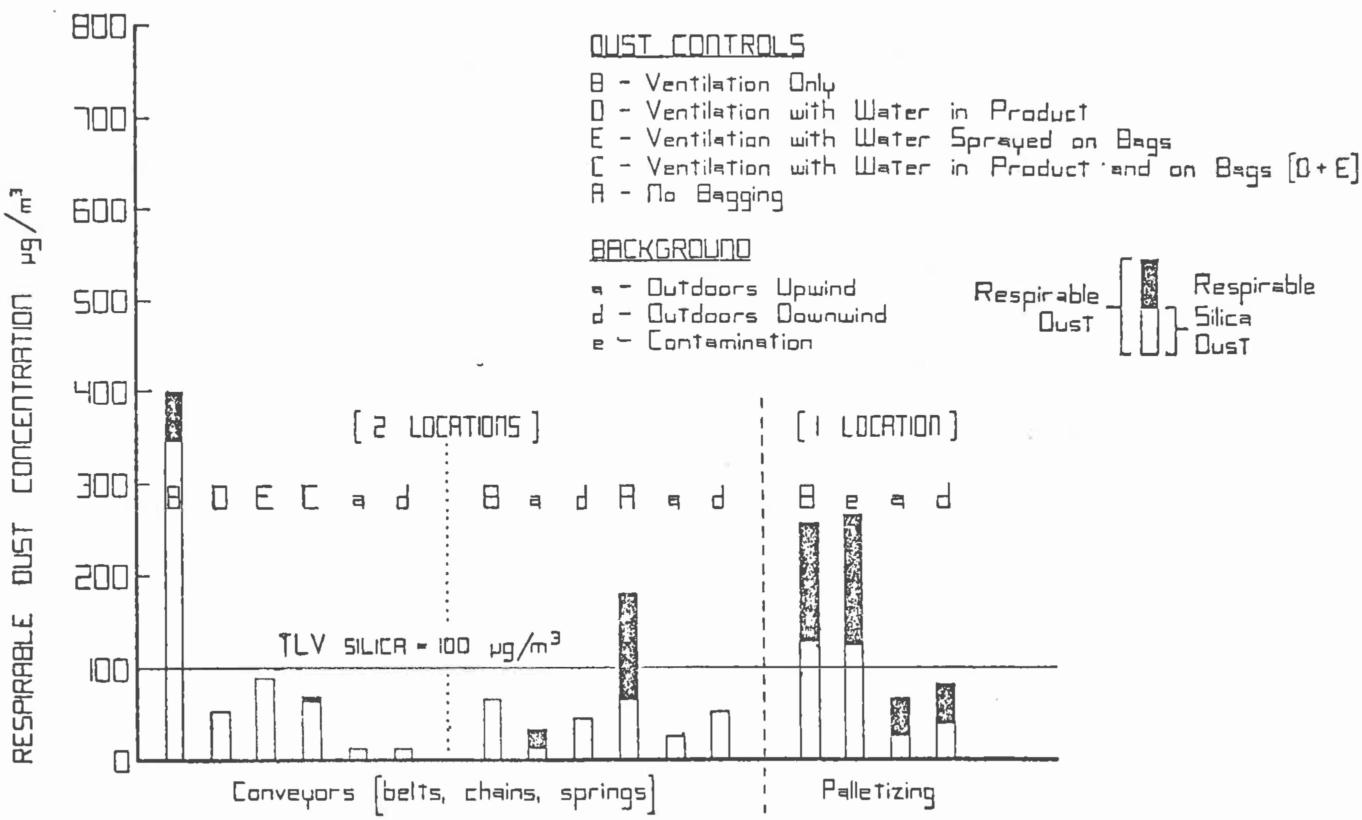
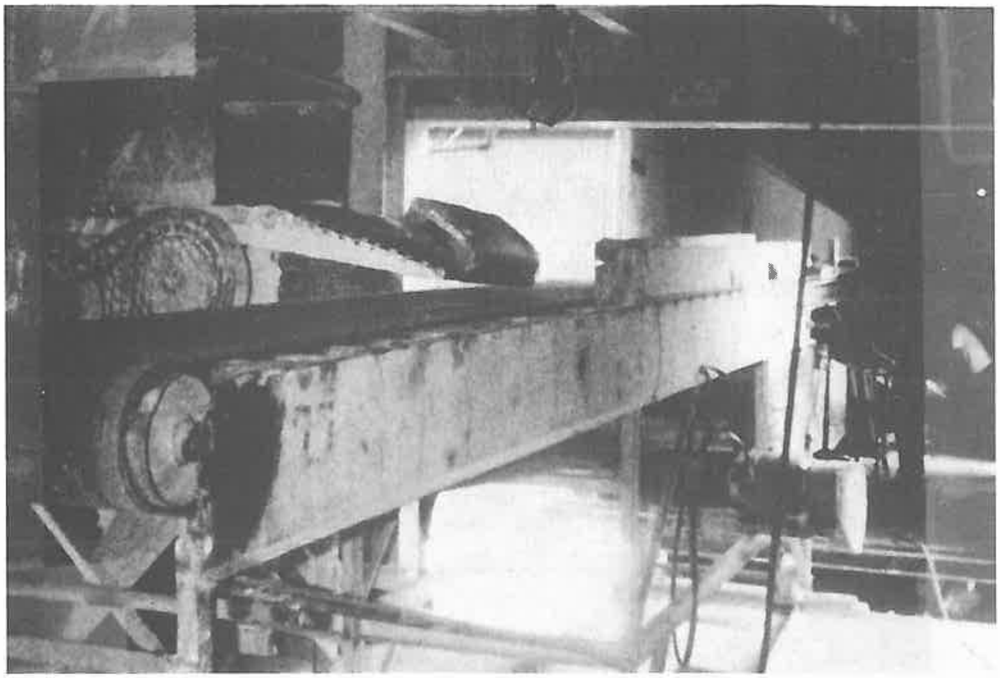


Figure C: DUST CONCENTRATION FOR BAG HANDLING

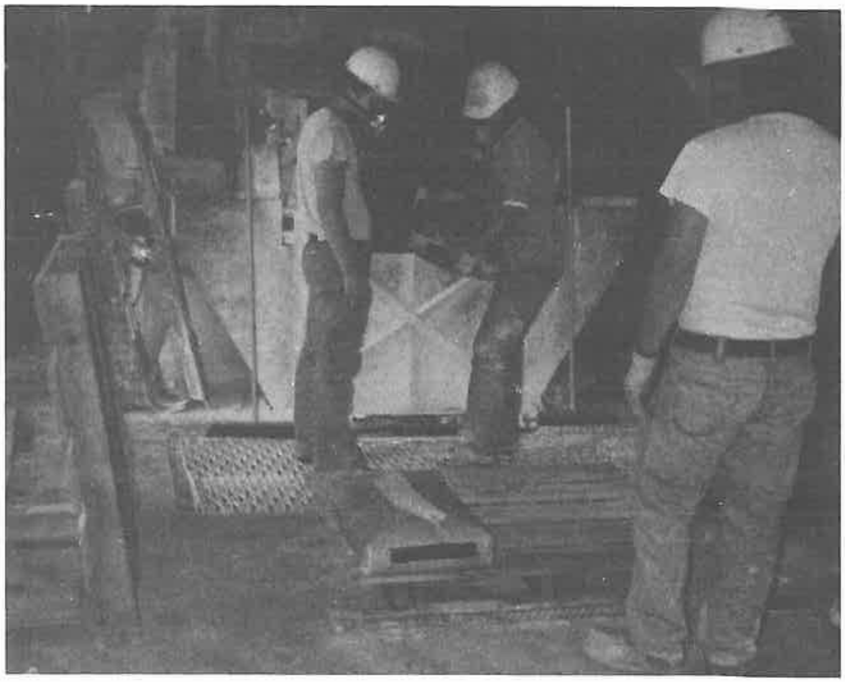
Transfer of Bags Between Conveyors



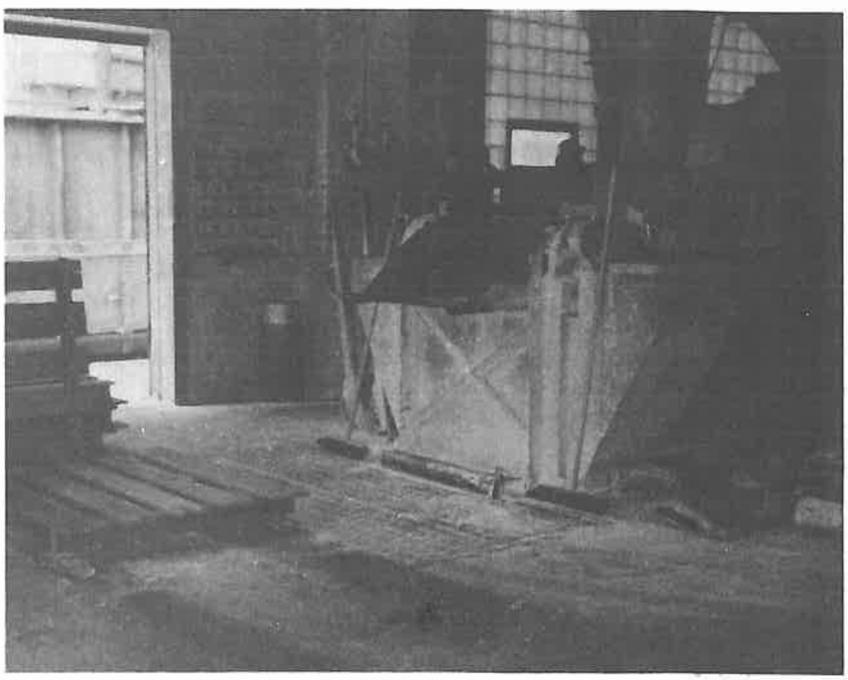
4. Conveyor transfer point; minimum drop, clean bags

5. Conveyor transfer point excessive bag drop, broken bag, incomplete spray capture, use of respirator

Loading of Bags on Pallets



6. Exaust floor grill; use of respirators



7. Down draft floor grill; dry sweeping of spills; broken bags at dust source

Loading into boxcars and trucks

Boxcar and truck loading directly from conveyor belts is a major source of dust dispersion (Figure D). Table 2.6b and c shows respirable silica dust levels ranging from 264 to 1625 $\mu g/m^3$ under normal operating conditions. (Photos 8, 9, 10). Although no evaluations were made of loading palletized product into boxcars or trucks by forklift, it may also be a major source of atmospheric dust.

Bulk loading of hopper cars

Bulk loading of closed railroad hopper cars can be accomplished with (dispersion) minimal dust dispersion, when performed under the control of local exhaust ventilation (Photos 11-14 and Figure D). Table 2.7 shows that the average respirable silica dust level around a controlled loading spout is 80 $\mu g/m^3$. This is higher than the background upwind dust level of 35 $\mu g/m^3$, at this plant, but below the MSHA standard.

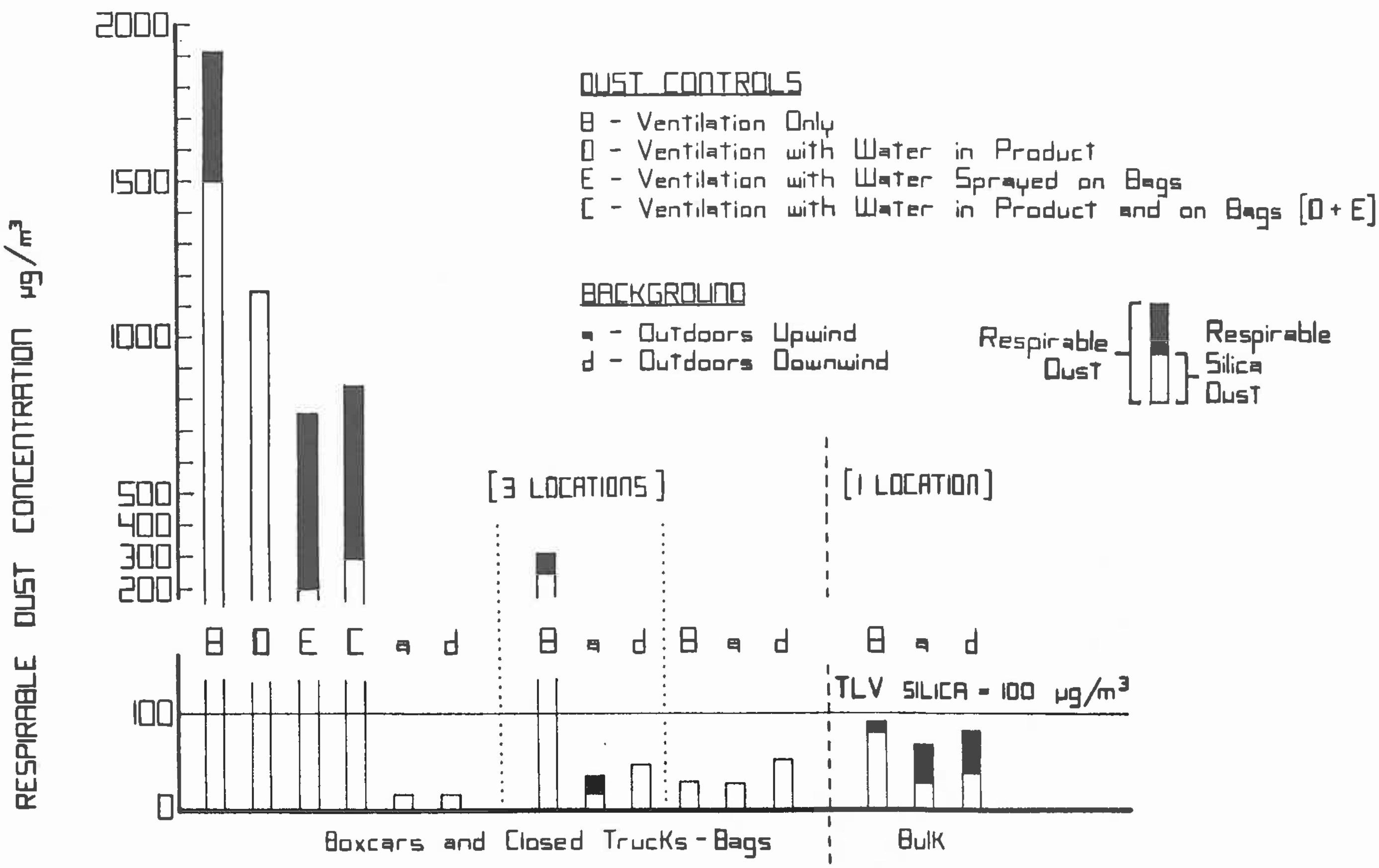
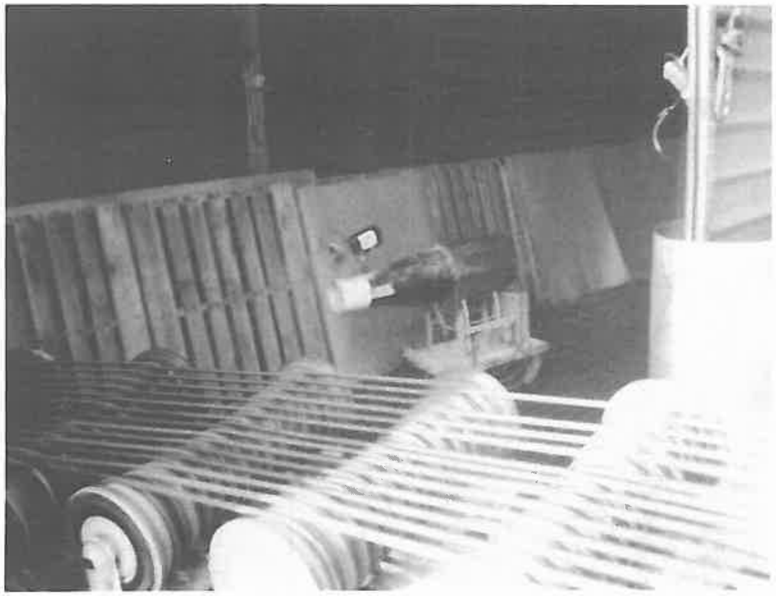


Figure D: DUST CONCENTRATION AT LOADING

Stacking Bags in Boxcars and Trucks

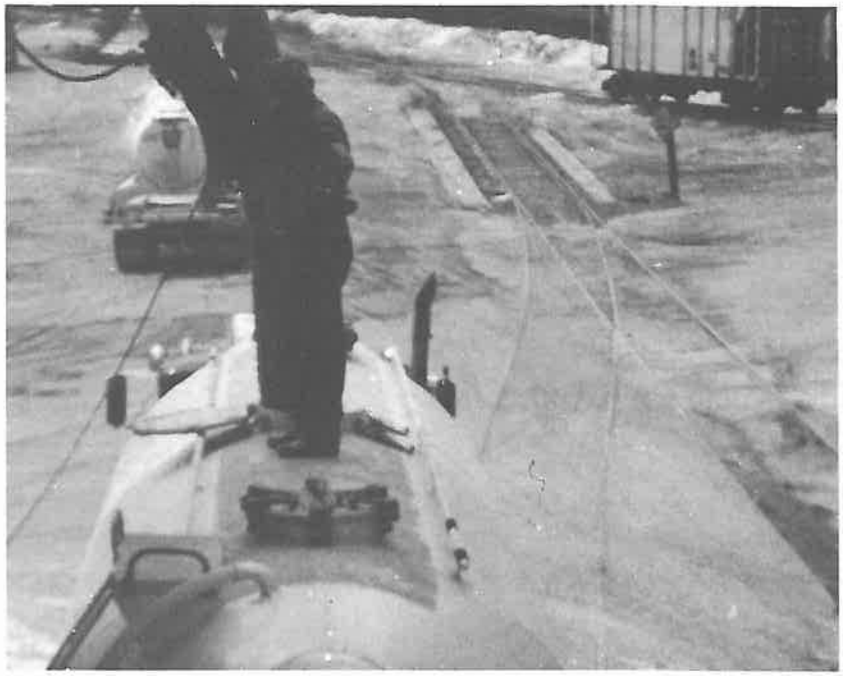


8. Boxcar before bag loading; Ritter Electrostatic Fogger

9. Stacking bags in boxcars; no pallet; dirt on floor and bags, use of respirator

10. Stacking bags in truck on pallets; use of respirator

Bulk Loading in Trucks

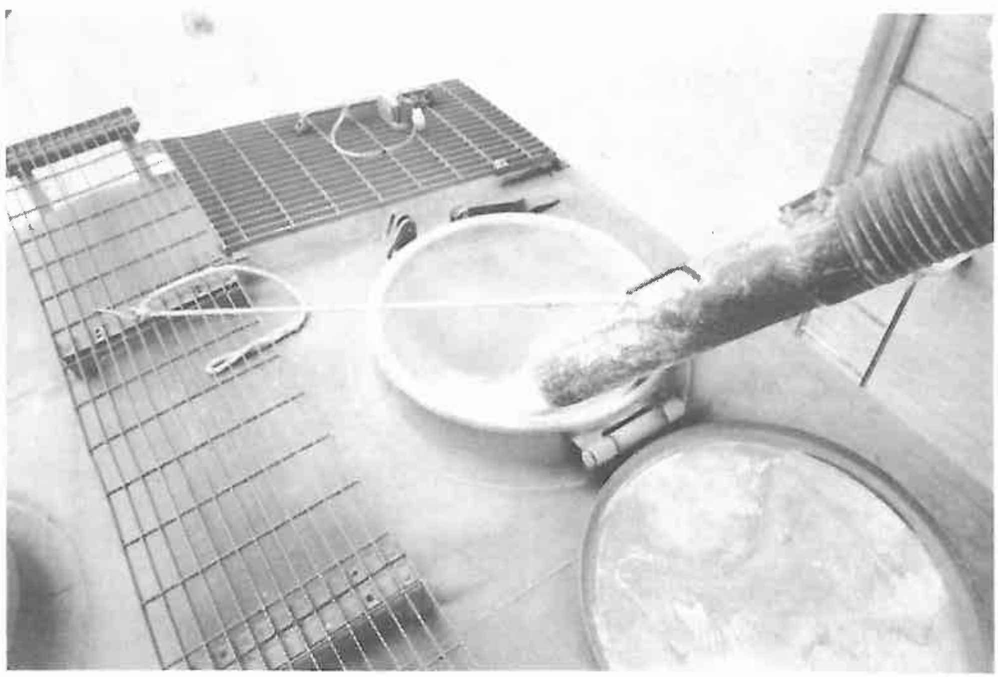


11. Bulk loading closed hopper truck with exhaust; dust well controlled

12. Bulk loading open truck with sand; men standing by

Bulk Loading in Closed Hopper Car

13. Bulk loading closed railroad hopper car with exhaust; fill-spouts and exhaust



14. Bulk loading closed railroad hopper car with exhaust

B. Effectiveness of Engineering Controls

1. Local Exhaust Ventilation Systems

Table 3 describes and summarizes the ventilation control systems at the various operations.

a) Bag packing (Photos 1, 2, 3)

Local exhaust ventilation systems were capable of maintaining silica dust concentrations close to or below the MSHA TLV of 100 $\mu g/m^3$, when main product silica flour was being packed. However, they were not capable of reducing dust levels to the NIOSH recommended level of 50 $\mu g/m^3$. At one plant (Figure E and Table 3.1), the packer exhaust system moved air laterally, from the packer operator toward the packer machine. Simultaneously, the conveyor belt exhaust system moved air from the operator toward an exhaust slot beneath and behind the operator in opposition to the air flow of the packer exhaust system. This appeared to create a "null zone" of air movement in the vicinity of the packer operator. The average air velocity at the face of the packer machine hood was low, 45 feet per minute (fpm), (Figure F); the average velocity at the face of the hood behind the packer operator's seat was 1000 fpm. Dust levels were controlled to 103 $\mu g/m^3$ respirable dust and 96 $\mu g/m^3$ respirable silica dust.

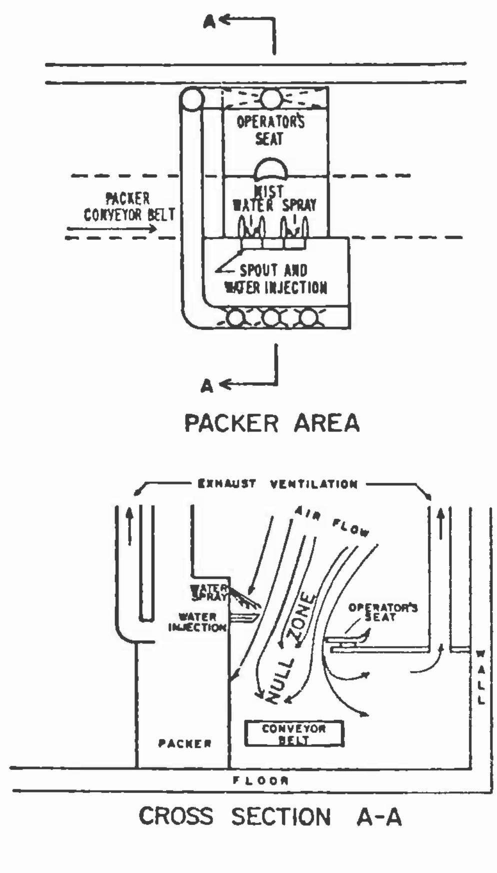


Figure E: Packer - Ventilation and Water Controls

Table 3.

Ventilation Control Systems

Location/operation	Description of System	Velocity Measurement fpm	Respirable dust concentration total $\mu g/m^3$	silica $\mu g/m^3$	silica content %	Remarks
1. 4-spout main product packer, packing 100# bags a) behind packer machine b) directly behind packer operator	(Figure E and F) 5 ft x 4 ft hood directly behind 4 spouts of machine 4 ft x 4 in. slot, pull-air from conveyor belt	at hoodface - 45 av. 1 ft from face - 20 av. at slot - 1000 av.	103	96	93	Fair Control - air velocity fairly uniform around spouts. Slot behind operator pulls in opposition to packer machine hood. It could be more strategically located. Most dust emanates from packer
2. 4-spout main product packer, packing 100# bags behind packer machine	(Figure H) 53 in. x 33 in. lateral hood, plus area fan above head of operator	at hoodface (av.) top = 134 middle = 116 bottom = 28	145	63	43	Good control; air moves from above and back of operator downward and to rear of packer machine. Most dust emanates from general environment
3. 4-spout main product packer, packing 100# bags a) behind packer machine b) below and behind packer operator	(Figure I and J) 60 in. x 45 in. lateral hood, directly behind packer machine, moves air laterally away from operator 30 in. x 4 in. lateral slot moves air down and away from operator	at hoodface (av.) top = 343 middle = 356 bottom = 288 rt end = 1200 control = 2150 left end = 1100	212	112	53	Good control; air moves from above and back of operator downward and to rear of packer machine. Most dust emanates from general environment
4. 2-spout fine product packer, packing and palletizing a) left side of #1 fill spout b) behind #2 fill spout	(Figure K) 22 in. x 14 in. side hood, adjacent to #1 spout 7 in. x 4 1/2 in. side	at hoodface (av.): top = 180 middle = 100 bottom = 40 at slot = 4800 at spout = 900	686	578	84	Uneven air flow. good control control at #1 packer; poor at #2 packer, cross drafts and palletizing permit dust dispersion. Most dust emanates from packer spouts and bag handling

Table 3. Cont'd

Ventilation Control Systems

Location/operation	Description of System	Velocity Measurement fpm	Respirable dust concentration total $\mu g/m^3$	silica $\mu g/m^3$	silica content %	Remarks
5. 1-spout fine product packer, packing and palletizing	(Figure E and F) 18 1/2 in. x 11 1/2 in. hood behind and below spout	at hoodface (av) top = 200 middle = 247 bottom = 105	344	119	58	Good air velocity, but open sides and remoteness of hood from spout, spills on floor and cross drafts reduce efficiency. Dust from packer and general environment
6. Transfer point from chain conveyor to pallet loading station, loading pallets	(Figure K)		255	< 128	50	Good air movement, but handling of bags, and loading pallets cause some contamination. Some dust emanates from general environment
a) at conveyor take off	38 in. x 15 in. hood enclosure at belt discharge	at hoodface (av.) at face = 325				
b) floor grill at loading station	90 in. x 43 in. floor grill	at grill = 127				
7. Transfer point from declining conveyor to horizontal conveyor, main level, manually handling bags	(Figure M) Enclosure hood with canvas curtain	At hoodface (av): no bags present: 20 - 40 bags present: 50	400	345	86	Hood not completely effective, most dust emanating from bag handling.
8. Railroad hopper car, batch loading floor through hatch	(Figure O) Four 30 in. diameter loading hatches. One 30 in. exhaust duct. Two 10 in. fill hoses in 2 hatches; one hatch closed	Inflow to open hatch (av.) - 230	91	80	88	Good dust control, all visible dust drawn into hopper car

$\mu g/m^3$ = micrograms per cubic meter

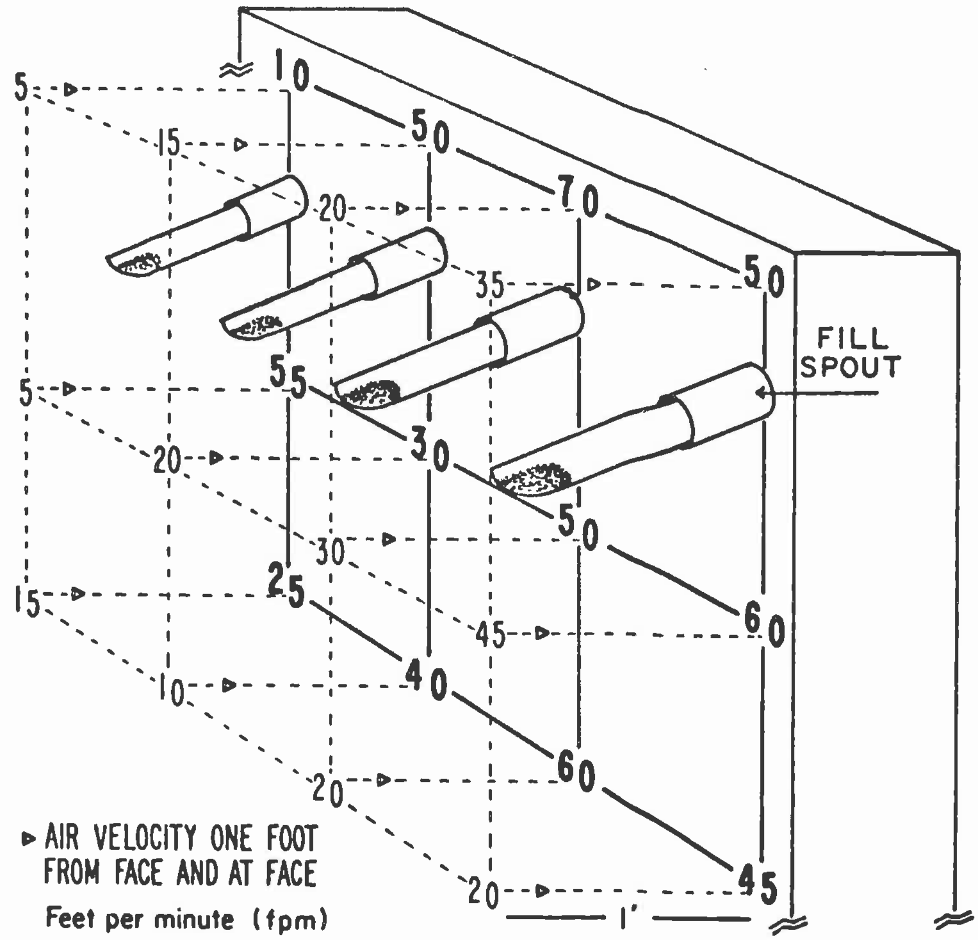
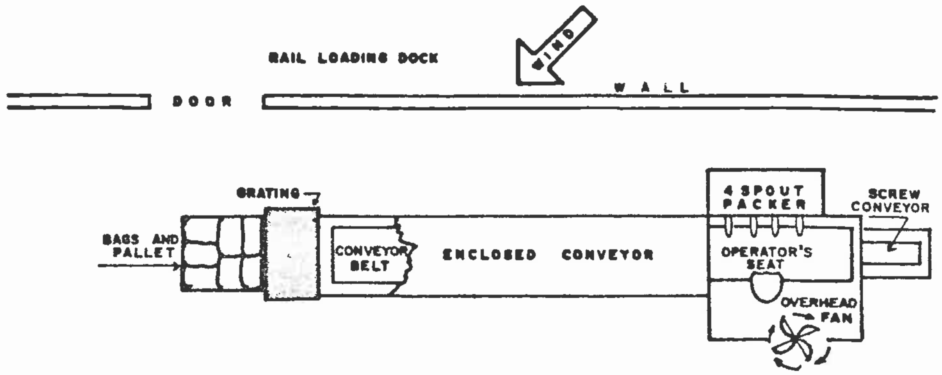
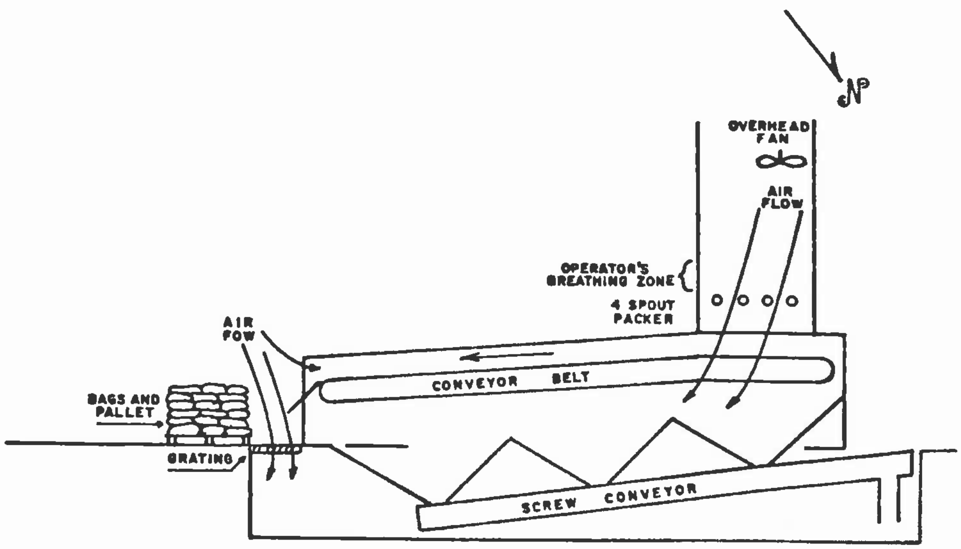


Figure F: Ventilation measurements - Main Product Packer

At a second packer station, (Figure G and Table 3.2), dust levels were 145 μg/m^3 respirable dust and 63 μg/m^3 respirable silica dust. Effective dust control was developed by a "push-pull" ventilation system. This included an exhaust hood behind the packer machine; a second system below the conveyor; and an over head area fan behind the packer operator. The fan provided a curtain of clean air past the operator's breathing zone. The average air velocity at the face of the packer machine hood was 92 fpm (Figure H). The silica content of the airborne dust in this area was low, approximately 43%, and the flour product being packed was essentially pure silica. Thus, a major portion of the dust load in this area probably evolved from sources other than the packer, i.e., background dust.

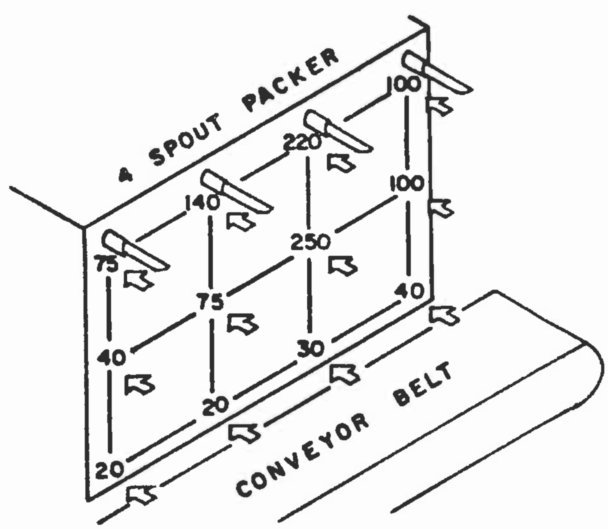


PLAN VIEW



CROSS SECTION

Figure G: Packing Area - Main Product



AT FACE OF PACKER

Figure H: Ventilation at Main Product Packing Area

At a third plant, silica dust emissions from the packer machines were controlled by an exhaust system involving two sets of hoods, (Figure I and J, and Table 3.3). One set of hoods, behind the packer machine, moved air laterally away from the operator toward the packer machine. The average air velocity at the face of the packer machine hoods was 324 fpm. A second set of hoods, below the packer operator and adjacent to the conveyor, moved air downward. The average air velocity of this slot hood was 1650 fpm (Figure J). This system resulted in an air pattern down and away from the operator's breathing zone. Air samples were taken during periods of "no packing" and of "packing." During "no packing" dust concentrations averaged 220 $\mu g/m^3$ respirable dust and 75 $\mu g/m^3$ respirable silica dust (34% silica). During a period of "packing," dust concentrations averaged 212 $\mu g/m^3$ respirable dust and 112 $\mu g/m^3$ respirable silica dust (53% silica) (Table 7.2).

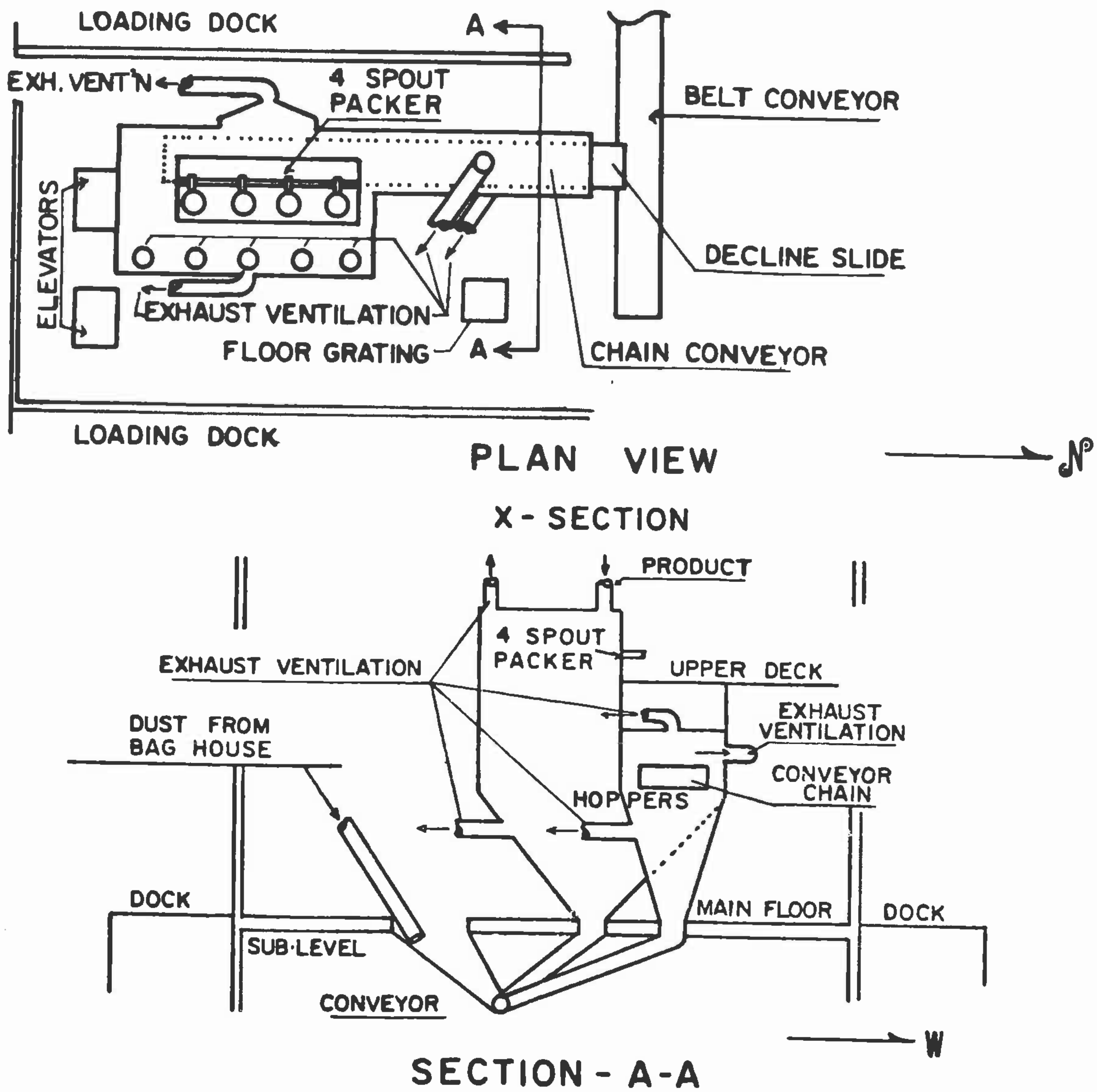


Figure I: Packing Area - Main Product

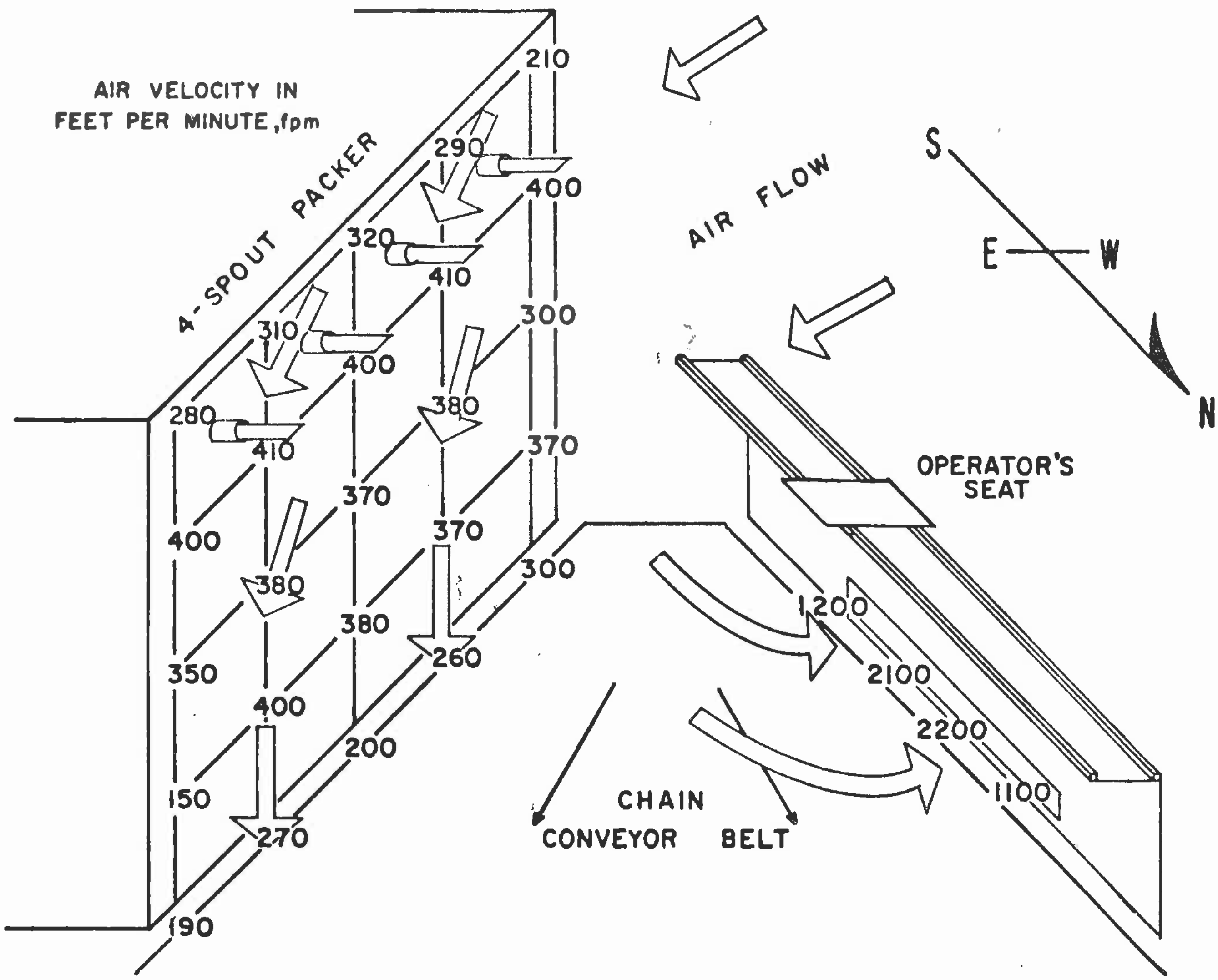


Figure J: Ventilation at Main Product Packing Area

Since the silica content of the airborne dust was relatively low during both operating conditions, probably the major source of dust was background contamination.

Dust levels at two fine powder packing stations were high, averaging about 515 $\mu g/m^3$ respirable dust and 350 $\mu g/m^3$ respirable silica dust (Table 3.4 and 3.5 and Figure K). Although exhaust ventilation flow rates were high, ranging from 100 to 4800 fpm at the hood faces, dust control was ineffective. This was probably caused by: uneven flow patterns, created by cross drafts in the packer areas; exhaust hoods located remotely from dust sources; and spills on floors, which were not removed promptly or properly.

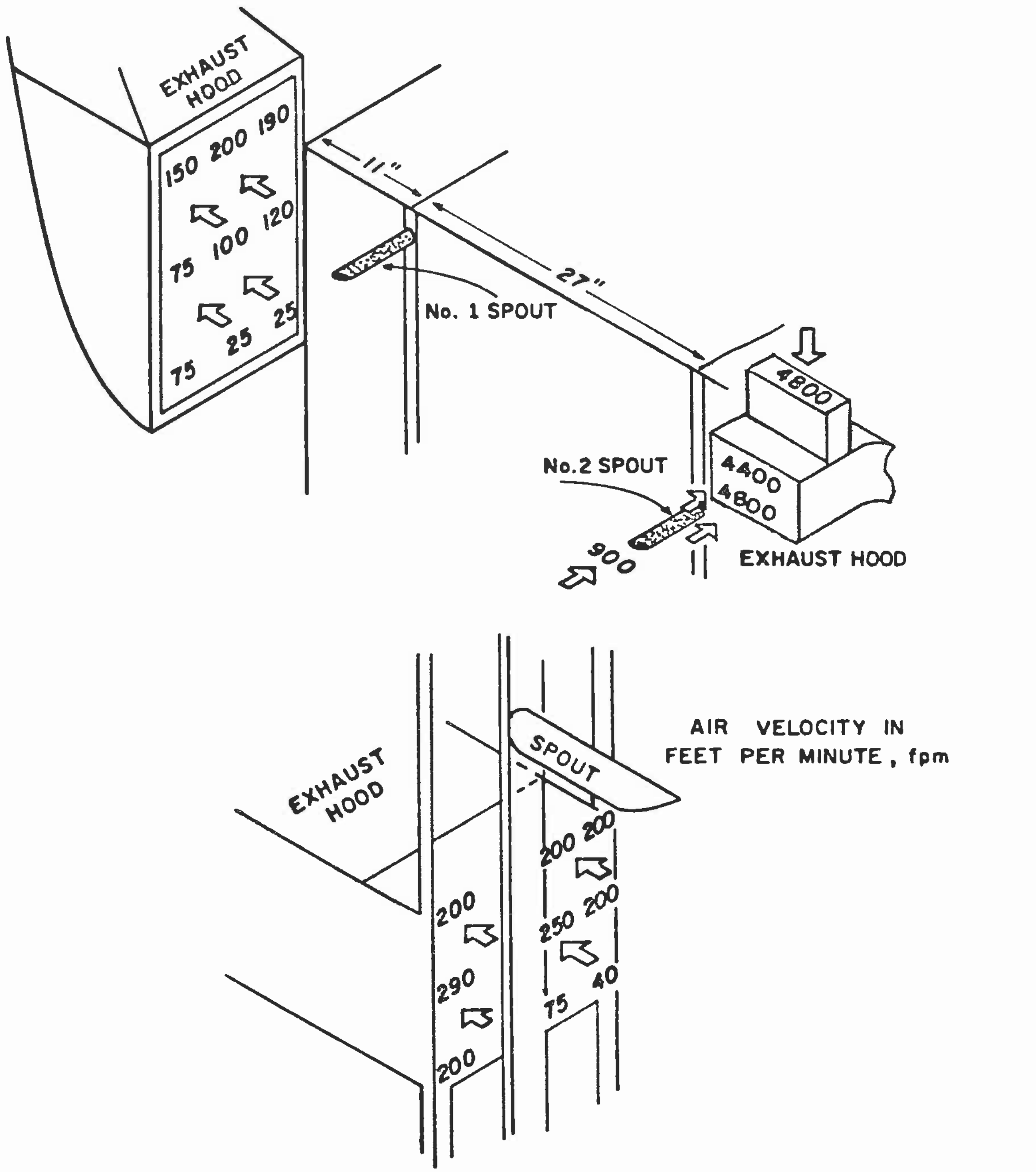


Figure K: Ventilation at Fine Product Packing Areas

b) Transfer between conveyors

Two locations were observed where filled bags were transferred between conveyors. At one location, transfer was manually assisted (Photo 5 and Figure L). A ventilated hood, close to the transfer point, developed in-let air velocities of 20 to 40 fpm. This air movement was insufficient to capture all of the generated dust. Dust levels averaged 400 µg/m^3 respirable dust and 35 µg/m^3 respirable dust during normal operations (Table 3.7). Spilled dust from broken or dirty bags was periodically removed by washing down of floors.

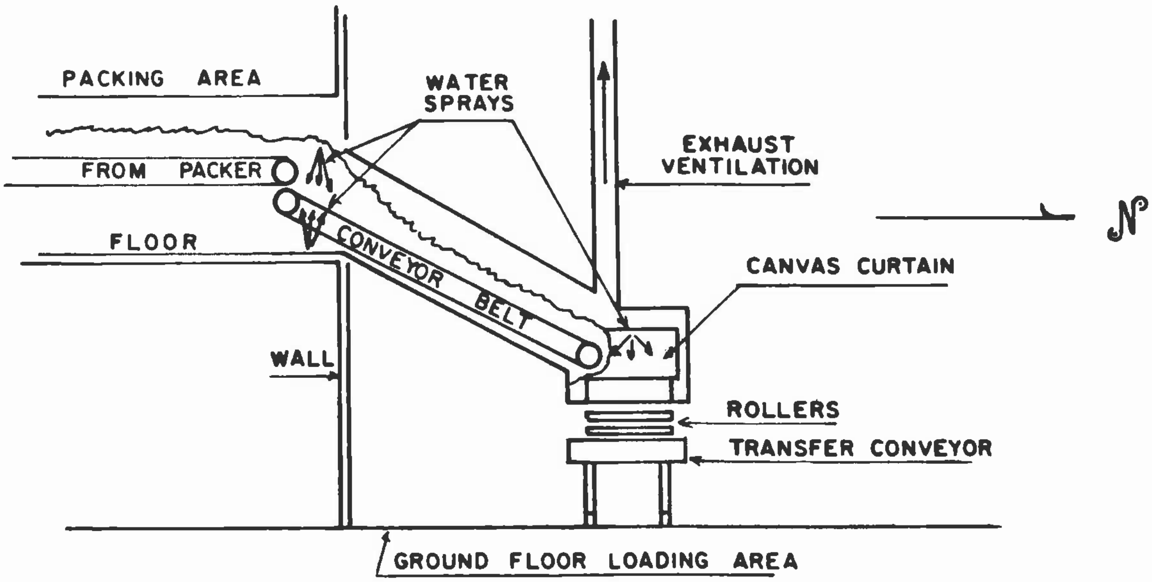
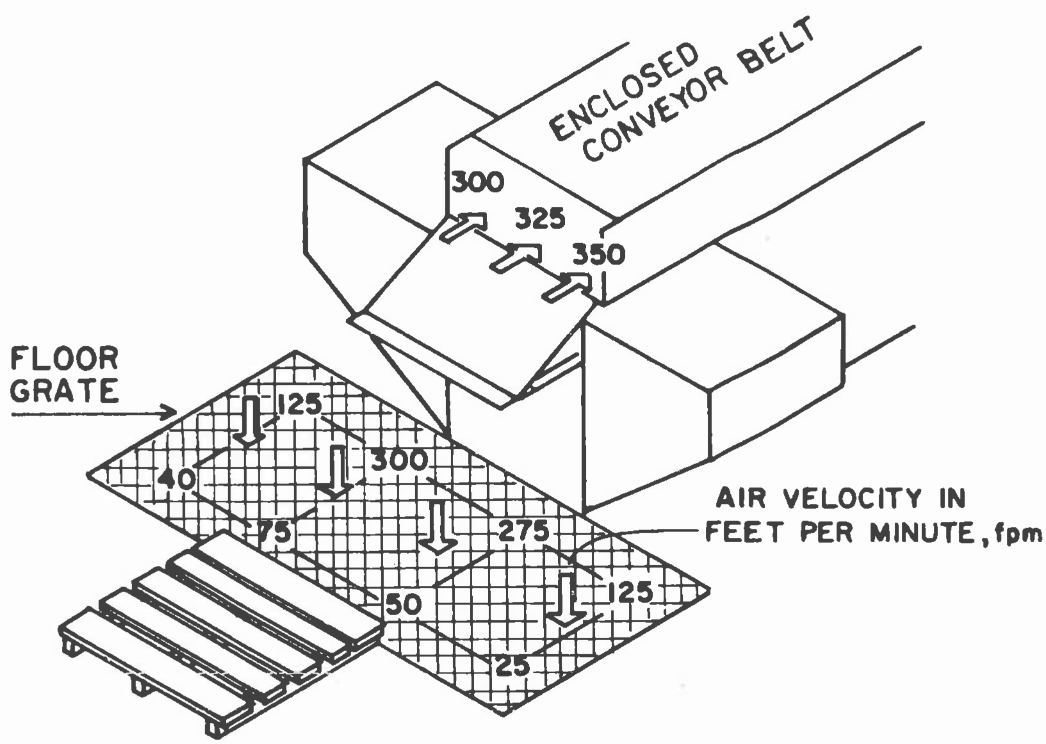


Figure L: Transfer Points - Ventilation and Water Sprays

At the second location (Photo 5 and Figure I), transfer between conveyors was automatic, with minimal manual handling of bags. Although no enclosure or ventilation was present at the transfer point, dust levels were low during packing operations, averaging 66 µg/m^3 respirable dust and 66 µg/m^3, respirable silica dust (Table 7.3). This control condition was probably caused by several factors: 1) bags were cleaned during their transport along the horizontal chain conveyor by a ventilation system of four hoods (2 above and 2 below the conveyor); 2) the drop between conveyors was less than two inches causing minimal dispersion of dust to the atmosphere; 3) bag breakage was minimal, less than 2%, both during bag transport and during packing and pallet loading; and 4) excessive flour, not captured by the ventilation ducts, fell through the chain conveyor into one of two hoppers and returned to storage silos.

c) Pallet loading

At one plant, filled bags are transported on an enclosed chain convéyor to a pallet loading area (Photos 6 and 7 and Figure M). A ventilation hood, enclosing the conveyor, exhausted air laterally at an average velocity of 325 fpm. Simultaneously, a down draft floor grill (7 1/2 ft. by 3 1/2 ft.) moved air downward at approximately 125 fpm. The average dust concentration at this location was 225 ug/m^3, respirable dust and 128 $\mu g/m^3$ respirable silica dust Table 3.6). However, downwind of the conveyor, two samples averaged 375 $\mu g/m^3$ respirable dust and 250 $\mu g/m^3$ respirable silica dust (Table 6.1B.2), while upwind dust levels, average of three remaining samples, were 217 $\mu g/m^3$ respirable dust and 87 $\mu g/m^3$ respirable silica dust. These concentrations indicate that a significant portion of the dust was background. Bag leakage and dry sweeping clean-up may also have been major sources of atmospheric dust. Visual observations indicate that an additional dust source may have been from open bulk loading of sand into open trucks along the east side of the building (Photo 11).

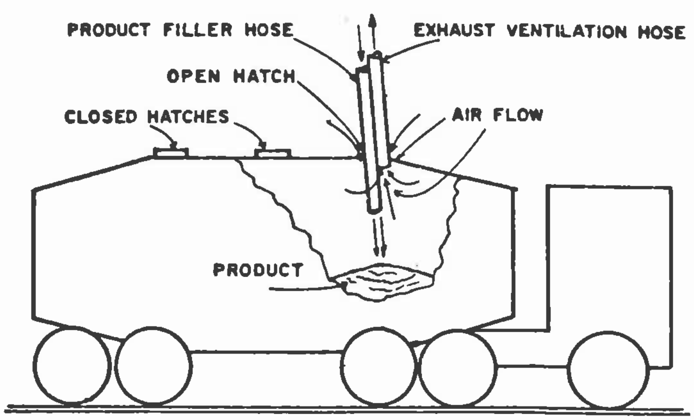


AT FACE OF CONVEYOR DISCHARGE AND FLOOR GRATE

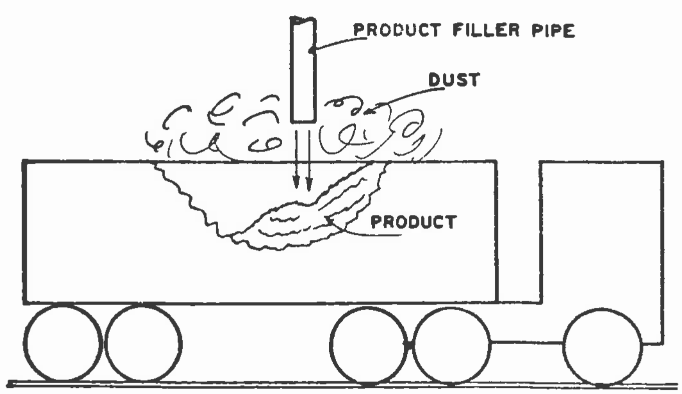
Figure M. Ventilation at Pallet Loading Area

d) Bulk loading

At one plant, closed hopper trucks and hopper railroad cars were loaded with silica flour and sand under the control of local exhaust ventilation (Photos 12 through 14, and Figures N and O). At the same plant, open trucks were being bulk loaded with silica sand (Photo 11). Photos 11 and 12 show the difference in dust dispersion under controlled and uncontrolled conditions. During controlled loading of a closed railroad hopper car, atmosphere dust concentrations averaged about 91 $\mu g/m^3$ respirable dust and 80 $\mu g/m^3$ respirable silica dust. At the same time, background (upwind) dust levels were 74 $\mu g/m^3$ respirable dust and < 31 $\mu g/m^3$ respirable silica dust (Tables 6.4 and 6.5) Two 10-inch filler hoses were positioned in two open hatches. A 30-inch exhaust duct was positioned in a third hatch, while the 4th hatch remained closed (Photos 13 and 14). During filling, an average inward flow velocity of 230 fpm, at the filler hatch (Figure O), provided excellent emission dust control.



CLOSED HOPPER TRUCK (FLOUR) LOADING



OPEN TRUCK (WHOLE GRAIN SAND) LOADING

Figure N: Bulk Truck Loading

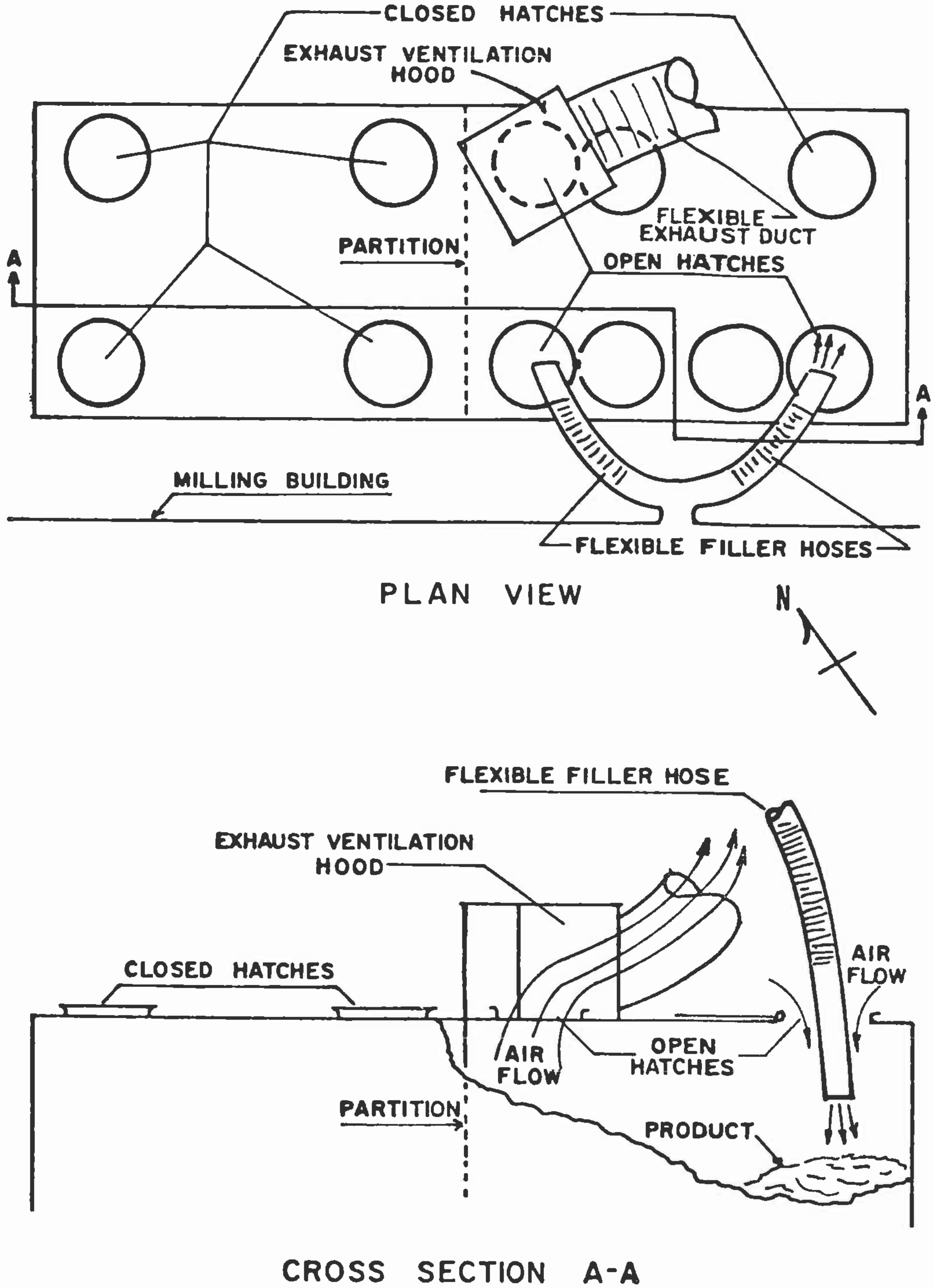


Figure O: Bulk Rail Hopper Car Loading

2. Agglomerating agents

In one plant, water (up to 1.5% by weight) was injected into silica flour, at each filler spout during bag packing (Figure E). The water causes fine dust particles to agglomerate, thereby reducing the emission of dust during bag handling. A series of dust evaluations were conducted under different control conditions. Table 4, Run D (with water injection) indicated that respirable silica dust concentrations were reduced by more than 60% at the packer station, from 96 $\mu g/m^3$ to 39 $\mu g/m^3$, (Figure B) and by approximately 85% at the bag handling areas, from 345 $\mu g/m^3$ to 53 $\mu g/m^3$, (Figure C). At boxcar loading operations, however, only 23% reduction in silica dust concentration was achieved, from 1521 $\mu g/m^3$ to 1164 $\mu g/m^3$, by water injection (Figure D). Thus, this technique showed excellent potential for reduction of dust exposures around packing and bag handling operations, if the product is acceptable with this water content.

At a second plant the agglomerating agent, Deter Micro Foam(R)* was being tested for its reduction of dust dispersion, after its injection into sand. At the time of this study, Micro Foam(R) was being added only to sand in its transfer through the sand screening building. In this system, a mixture of compressed air (approximately 99%), water (approximately 0.9%) and Micro Foam(R) (approximately 0.1%) was nebulized into a conveyor stream of silica sand. Minute foam bubbles, between 100 and 200 μm in diameter, were formed. These bubbles intercepted fine dust particles and agglomerated them into larger, heavier, and non-respirable particles. Although the effectiveness of this material for silica flour dust suppression has not yet been evaluated, it has shown to be effective in sand dust suppression.

Tests conducted by the company, indicate that, when added to sand, it may reduce dust levels by as much as 67%, from 84 mg/m^3 to 27 mg/m^3, inside an enclosed hopper car during bulk loading (Table 4).

Tables 5, 6 and 7 present the general findings of dust concentrations at the three plants investigated. Table 8 presents the chemical and size analyses of bulk air, product, and rafter samples at one plant.

*Deter Micro Foam(R) 1010 is a registered product of the Deter Company, Inc., East Hanover, N.J.

Table 4. Effect of Addition of Deter MicroFoam(R) to Sand Products (Company data)

Location	Total Dust Concentration Without Deter (mg/m^3)	Total Dust Concentration with Deter (mg/m^3)	Reduction (%)
Screen Building 5th Floor - inside conveyor 4 ft. from Deter(R) nozzle	218	175	20
Screen Building inside conveyor transfer point to storage site	164	111	33
Bulk loading covered hopper railroad car, inside hopper	84	27	67

(R) - Deter MicroFoam, manufactured by Deter Company, Inc.

mg/m^3 - milligrams per cubic meter of air

3. Cleaning of bag surfaces

a) Water spray

At one plant, water was sprayed on filled bags with Sonic(R) sprayers* at three strategic locations between the packing and palletizing operations. These locations are: 1) at the fill spouts - directly on the top of filled bags (Photo 1 and Figure E); 2) at the transfer point between a horizontal conveyor and a declining conveyor (upper level) - to the top and bottom of each bag (Photos 15 and 16 and Figure L); and 3) at the transfer conveyor (lower level) - on both sides of bags (Photo 4, and Figure L). The spray patterns were overlapped so that all exterior surfaces were thoroughly washed to agglomerate and remove spilled product. Table 4, Run E (spray on bags) indicates that respirable silica dust concentrations were reduced by approximately 50% at the packer station, from 96 $\mu g/m^3$ to <44 $\mu g/m^3$ (Figure B); by approximately 75% at the bag handling areas (from 345 $\mu g/m^3$ to 90 $\mu g/m^3$ (Figure C); and by 87% at the boxcar loading operations, from 1521 $\mu g;m^3$ to 204 $\mu g/m^3$ (Figure D). This technique also indicated potential for reduction of dust dispersion during packing, transport, palletizing and boxcar loading of bagged silica flour.

When water is injected into product and sprayed onto bags simultaneously (Table 4, Run C), 62% to 81% reductions in silica dust concentrations can be achieved in all areas of bag handling. Even with optimum dust control, however, respirable silica dust levels during boxcar loading continues to be hazardous, on the order of 317 $\mu g/m^3$ (Figure D).

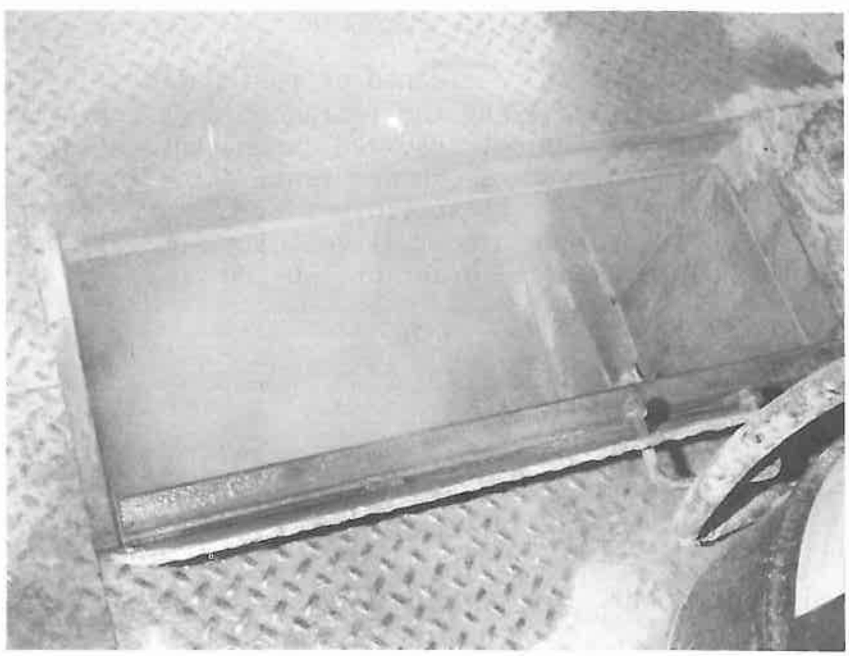
b) Air cleaning

Bags may also be cleaned of residual dust by the use of air jets located along their transport on conveyors. This procedure was not observed during this study. In the design of such a system, exhaust ventilation inside a conveyor enclosure must be sufficient to capture all of the jet air, and to provide a control velocity into all openings of the enclosure on the order of 150-200 fpm.

*Manufactured by the Sonic Development Company, Upper Saddle River, New Jersey, 07458.

Spraying Water on Bags

15. Spray nozzles (above and below) wash bags



16. Spray inside conveyor housing agglomerating dust

4. Other engineering controls

The effectiveness of other enginering control measures, involving equipment, facilities, and operations, were evaluated qualitatively.

a) Equipment modification

1) Bag removal - An automatic bag ejector resulted in less product spillage from the fill spouts and bag valves (Photo 2). This device does not operate until the feed valve shuts off, allowing adequate delay time between valve shut-off and automatic kick off. This permits the air in the bag to bleed off, thereby, reducing bag valve leakage.

2) Nozzle design - Tapered sleeves and inflatable valve seals improve the seal at the nozzle/bag interface. These must be properly sized to fit the bag valve and must be maintained in good working order.

3) Conveyor transfer points - Minimal drop distance for filled bags from one conveyor to another reduces bag leakage from the valve or loose seams (Photo 5). Also, bag breakage will be reduced.

4) Fluid bed driers and extended stacks - Extended the stacks on baghouses and other ventilation systems reduces background dust concentrations. Replacing steam driers with enclosed fluid bed driers also produces less dust.

5) Automatic shakeouts - Automatic shakeouts on a timed cycle can improve the operation of the baghouses, further reducing employee exposure.

6) The Ritten Electrostatic Fogger* (Photo 8), has also been used to agglomerate airborne dust in high dust areas, such as boxcar loading. The effectiveness of this device should be evaluated.

b) Facilities modifications

1. Plastic curtains - Overlapping strips of transparent plastic form a curtain to provide easy traffic flow and to increase the effectiveness of the local exhaust control system (Photo 17).

*Manufactured by the Ritten Corporation, Ltd., Ardmore, PA. 19003.

2) Centralized bulk loading - This permits more effective dust control with local exhaust ventilation.

3) Outside environmental control, i.e., surface modification, paving, revegetation, and stock pile covering - Paving of roads and parking spaces and the use of brine or water containing a surfactant to wet dirt roads help to reduce background dust levels. Revegetation is used as wind screens and helps to hold surface soil in place. Covering of stock piles with shrouds or spraying with water reduces dust from this source.

4) Sealed buildings - Sealing buildings and recirculating plant air through bag collectors may reduce the infiltration of background contamination. Placing the bag filling operation(s) in sealed rooms with a filtered air supply is also effective.

5) Floor grills - A floor clean-up grill at a conveyor discharge and at pallet loading area(s) reduces dust dispersion caused by bag breakage or spillage (Photos 6 and 7).

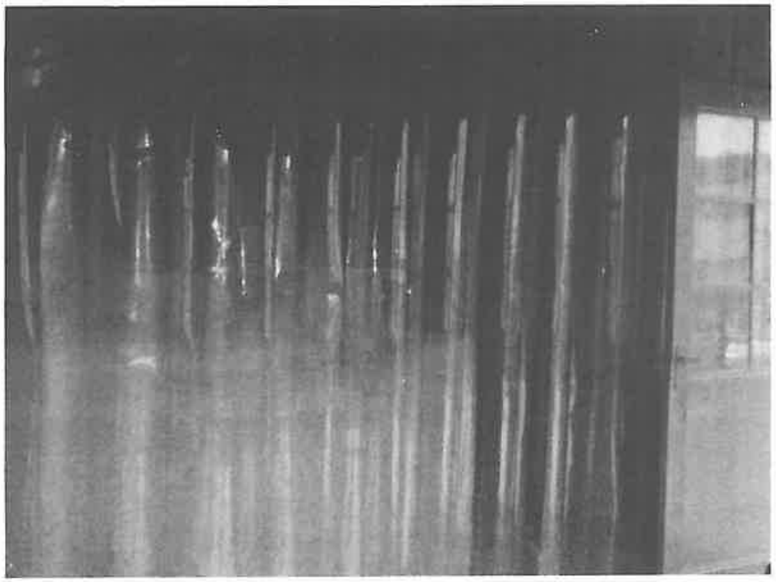
6) Control room air filtration - If mill operators spend a significant part of the work shift in a control room, tneir average daily dust exposure may be reduced by introducing filtered air into the room. The volume of filtered air introduced to a control room must be sufficient to maintain a positive pressure in the room when doors or windows are opened.

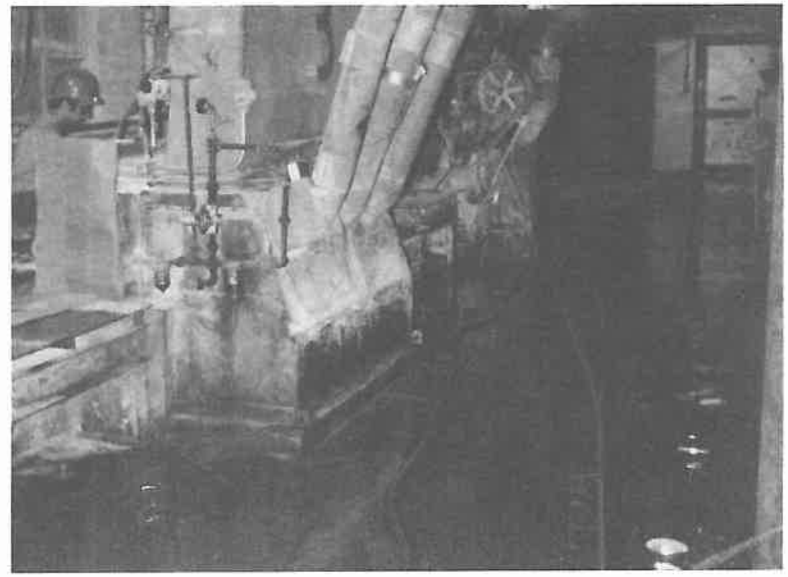
c) <u>Process/operation modification</u>

1) Vacuum cleaning and wet sweeping versus dry sweeping - Both vacuum cleaning and wet sweeping are superior to dry sweeping. Walls and floors should be washed to remove accumulated dust and to flush spillage before it can become airborne (Photo 18). The use of kerosene emulsions helps to reduce dust dispersion by providing a more persistent surface coating than water alone.

2) Bulk loading versus bag packing - Bulk loading with controlled ventilation reduces exposures by eliminating numerous sources of dust from packing and bag handling operations. Also, the number of employees directly involved is greatly reduced.

3) Plastic wrapping or covering of loaded pallets - Dust dispersion from bags may be further reduced by plastic covering or wrapping (either shrink wrap or stretch wrap) of loaded pallets. This technique reduces the breakage of bags during warehousing and shipping (Photo 19). It also





17. Use of plastic curtains to reduce cross-drafts

18. Wet washing of floor

19. Plastic covering on loaded pallets, during storage

reduces dispersion of residual dust on bag surfaces and improves the weatherability of pallet loads in open trucks and boxcars.

4) Wet slurry transfer - Replacement of covered conveyor belts with a pipeline to remove the ore as a wet slurry eliminates a source of background dust.

C. Control Monitoring

1. Environmental monitoring

Environmental monitoring procedures were also evaluated qualitatively at these three plants.

Environmental monitoring is conducted for at least four purposes: ventilation control evaluations; contaminant source identification; work area monitoring; and personal exposure monitoring. The first three monitoring procedures were performed in this study.

a) Ventilation control monitoring was conducted to quantify air velocities and to define airflow patterns at specific work areas. Since ventilation control constitutes a primary control technique at silica flour mills, a routine, periodic ventilation monitoring program is valuable. Vane or hot wire type direct reading velometers are useful in measuring air velocities. They must be capable of measuring both low flow velocities (10 to 500 fpm) and also high flow velocities (1000 to 6000 fpm). Weekly or biweekly measurements of hood velocities, duct static pressures, differential pressures across air filters, and visual inspection of integrity of equipment are necessary to assure proper ventilation system performance. Airflow patterns may be evaluated effectively with ventilation smoke tubes.

b) Contaminant source monitoring was conducted to locate and quantitify the magnitude of sources of airborne dust and to measure the effectiveness of control systems. Direct reading dust monitors, such as the GCA Respirable Dust Monitor and the TSI Respirable Aerosol Mass Monitor were used in this study. They measure peak dust concentrations over a short period of time (seconds to minutes) thus, describing dust concentration patterns. However, they are unable to differentiate between solid particulates (mineral dusts) and liquid particulates (water spray mists). This was a particular problem, where sonic water sprays were used for dust control. Furthermore, these instruments do not differentiate between silica dust and non-silica mineral dusts.

In the plants investigated, outside (ambient) airborne dust contained approximately 30 to 40 percent silica, whereas, flour products were essentially pure (99+%) silica. Therefore, the composition of a dust cloud may identify its probable source. For example, in a packer area, if the primary source of airborne respirable dust were the packer machine and/or filled bags, the silica content of an airborne dust sample or rafter sample would be high (70 to > 90% silica). However, if the primary source of the contamination were outside (ambient) dust, an airborne dust or rafter sample would be lower in silica content (less than 50%). This type of evaluation could indicate the effectiveness of a local dust control system in comparison to the general dust control of the area; it could assist in decisions for improving dust control design.

c) Area samples were collected to estimate average atmospheric dust concentrations of specific work locations, over an extended period of time (several hours). Work area samples were collected with MSA Gravimetric Dust Samplers using cyclone preseparators to remove non-respirable (> 10 µm) particles. At all plants, MSHA's periodic monitoring was the major source of available environmental data.

2. Medical monitoring

Although this study did not include an evaluation of the medical monitoring programs, such programs are essential in this industry. They are now being provided at each of the three companies visited. These programs are described in the NISA, report "Occupational Health Program for Exposures to Free Crystalline Silica."[1] They should include periodic (annual or biennal) chest x-rays and pulmonary function testing for all personnel potentially exposed to silica dust.

D. Work Practices

Good work practices and effective housekeeping procedures are essential for maintaining dust exposures at a safe level. These were also evaluated qualitatively. At each plant evaluated, management has estimated that as much as one-half of their dust control program involves effective housekeeping and maintenance procedures. Some effective work practices include:

1. If incentive pay plans are used, they should take into consideration the necessity for prompt clean-up of dust spills and allow time for this function. All ill-conceived incentive pay plans may result in poor housekeeping and poor work practices, especially bag handling.

2. Proper bag handling during placement on pallets, conveyor belts, or during stacking in boxcars is essential for minimizing dust dispersion. This precludes such practices as throwing or dropping (instead of placing) of bags, which results in bag breakage and dust dispersion.

3. Spills should be cleaned up as soon as possible after they occur (by vacuum or wet cleaning) to minimize dust dispersion into the atmosphere.

4. The practice of uncontrolled cleaning of workers' clothing with a high pressure air hose, is both a safety and a health hazard. MSHA regulations(12) prohibit the directing of compressed air toward a person. The use of vacuum cleaning of clothing is less hazardous both from a safety and a health viewpoint.

5. A regularly scheduled inspection and preventive maintenance program is essential for effective dust control. This should include an evaluation of equipment and performance of ventilation systems. The environmental control maintenance staff should be as well trained and experienced as the production maintenance staff. The use of duct tape and other means of temporary repair instead of permanent repair of equipment should be minimized.

E. Respiratory Protective Program

The proper use of personal protective equipment (PPE) is an important part of an effective hazard control program. A complete PPE program consists of procedures for protection of the respiratory system, head, eyes, ears, feet, and whole body. A critical aspect of this program is respiratory protection in the silica flour industry.

Because respiratory protection plays such a critical role in worker protection, one employee, accountable to the plant manager, should be responsible for the proper selection, fitting, training, cleaning, inspection, maintenance, and storage of respirators. In addition, one portion of the plant area should be designated for these procedures.

Detailed information about the selection of respirators can be obtained from the joint NIOSH/OSHA Respirator Decision Logic.(17) Adequate respiratory protection for most of the process areas studied can be achieved with any NIOSH approved(18) half-mask, quarter-mask, or single-use respirator with its appropriate particulate filter.

Appendix B shows an effective respiratory protection program found at one of the study facilities. At this plant, one full-time technician, accountable to the plant manager, is responsible for the above mentioned respirator procedures. Also, two or three respirators are assigned to each employee so that the worker always has at least one properly maintained and fitted respirator available. One facility in the plant area has been dedicated for respirator maintenance and fitting. "High dust exposure" areas are designated for "mandatory respirator use." Finally, all supervisors are responsible for monitoring the proper use and operational condition of respirators.

IV. GENERAL OBSERVATIONS, CONCLUSIONS, AND RECOMMENDATIONS

A. Control of dust in all areas requires a combination of good engineering controls such as the use of dust suppressant additives, exhaust ventilation, and controlled bulk loading of products; good work practices, including product handling and housekeeping procedures; effective environmental and medical monitoring programs; and an effective respiratory protection program. As dust emissons from point sources are reduced, it normally follows that the levels of personal exposure to atmospheric dust are also reduced proportionately.

B. A firm commitment by management and workers to implement and use good environmental control and occupational health programs is essential. This commitment was demonstrated at the plants investigated.

C. Standard ventilation and housekeeping procedures, presently in use at these plants, are capable of maintaining respirable silica dust concentrations below the present TLV of 100 $\mu g/m^3$ at the following operations and areas: normal packing of main product silica flour; conveyor transfer points; pallet loading of bags from conveyors (with down draft floor grills); and bulk loading of railroad and truck hopper cars, under local exhaust ventilation control. Major areas of high dust exposure include hand loading of boxcars and trucks from conveyors or fork trucks; and intermittent packing and palletizing of fine silica flour.

D. Outside areas may contribute as much as one-third to one-half of the in-house dust contamination problem. Ambient dust sources, which normally contain approximately 20 to 30 percent silica, may be reduced by resurfacing roads, planting vegetation, covering sand piles (with sealants or shrouds), and wetting road surfaces with salt water.

E. Several experimental methods of dust control indicated that:

1. Injection of agglomerating agents, such as water or Deter Micro Foam(R), into products was effective in reducing dust emissions by an average of 60% in packing and bag handling areas, and in bulk loading of silica sand and flour. It was less effective (23% reduction) in manual loading of bags into boxcars.

2. The spraying of water onto the outer surfaces of filled bags reduced dust levels by an average of 67%, particularly around packing, bag handling, and boxcar loading operations.

3. The combination of water spraying and injection of water into products resulted in overall reductions of dust of approximately 70%.

4. Bulk loading of silica flour into closed hopper cars can be well controlled by the use of local exhaust ventilation. Two systems were observed. In the first system the product was loaded into the hatch and air was exhausted from the same hatch. In the second system, the product was loaded and air exhausted through different hatches. Both methods appeared to be equally effective. All companies plan to increase their handling and shipping of product by bulk and to centralize bulk handling facilities.

F. Several additional engineering procedures and processes reduced dust exposures.

1. The installation of plastic strip curtains between rooms or work areas reduced air cross currents. These overlapping strips permit easy traffic flow and increase the effectiveness of local exhaust control systems.

2. The use of plastic covers or wrapping (stretch or shrink) around pallet loads reduces bag breakage and dust dispersion during pallet handling and storage. It also increases weatherability of exposed pallet loads during storage and shipping.

3. The installation of automatic bag ejectors, auger feeders on packing machines, the use of stronger 3-ply bags, and better designed feed spouts, result in reduced dust leakage during bag filling operations.

4. The transfer of primary and intermediate materials as a wet slurry through pipes, instead of transfer on conveyor belts, in a dry form, greatly reduces fugitive dust emissions.

5. Transfer between conveyors should be performed with minimum drop distances and minimal manual handling.

G. Good work practices are essential for maintaining effective control of dust sources.

1. Product spills should be cleaned up immediately using wet sweeping or vacuum cleaning equipment.

2. Proper bag handling techniques should be encouraged, which include placing of bags (instead of throwing or dropping) on pallets and careful handling of broken bags.

3. Clothing should be cleaned by vacuum air.

4. Preventive maintenance should be performed on a routine basis by well-trained maintenance staff.

5. If incentive pay plans are used, they should be designed to provide for effective and timely cleanup of spills and for the use of good work practices.

H. Environmental and medical monitoring programs are essential. They should include:

1. Environmental monitoring of potential dust sources; monitoring the performance of ventilation and other control systems; and personal monitoring procedures.

2. Periodic medical examinations, including serial pulmonary function testing and chest x-rays to detect changes in physiological conditions.

I. An effective respirator protection program should be instituted to ensure proper fit, maintenance, and use of respirators.

J. Additional experimental research needs to be conducted in the following areas:

1. The effectiveness of adding agglomerating agents, such as Deter Micro Foam®, to flour products has not yet been resolved.

2. A portable environmental dust monitor, capable of quantitative and qualitative analyses for silica, needs to be developed.

3. The relative effectiveness of wet sweeping, with emulsion additives, versus vacuum cleaning has not yet been determined.

4. The effectiveness of The Ritten Electrostatic Fogger in agglomerating atmospheric respirable dust needs to be evaluated.

5. Leakage from valves and seams of filled bags continues to be a source of contamination. A stronger, leak-proof bag needs to be developed.

Table 5.

Respirable Dust Concentrations During Four Experimental Runs

	RUN B (Dry) ventilation only				RUN D (water injection) plus ventilation				RUN E (spray on bags) plus ventilation				RUN C (injection and spray) plus ventilation			
	Respir-able dust	Reduc-tion from "Dry"	Respir-able silica dust	Reduc-tion from "Dry"	Respir-able dust	Reduc-tion from "Dry"	Respir-able silica dust	Reduc-tion from "Dry"	Respir-able dust	Reduc-tion from "Dry"	Respir-able silica dust	Reduc-tion from "Dry"	Respir-able dust	Reduc-tion from "Dry"	Respir-able silica dust	Reduc-tion from "Dry"
	$\mu g/m^3$	%	$\mu g/m^3$	%	$\mu g/m^3$	%	$\mu g/m^3$	%	$\mu g/m^3$	%	$\mu g/m^3$	%	$\mu g/m^3$	%	$\mu g/m^3$	%
1 Packer Station																
.2 South side	123	-	99	-	< 39	> 68	> 39	>61	89	28	56	43	< 36	> 71	< 36	> 64
.3 North side	82	-	78	-	< 39	> 52	> 39	>50	30	63	30	62	< 36	> 56	< 36	> 54
.4 East side	41	-	< 41	-	< 39	(> 5)	> 39	(> 5)	59	-44*	59	-44*	< 36	> 12	< 36	(> 12)
Avg.(2,3,4)	82		< 73		< 39	> 60	> 39	>56	59	18	48	20	< 36	> 48	< 36	> 59
.5 Bag Tansfer on conveyor	165	-	165	-	< 39	> 76	> 39	>76	< 30	> 82	< 30	> 82	< 36	> 78	< 36	> 78
Avg. (2,3,4,5)	103	-	96	-	< 39	> 62	> 39	>59	< 52	> 48	< 44	54	< 36	> 65	< 36	> 62
2 Bag Handling Area																
.6 Northwest of transfer point	332	-	332	-	40	88	40	88	-	-	-	-	70	79	< 66	> 80
.7 South of transfer point	539	-	456	-	40	93	40	91	149	73	149	67	106	80	95	79
.8 Northeast of transfer point	329	-	247	-	79	76	79	68	(30)	91	30	88	35	89	< 35	> 86
Average	400	-	345	-	53	87	53	85	90	78	90	74	70	82	< 65	> 81
3 Boxcar Loading Area																
.9 South of entrance	2125	-	1625	-	1440	32	1440	11	898	58	245	85	951	55	387	76
.10 North of entrance	1708	-	1417	-	887	48	887	37	653	62	163	88	775	55	246	83
Average	1917	-	1521	-	1164	39	1164	23	776	60	204	87	863	55	317	79
4 Outside of Plant																
.11 South of plant	13		13										< 13	( )	< 13	( )
.12 North of plant	< 13		13										< 13	( )	< 13	( )

< less than
\> greater than
( ) low degree of accuracy and reliability
*during Run E, atmospheric concentration was greater than Run B
ug/m - microgram per cubic meter of air

Table 6. Respirable Dust Concentrations During Two Experimental Runs

Location/Operation	Sample No.	RUN #1 Respirable Dust µg/m³	RUN #1 Respir-silica Dust µg/m³	RUN #1 Silica content (%)	RUN #2 Respirable dust µg/m³	RUN #2 Respir-silica Dust µg/m³	RUN #2 Silica content (%)	AVERAGE Respirable Dust µg/m³	AVERAGE Silica dust µg/m³	AVERAGE Silica content (%)
1 Main flour packing and Palletizing										
A. Packer machine										
.1 West side of packer	(7)	a	a	--	104	52	50	104	52	50
.2 East side of packer	(8)	186	80	43	139	70	50	163	75	46
.3 Center of machine	(9)	163	< 63	< 39	122	70	57	143	< 67	47
.4 OBZ of packer opr.	(10)	197	< 65	< 33	139	52	37	168	< 59	< 35
Average		182	< 69	< 38	126	61	48	145	63	< 43
B. Palletizing Area										
.1 No. side of conveyor	(4)	384	256	67	366	244	67	375	250	67
.2 NE side of conveyor	(3)	203	63	31	184	84	46	194	74	38
.3 NE side of conveyor	(5)	153	< 59	< 39	244	105	43	199	< 82	< 41
.4 So. side of conveyor	(6)	261	68	26	243	139	57	252	104	41
Average (2,3,4)		205	< 67	< 32	224	109	49	215	< 87	< 40
Average (1,2,3,4)		250	<112	< 45	259	143	55	255	<128	< 50
2 Fine Flour Packing										
C. Packer machine										
.1 So. side of packer	(18)	--	--	--	505	451	89	505	451	89
.2 No. side of packer	(19)	--	--	--	866	704	81	866	704	81
Average		--	--	--	686	578	84	686	578	84
D. Packer area background										
.1 East entrance door	(16)	--	--	--	162	< 41	< 25	162	< 41	< 25
.2 So. of bag rack	(17)	--	--	--	< 18	< 18	( )	< 18	< 18	( )
Average		--	--	--	< 90	< 30	( )	< 90	< 30	( )
3 Fine Flour Packing										
E. Packer machine										
.1 At pallet loading	(20)	--	--	--	344	199	58	344	199	58
F. Packer area background										
.1 At No. door-upwind	(21)	--	--	--	< 18	< 18	( )	< 18	< 18	( )
4 Railroad Hopper Car Bulk Loading Flour										
G. Top of car										
.1 West of loading port	(11)	34	< 34	(<100)	--	--	--	34	< 34	(<100)
.2 No. of loading port	(12)	206	172	83	--	--	--	206	172	83
.3 East of loading port	(13)	a	a	a	--	--	--	a	a	a
.4 So. of loading port	(14)	34	< 34	(<100)	--	--	--	34	< 34	(<100)
Average		91	< 80	< 88	--	--	--	91	80	80
5 Background Samples										
H. East loading dock	(15)	--	--	--	262	122	47	262	122	47
I. West (upwind)	(1)	119	< 34	<29	16	< 16	(<100)	67	< 25	< 37
J. East (downwind)	(2)	76	< 35	<46	83	38	46	80	< 37	< 46
Average (upwind/-downwind)		98	< 35	<36	50	< 27	54	74	< 31	< 42

Notes:
a Dust sample invalid, contaminated
OBZ - Operator's breathing zone
< - Less than
( ) - Low degree of accuracy and reliability
b downwind of conveyor
c upwind of conveyor

Table 7. Respirable Dust Concentrations
During Two Experimental Runs

	Run A	No. packing or Truck loading			Run B	Packing and Truck loading			Average			Ratio	Run B / Run A
	Sample #	Respirable dust $\mu g/m^3$	Respirable silica dust $\mu g/m^3$	Silica content %	Sample #	Respirable dust $\mu g/m^3$	Respirable silica dust $\mu g/m^3$	Silica content %	Respirable dust $\mu g/m^3$	Respirable silica dust $\mu g/m^3$	Silica content %	Respirable dust B/A	Respirable silica B/A
1 Outside Mill Building													
.1 North-near mill	A1	< 25	< 25	( )	B1	< 11	< 11	( )	< 18	< 18	( )	( )	( )
.2 North-50 feet from mill					B10	48	< 16	< 33	48	< 16	< 33		
.3 South-near mill	A2	51	51	100	B2	46	46	100	48	48	100	0.90	0.90
Average outside mill		< 38	< 38	(100)		< 35	< 24	(< 69)	< 38	< 27	(71)	(0.92)	(0.63)
2 Main flour packer area													
.1a South (right) side of packer	A4	131	105	80	B4	286	100	38					
b South (right side of packer					B8	163	140	86					
Average (right) side of packer		131	105	80		225	125	55	178	115	65	1.72	1.2
.2 Center of packer	A5	369	40	11	B5	220	132	60	295	86	29	0.60	3.3
.3a North (left) side of packer	A6	160	80	50	B6	286	88	31					
b North (left) of packer					B9	95	71	75					
Average north (left) side of packer		160	80	50		190	80	42	175	80	46	1.19	1.00
Average at packer area -		220	75	34		212	112	53	216	94	44	0.96	1.5
3 Bag handling area													
.1 Transfer point between conveyor	A3	180	64	36	B3	66	66	100	123	65	53	0.37	1.0
.2 Conveyor discharge	A7	< 28	< 28	( )	B7	330	264	80	< 179	< 146	< 82	(> 11.8)	> 9.4
Average of bag handling		<104	46	(44)		198	165	83	< 151	< 106	< 70	> 1.9	(>3.6)

Notes: $\mu g/m$ micrograms per cubic meter of air
( ) low degree of accuracy and reliability
< less than, > greater than

Table 8. Chemical and Size Analysis* of Bulk Air, Product, and Rafter Samples

Type Sample	Location/Source	Silica Content %	Particle Size (µm)	
			Mass Median Diameter	Aerodynamic** Diameter
1. Bulk Air (Electrostatic Precipitator	Behind Packer Upper level	≈ 77	3.0	5.0
2. Bulk Product	Flint Silica Flour #325	≈100	14.9	24.3
3. Bulk Product	Flint Silica Flour #324	≈100	13.8	22.5
4. Rafter	Pebble Mill	≈100	19.4	31.7
5. Rafter	South Side of Packer Level with Packer	≈100	7.6	12.3
6. Rafter	Main Floor Level, East Siae Behind Packer Machine	≈100	17.4	28.4
7. Rafter	West Walls Behind Packer, at Packer Level	≈100	29.8	48.6

*Size Analysis by electron microscope at 400X magnification
**Aerodynamic diameter and mass median diameter calculated assuming density of 2.66 g/cc
≈ Approximately
µm Micrometer

REFERENCES

1. Occupational Health Program for Exposure to Free Crystalline Silica. National Industrial Sand Association. Silver Spring, MD, 20910, 1977.

2. Guidance and Solutions to Reducing Respirable Dust Levels in the Bagging of Whole Grain Silica Products. National Industrial Sand Association. Silver Spring, MD 20910, 1977.

3. Nelson, H.M., G.S. Rajhans, S. Morton, and J.R. Brown. Silica Flour Exposures in Ontario. AIHAJ(39), Apr. 1978.

4. Watt, A.R. Private Communication. Indusmin Ltd., Midland, Ontario, Canada, 1975.

5. Product Information Sneet. Tammes Industry, Chicago, IL, 1975.

6. Product Information Sheet. Ottawa Silica Co., Ittawa, IL, 1975.

7. Stockinger, H.E. Toxicologic Aspects of Occupational Hazards, Annual Review of Medicine. Vol. 7, 1956. ref(17)Desolle, H., S. Tara, V. Delplace, and A. Carigneaux. Arch. maladies profess. med. Trovailet, Securite' sociale, 14, 279-83, 1953.

8. Morring, K.L., and D.E. Banks. Hazard Evaluation and Technical Assistance Report. No. 79, 103-108, Illinois Minerals Company, U.S. Dept. of HEW, PHS, CDC, National Institute for Occupational Safety and Health (NIOSH), Cincinnati, Ohio, 45226, 1979.

9. Morring, K.L., and D.E. Banks. Hazard Evaluation and Technical Assistance Report. No. 79, 103-108, Illinois Minerals Company, U.S. Dept. of HEW, PHS, CDC, National Institute for Occupational Safety and Health (NIOSH), Cincinnati, Ohio, 45226, 1979.

10. Banks, D.E., K.L. Morring, and B.A. Boehlecke. Summary Report...Silicos in the 1980's. AIHAJ, 42, 77-79, 1981.

11. Unpublished data from Mine Safety and Health Administration, 1980.

12. Regulations and Standards Applicable to Metal and Non-metal Mining and Milling Operations. 30CFRPart 57.5-1(a), Completed by U.S. DOL, January 1, 1980.

13. National Institute for Occupational Safety and Health. Criteria for a Recommended Standard....Occupational Exposure to Crystalline Silica. DHEW(NIOSH) Publication No. 75-120, 1974.

14. NIOSH Current Intelligence Bulletin #36. Silica Flour: Silicosis, June 30, 1981.

15. Cole, Jr., H.W. "Microfoam for the Control of Source and Fugitive Dust Emissions." Deter Company, Inc.

16. Chemical Engineers' Handbook - 3rd Edition, Ed. J.H. Perry, P. 963, 1950.

17. Pritchard, J.A. "A Guide to Respiratory Protection." USDHHS, PHS, CDC, National Institute for Occupational Safety and Health, June 1976, HEW Publication No. (NIOSH) 76-189. p 137-148. Appendix B and F.

18. NIOSH Certified Equipment List as of June 1980. USDHHS, PHS, CDC, National Institute for Occuptional Safety and Health. DHHS(NIOSH) Publication No. 80-144.

Appendix A.

Description of Air Sampling and Analytical Equipment

1. MSA Gravimetric Dust Sampler, manufactured by Mine Safety Appliances, Inc. This sampling system consists of a 10 mm plastic cyclone separator to remove "non-respirable" dust; a three-piece plastic filter holder cassette, containing a 37 mm PVC filter, No. M5, manufactured by Millipore Corporation or a FWS-B filter, manufactured by Mine Safety Appliances, Inc.; and an MSA portable, battery powered pump, Model G. This sampler is operated at 1.7 liters per minute, which is the standard flow rate for collecting (respirable) silica and total dust samples.

2. Del High Volume Electrostatic Precipitator Sampler, Model ESP-100A, manufactured by Del Electronic Corp. This sampler, with respirable cyclone separation, operates at 17 cubic feet per minute.

3. TSI Respirable Aerosol Mass Monitor, Model 3500, manufactured by Thermo-Systems, Inc. This instrument permits direct measurement of dust concentrations, at either two-minute or 24-second intervals. It collects particles from 0.01 to 10 µm in diameter. In a one-minute sampling time it will measure mass concentrations in the range of 100 $\mu g/m^3 \pm 10$ accuracy.

4. Crystalline silica was analyzed with a Phillips automated powder diffractometer, Model ADP-3501, with the "limit of detection" of 18 ug per sample. Total dust weights were measured on a Perkin-Elmer Electrobalance, 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 B

RESPIRATORY PROTECTION PROGRAM

The basic purpose of the respiratory protection program is to provide the worker with a healthful environment. The primary method of protecting the worker against respiratory hazards is engineering controls that either eliminate or reduce the dust hazard. However, when situations occur where engineering or administrative controls are impractical or ineffective, personal respiratory protection must be worn.

In order to have adequate protection against respiratory hazards by the use of respirators, a comprehensive program detailing the use of respirators must be carried out.

All employees at the plant will be furnished with two respirators and the following shall govern their uses:

Respirators

Mine Safety Appliance "Dustfoe 66" or "Dustfoe 77" respirators will be provided.

Training

Respirator training shall be provided as mandated under 30 CFR 48.24(2) - "Self Rescue and Respiratory Devices" - MSHA Training.

Maintenance

1) Each employee who has used a respirator during the shift shall deposit it in the assigned container.

2) Each respirator shall be collected daily.

3) Each respirator shall be disassembled, inspected, cleaned, dried, repaired as required, and enclosed in an individual plastic bag.

4) Each cleaned respirator shall be returned to its assigned bin by 3:00 p.m. each day.

5) The respirators shall be sanitized with "MSA Cleaner and Sanitizer."

6) A daily log shall be kept of each person's respirator use.

Supervision

All supervisors shall routinely monitor the use and condition of the respirators.

Administration

One qualified person shall be responsible for the program and shall be accountable to the plant manager.

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