SENTINEL EVENT NOTIFICATION SYSTEM FOR OCCUPATIONAL RISKS (SENSOR):

RECOMMENDATIONS FOR CONTROL OF SILICA EXPOSURE

AT

Unimin Dividing-Creek Sand Plant
Millville, New Jersey

REPORT WRITTEN BY:
Thomas C. Cooper
Dennis M. O'Brien
John W. Sheehy
Phillip A. Froehlich
NIOSH

David Valiante
Alicia Stephens
New Jersey Department of Health

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

DISCLAIMER

PLANT SURVEYED:	Unimin Dividing-Creek Sand Mine P.O. Box 145 Millville, New Jersey 08332 (609) 785-2700
SIC CODE:	1446 Industrial Sand, Glass Sand Mining
SURVEY DATE:	September 12-15, 1988
SURVEY CONDUCTED BY:	NIOSH/DPSE: John W. Sheehy Dennis M. O'Brien Thomas C. Cooper Phillip A. Froehlich New Jersey Department of Health: David Valiante Alicia Stephens
EMPLOYER REPRESENTATIVES CONTACTED:	Scott Phillips, Plant Manager Russell W. Konschak, Corporate Safety and Health Manager, (703) 858-3448
EMPLOYEE REPRESENTATIVES CONTACTED:	None (non-union)
ANALYTICAL WORK PERFORMED BY:	Data Chem, Inc. Salt Lake City, Utah

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I. SUMMARY

In 1987, NIOSH initiated the SENSOR (Sentinel Event Notification System for Occupational Risks) program, a cooperative state-federal effort designed to develop local capability for the recognition, reporting, follow-up, and prevention of selected occupational disorders. The New Jersey Department of Health is participating in the SENSOR program for occupational asthma and silicosis. The Engineering Control Technology Branch (ECTB) of NIOSH is assisting in the conduct of follow-back surveys to recommend improved controls in selected plants. This report describes an in-depth survey of exposure to silica dust at the Unimin Dividing-Creek Sand Mine, Millville, New Jersey, as part of this effort. Environmental and engineering evaluations were conducted in September 1988.

The environmental evaluations included the collection of 2 bulk/material samples analyzed for crystalline silica content; and 31 personal and area air samples analyzed quantitatively for respirable crystalline silica dust and respirable dust. Personal exposures to respirable quartz dust ranged between <0.02 and 0.05 mg/m^3 for nine collected samples. None of the nine personal samples exceeded either the NIOSH Recommended Exposure Limit (REL) or the MSHA Permissible Exposure Limit (PEL) for quartz. The area samples indicated operations with the potential for overexposure. Two of 22 (9%) area samples exceeded the NIOSH REL; 1 of 22 (5%) exceeded the MSHA PEL. The highest area concentration (0.77 mg/m^3 respirable quartz) occurred on the catwalk on top of a railroad hopper car during filling using an uncontrolled loading spout, indicating the need for revision of this operation. In the sand screening area, one of three samples exceeded the NIOSH REL (0.07 mg/m^3); none exceeded the MSHA PEL.

Deficiencies in the design and maintenance of equipment, work practices, and ventilation control systems were identified and recommendations for their modification or improvement are offered.

ABSTRACT

This report describes an in-depth survey of exposure to silica dust at the Unimin Dividing-Creek Sand Mine, Millville, New Jersey, as part of this effort. Personal exposures to respirable quartz dust ranged between <0.02 and 0.05 mg/m^3 for nine collected samples. None of the nine personal samples exceeded either the NIOSH Recommended Exposure Limit (REL) or the MSHA Permissible Exposure Limit (PEL) for quartz. Area air samples indicated that the railroad car filling operations and the sand screening area were potential areas for overexposure to silica.

Keywords: SIC 1446; industrial sand; glass sand mining; silica; silicosis; respirable dust; real-time monitoring; aerosol photometers; loading spouts; manual materials handling.

II. INTRODUCTION

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

Since 1976, ECTB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. The objective of each of these studies has been to document and evaluate effective techniques for the control of potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

In 1987, NIOSH initiated the SENSOR program (Sentinel Event Notification System for Occupational Risks), a cooperative state-federal effort designed to develop local capability for the recognition, reporting, and prevention of selected occupational disorders. Under this program, the state health department (or other agency) launches three types of actions upon notification of a case of occupational disease: first, disease management guidelines will be made available to the health care provider; second, medical evaluations of co-workers who may be at risk of developing similar disorders will be conducted; and finally, action directed to reduce work site exposures will be considered. To assist the states in developing intervention plans for exposure reduction, ECTB will conduct a pilot engineering assistance project with selected states participating in SENSOR. This assistance may include specific control recommendations for an individual plant identified and selected by the state, or for an industry that would be selected based on the state disease records, with the intent of developing guidelines for the elimination of occupational disease in the entire industry.

Since 1984, the New Jersey Department of Health (NJDOH) has been involved in the surveillance of the occupational disease, silicosis, under the NIOSH Capacity Building Program. This surveillance system utilizes morbidity (hospital discharge) data and mortality (death certificate) data to identify cases of silicosis. NJDOH is currently participating in the SENSOR program for occupational asthma and silicosis, which utilizes physicians' reports of silicosis. Health department surveillance data indicate the largest number of silicosis cases in the state exists in the sand mining and processing, foundry, and pottery (sanitary ware) industries. This disease is caused by exposure to crystalline silica in these industries.

At least one study is being conducted by ECTB in a facility of each of these industries to develop specific control recommendations to eliminate future cases of disease; to train state personnel in the application of engineering control; and to develop a model protocol for the identification and control of exposure sources. This report describes an in-depth survey conducted as a part of this federal-state effort at Unimin Dividing-Creek Sand Mine, Millville, New Jersey.

The New Jersey Department of Health has identified cases of silicosis at a sand mine that, at the time, was operated by the National Glass Sand Corporation, which has since shut down. (Unimin now operates this sand mine near Millville.) Most of the sand mines in the state are older mines, with many having reported case of silicosis. Over the past 10 years, Unimin has modernized the dust control system at this operation. For this reason, this facility was selected for survey. The purposes of this survey were to identify and evaluate worker exposures to silica-containing dusts; to evaluate the effectiveness of current engineering controls, work practices, and administrative control programs in reducing dust exposures; and to recommend improvements in the dust control and disease prevention programs. What was learned at Unimin can be applied to similar operations with the ultimate goal of preventing further cases of silicosis.

Plant Description

Unimin Corporation is predominantly in the sand mining business with 19 mines in the United States: 2 underground mines, 2 dredging operations, and 15 open pit operations. The Dividing-Creek operation, shown in Figure 1, supplies washed sand mainly to the glass industry. An outside contractor removes trees and topsoil from the area to be mined. Since the site is only a few feet above sea level, once sand is uncovered it rapidly floods with ground water. Two dredges are used to mine sand from the flooded area, typically reaching depths of 50 feet. Two operators work the dredges. The sand/water slurry is pumped to a scalper to remove rocks and slime from the slurry. It is then pumped to a holding tank outside the process building. In the process building, the sand is sized by settling (coarse fraction removed), dewatered (clay removed), passed through a scrubber, again dewatered by two parallel screws, and then passed through a flotation circuit (iron impurities removed). A ball milling step can be added to the process for size reduction. One operator and one helper work in the processing building. After processing, the wet sand is conveyed outside and stockpiled in the open. A front-end loader moves the sand to a covered belt conveyor, which transports it 1,000 feet to the sand drying and loading area, shown in Figures 2 and 3.

Damp sand discharges from the covered belt conveyor into a bucket elevator which transports the sand to the dryer. The sand is dried, screened, and transported by a second bucket elevator to a screw conveyor which empties into one of three concrete silos. Sand can be loaded directly from the silos through one of three uncontrolled (nonventilated) loading spouts into railroad hopper cars or one uncontrolled loading spout into trucks. Sand is also transported by screw conveyor from the bottom of the silos to a third bucket elevator which empties into two elevated hopper bins each equipped with a controlled (ventilated) loading spout (Midwest International, Charlevoix,

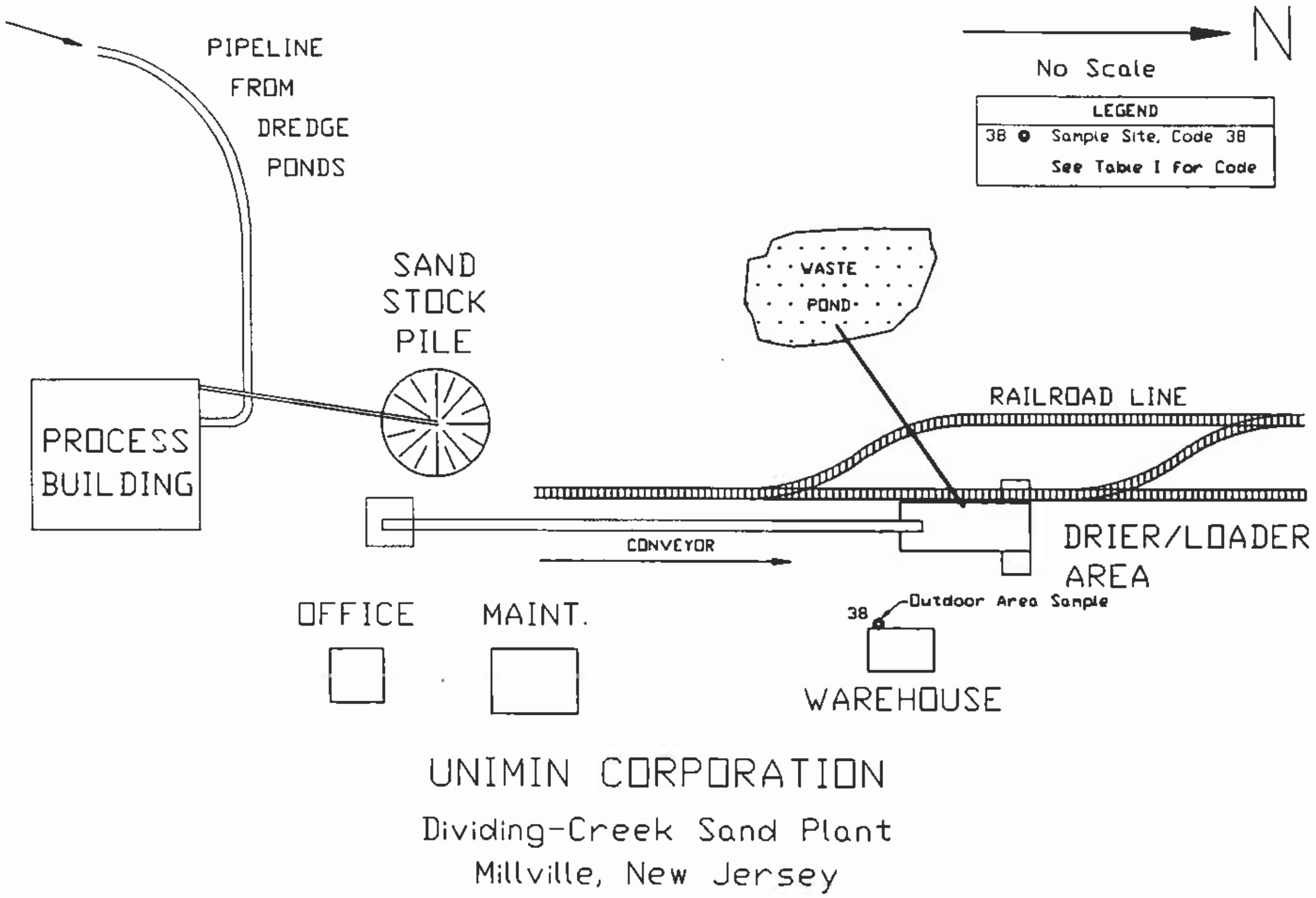


Figure 1. Unimin Corporation, Dividing-Creek Sand Plant.

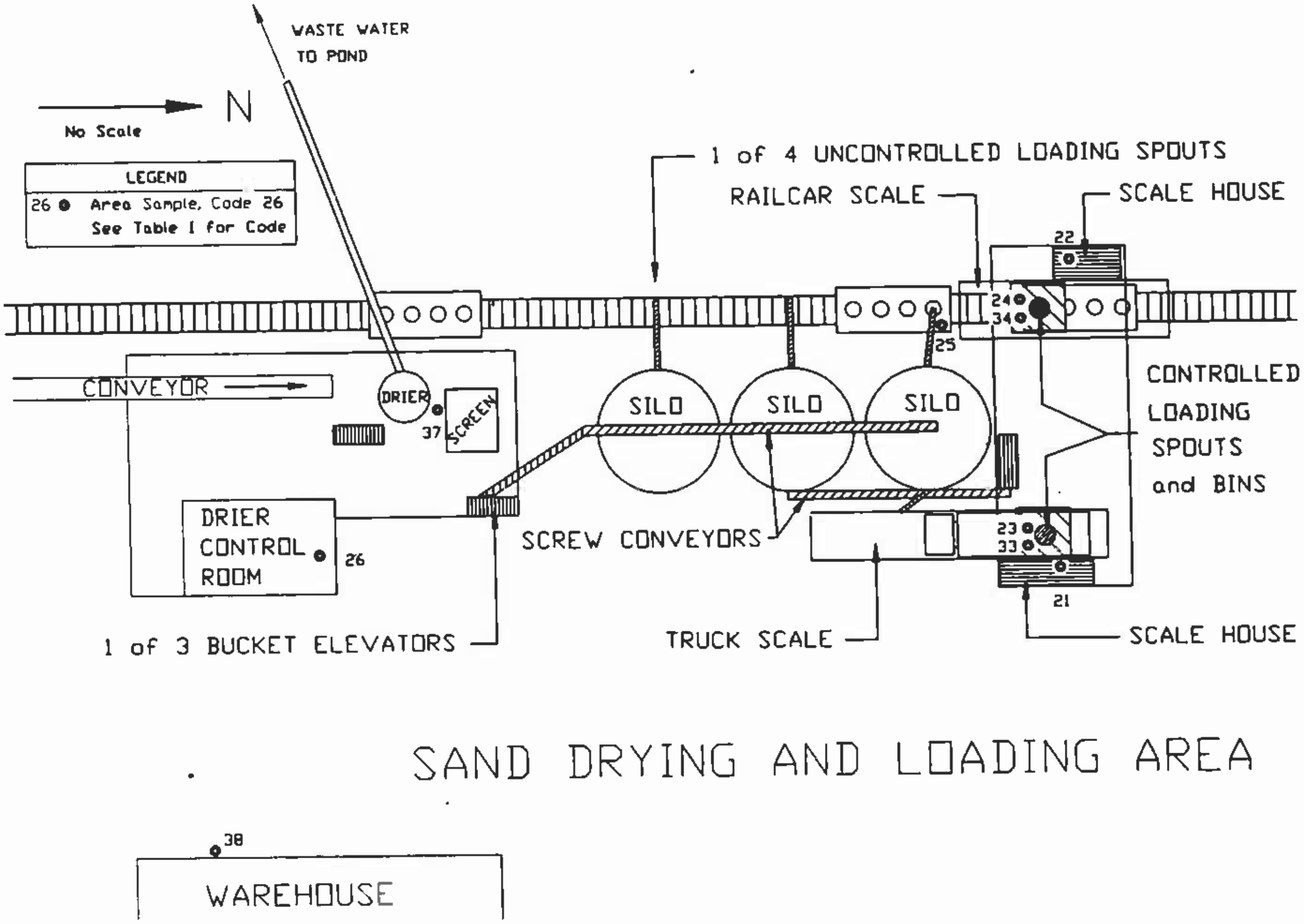


Figure 2. Sand Drying and Loading Area.

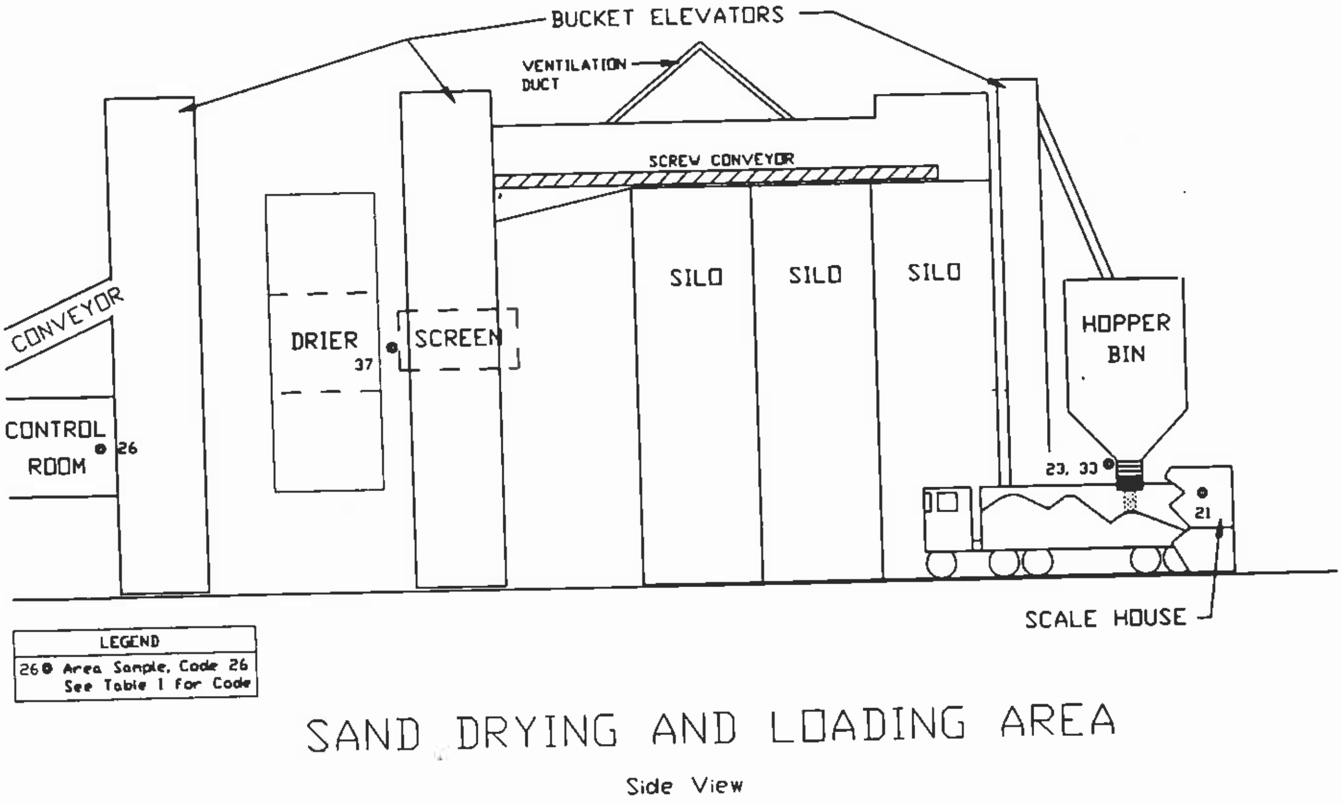


Figure 3. Sand Drying and Loading Area, Side View.

Michigan). One spout is used for finish filling of railroad cars and the other spout is used for filling trucks. (Typically, the uncontrolled spouts are used to pre-fill railroad cars and the controlled spouts are used for the final filling of railroad cars and the complete filling of trucks. The uncontrolled spout is normally not used to fill trucks.) Total railroad and truck shipments represent approximately equal tonnage.

The truck loading area consists of a bulk sand hopper bin, an uncontrolled loading spout (not in use), a controlled enclosed-type retractable spout (Figure 4), truck scales, and an enclosed control room. One operator spends the shift filling several different types of trucks (shown in Figure 5) at this station. (The same operator also fills railroad cars.) The job sequence is as follows: An empty truck stops on the truck scales beneath the loading spout. The loader operator, from within an elevated control room, lowers the spout either into the open truck, down to the hatch on a hopper truck, or down to the center rib of cross ribbed truck and starts the sand to flow. In open trucks, the spout remains a few inches above the top of the sand pile in the truck and is retracted as the sand pile rises. When the sand pile reaches the desired height, the sand flow is stopped, the truck moves forward a few feet, the spout is lowered, and loading resumes. This process is repeated until the truck is filled, with the load being distributed throughout the truck. For hopper trucks, the spout remains a few inches above the open hatch. This permits visual observation from the control room into the truck, so as to reduce the risk of spillage from overfilling. As the truck fills, the sand flow is stopped, the spout raised, the truck moved forward, the spout lowered down to the next open hatch, and loading resumed until the truck is filled. For trucks with ribs (no longitudinal rib) the spout is usually lowered between the ribs and filled like the open truck. When the sand reaches the desired height in the truck, flow is stopped, the spout retracted above the ribs, and the truck moved forward. The spout is lowered again and loading resumed. For trucks with a longitudinal rib, the spout is lowered down to this rib and the sand flows over this rib into the truck. As the truck fills, sand flow is stopped to allow the truck to move forward, and resumed until the truck is filled. For open top trucks, a tarp is stretched over the trailer and tied down before leaving the site. It takes approximately 5 minutes to load 50,000 pounds (500 cubic feet) of sand (an average load for most trucks).

The railroad car loading area consists of three uncontrolled loading spouts, a bulk sand storage hopper bin, a controlled enclosed-type retractable spout with horizontal travel capability, scales, and an enclosed control room. The same operator that fills trucks also fills several different types of railroad hopper cars (shown in Figure 6) at this station. The job sequence is as follows: Prior to filling, the hatches are opened; the cars inspected and if needed, washed out; and then positioned alongside the silos. Preliminary filling is done from an uncontrolled spout (a flexible hose with a metal pipe fitted with a gate) directly from one of the three silos, shown in Figure 7. The spout is positioned over the open hatch and sand flows by gravity into the car. When the portion of the car under the open hatch is filled, the flow is stopped, the car moved forward, the hatch just filled through is closed, and the flow resumed into the next open hatch. It takes approximately 45 minutes to load 100 tons of sand from the uncontrolled spout.

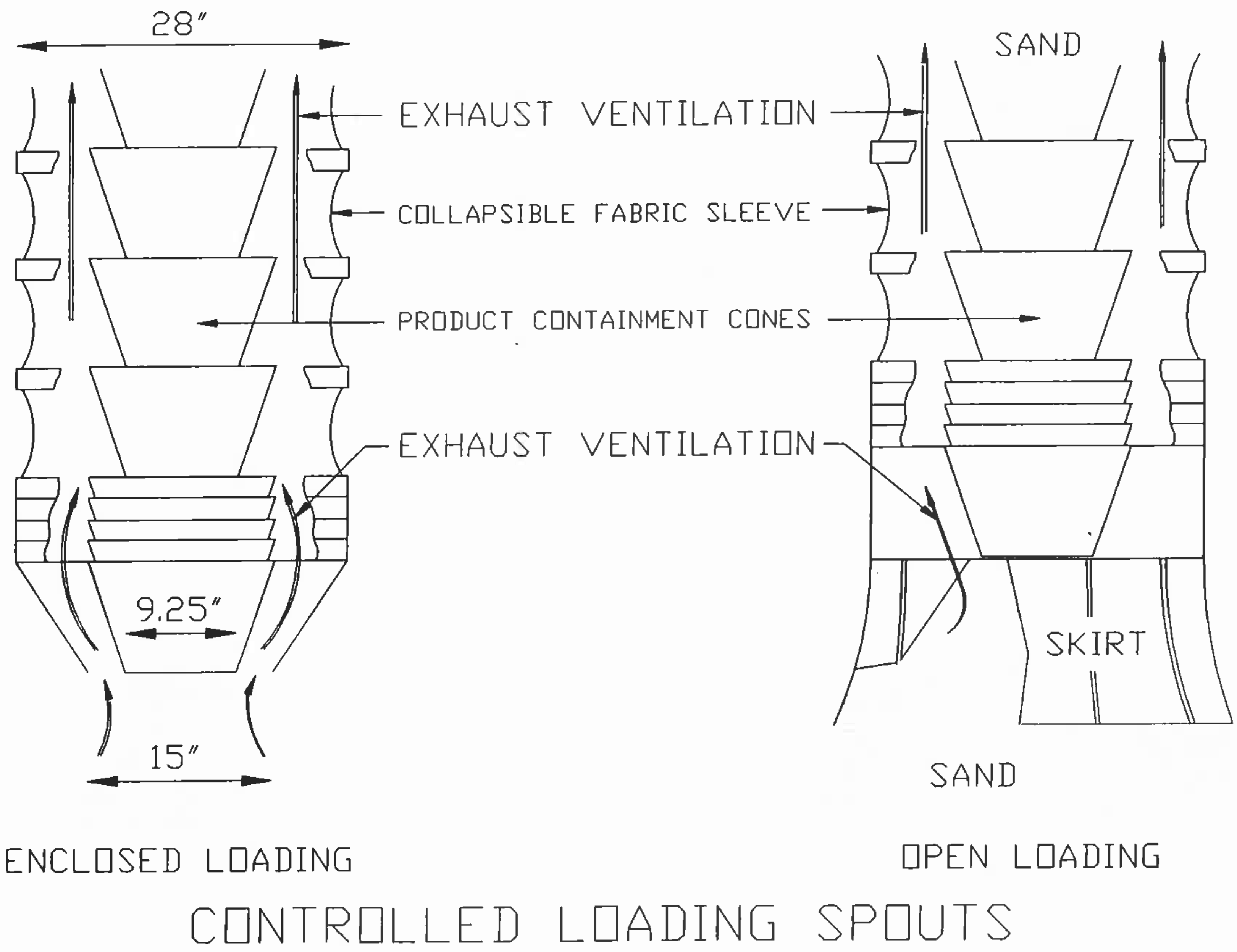
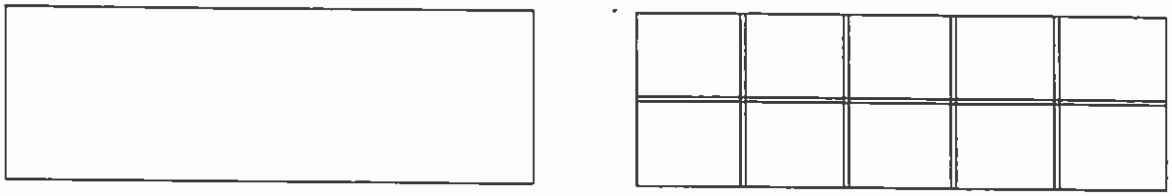
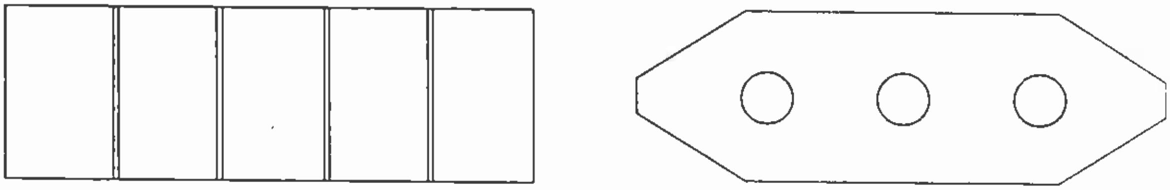


Figure 4. Retractable Controlled Loading Spouts, Enclosed-Type and Open-Type.



OPEN

CROSS RIBS
with LONGITUDINAL RIB



CROSS RIBS

CLOSED HOPPER WITH 3 HATCHES

Figure 5. Types of Truck Openings.

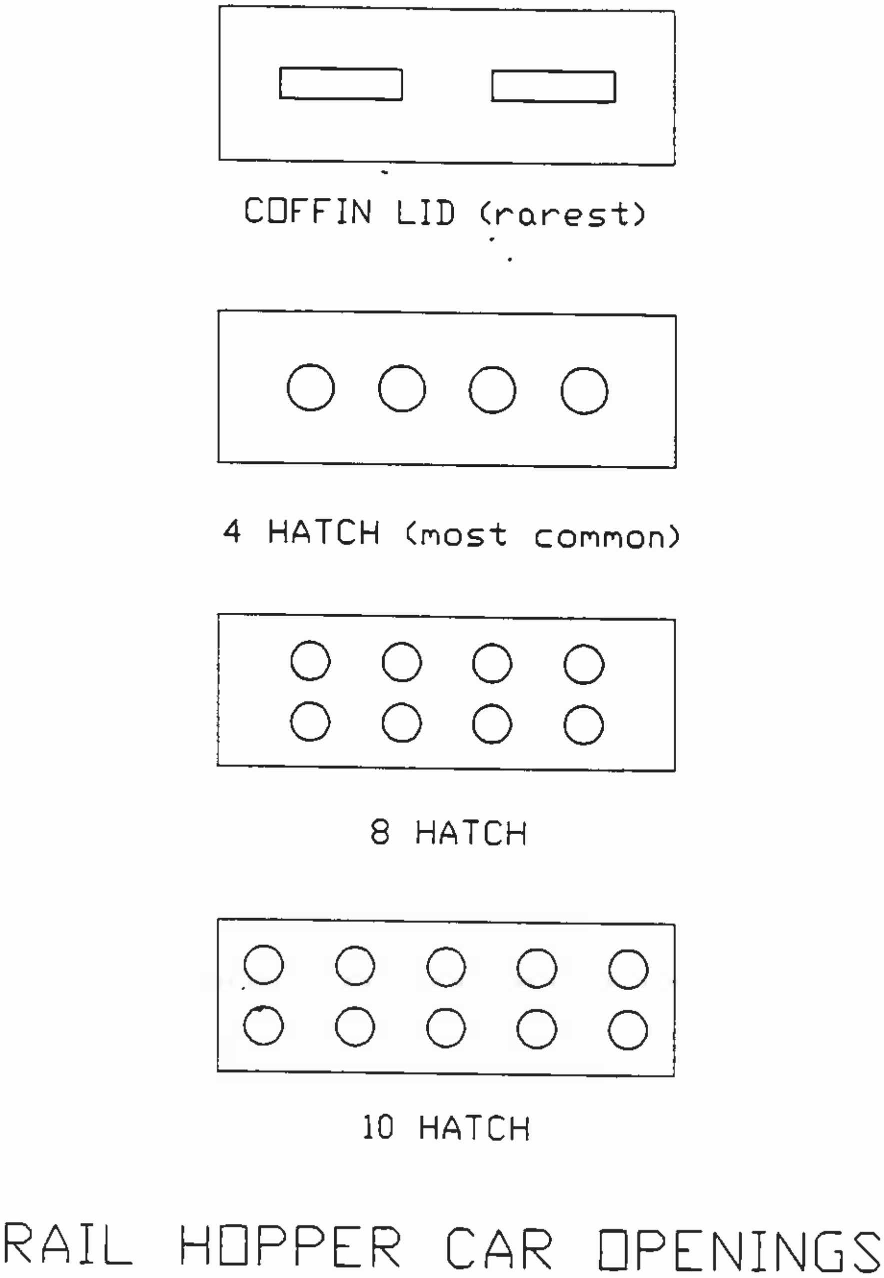
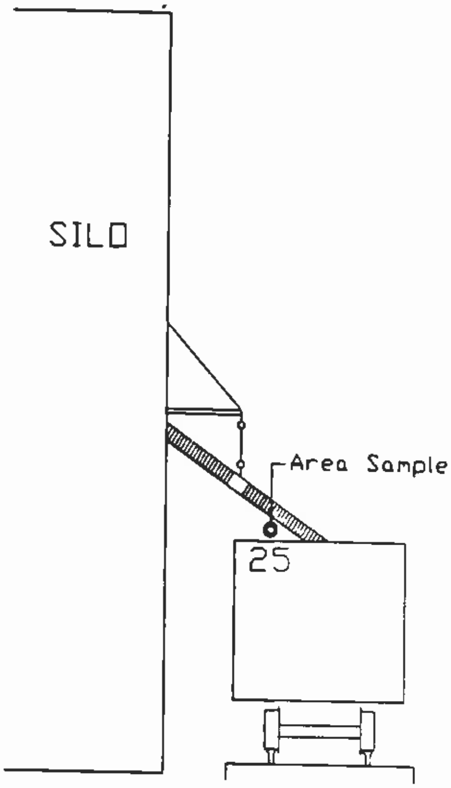

COFFIN LID (rarest)
4 HATCH (most common)
8 HATCH
10 HATCH
RAIL HOPPER CAR OPENINGS

Figure 6



UNCONTROLLED
RAIL CAR
LOADING

Figure 7

When the railroad car is nearly full, flow is stopped, all hatches except the last one filled through have been closed, and the car is moved forward under the controlled spout. The operator, standing on an open platform overlooking the top of the car, positions the spout over the open hatch and lowers it to the hatch. Then, the operator, from the enclosed control room at ground level, adds the last of the sand to complete the car's load. The spout is retracted, the hatch closed, and a front-end loader moves the car to a pickup area. It usually takes less than a minute to top off each car using the controlled spout.

The front-end loader operator operates an enclosed cab rubber-tired loader at different locations throughout the facility. He may transfer damp sand from the stockpile to the covered belt conveyor, move empty and filled railroad cars, and whatever else may be needed.

The plant operates three shifts (midnight to 8 a.m., 8 a.m. to 4 p.m., 4 p.m. to midnight). During each of the three shifts in the Dryer/Loader Area, one operator oversees sand drying and conveying and the second operator fills the trucks and railroad cars.

This site, formerly mined by the Whitehead Bothers Company, was purchased by Unimin in 1980 and a new processing plant was built at that time. The dryer and sand silos were built in the 1940s, but the loading facilities have since been modified by Unimin with the addition of ventilated loading spouts.

III. POTENTIAL HEALTH HAZARDS AND ENVIRONMENTAL CRITERIA

A. Crystalline Silica

1. Effects of Exposures

The principle material investigated in this study was crystalline silicon dioxide (often referred to as silica or free silica). Silica may be present in at least three crystalline forms: alpha quartz, cristobalite, and tridymite, and several amorphous (noncrystalline) forms. Amorphous silica is usually considered to be of low toxicity and may produce X-ray changes in the lung without disability.[1,2] Therefore, its content was not evaluated in either air or bulk material samples. In this study, only alpha quartz was determined to be present in any of the airborne dust samples. In this report, all references to silica dust concentrations refer to the crystalline quartz content of the respirable fraction of airborne dust.

The crystalline forms of silica can cause severe lung damage (silicosis) when inhaled. Silicosis is a form of pulmonary fibrosis caused by the deposition of fine particles of crystalline silica in the lower portions (alveoli) of the lungs. Symptoms usually develop insidiously, with cough, shortness of breath, chest pain, weakness, wheezing, and nonspecific chest illness. Silicosis usually occurs after years of exposure, but may appear in a shorter time if exposures are very high. There is evidence that cristobalite has a greater capability to produce silicosis than quartz.[3,4,5,6,7]

Other factors, chemical or biological, can influence the rate of reaction of the free silica with the tissue and can create problems in diagnosis. One of the most frequent complications in the past was the occurrence of tuberculosis with silicosis, in which case the disease was called silicotuberculosis or tuberculosilicosis.[8]

The relationship between exposure to silica dusts and onset of lung cancer has not yet been conclusively established. A recent article describes NIOSH's current position on this relationship:

> "Studies of workers exposed to respirable quartz dusts have found varying degrees of lung fibrosis accompanied by excess lung cancer. Unfortunately, these studies have not considered quantitatively concomitant exposures to known carcinogens. Thus, support at the present time for an association between exposures to quartz dust alone and lung cancer can come only from theories associating fibrotic tissue formation with cancer. NIOSH presently believes that its recommended standard for crystalline silica is adequate for protection against fibrotic disease. It is urged that further research be conducted to determine the association between silica exposure and the development of lung cancer."[9]

2. Hygienic Standards

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week, for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent becomes available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH recommended exposure limits (RELs), (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and (3) the U.S. Department of Labor (MSHA) Permissible Exposure Limits (PELs). In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet only those levels specified by a MSHA PEL.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values, which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

The NIOSH Recommended Exposure Limit (REL): NIOSH recommends that occupational exposure be controlled so that no worker is exposed to a time-weighted average (TWA) exposure concentration of crystalline free silica greater than 50 micrograms per cubic meter of air (0.05 mg/m^3) as determined by full-shift respirable dust sample for up to a 10-hour workday, 40-hour workweek.[8]

The MSHA Threshold Limit Value: At the time of this study, the MSHA PEL for respirable dust containing quartz was dependent upon the percent silica in the sample. Thus, the respirable dust exposure PEL, time-weighted average (TWA) for an 8-hour day, should not exceed the value obtained by the formula:[10]

$$\text{PEL} = \frac{10\ mg/m^3}{\%\ SiO_2+2}$$

MSHA proposes that this rule be changed and the new PEL be 0.1 mg/m^3 (quartz) as a TWA for an 8-hour day.[11] At the earliest, it would be one or more years before this new PEL would become enforceable.

IV. STUDY PLAN/METHODOLOGY

A. Quantitative Evaluations

NIOSH/NJDOH investigators conducted environmental evaluations in several work areas of the Dryer/Loader Area including the Dryer Control Room, Controlled Loading Spouts, the Uncontrolled Loading Spouts, and near the Screen. Bulk samples of sand were collected and analyzed for crystalline silica content.

Airborne exposure to dust was evaluated in several ways:

1. <u>Personal samples</u>, for the estimation of respirable dust and respirable quartz dust exposures, were collected on preweighed, 37 mm (diameter), 5 μm (pore size) PVC membrane filters (FWSB - Mine Safety Appliances, Inc., Pittsburgh, Pennsylvania), mounted in series with 10 mm nylon cyclones (Mine Safety Appliances, Inc., Pittsburgh, Pennsylvania). Air was drawn through the filter at an approximate flow rate of 1.7 liters per minute (lpm) using a battery-powered sampling pump (SKC Air Check Sampler, Model 224-PC X R7, SKC Inc., Eighty-Four, Pennsylvania). Time-integrated samples were collected in the breathing zone of workers for a full day shift, generally for about 7 hours (ranging from about 6.5 to 7.5 hours depending on individual work schedules). Three workers (Dryer Operator, Sand Loading Operator, and Front-End Loader Operator) in the Dryer/Loader Area was exposed to quartz dust. These workers (five employees) were sampled for three shifts.

2. Area samples, collected in general work areas, were collected using the same type of preweighed PVC filters and portable, battery-operated pumps. Additional area samples were collected using high volume (hi-vol) pumps (Gast Manufacturing Corporation, Benton Harbor, Michigan) operating at a nominal 10 lpm, using the same type of preweighed PVC filters mounted in series with a 0.5-inch HASL cyclone (Bendix Environmental and Process Instruments Division).

   All air samples were analyzed for respirable dust and respirable crystalline free silica dust content. Respirable dust content was analyzed gravimetrically according to NIOSH Method 0500 with the following modifications: (1) The filters were stored in an environmentally controlled room (21±3°C and 40±3% R.H.) and are subjected to the room conditions for a long duration for stabilization. Therefore, the method's 8- to 16-hour time for stabilization between tare weighings was reduced to 5 to 10 minutes. (2) The filters and backup pads were not vacuum desiccated.[8] The Limit of Detection (LOD) was determined to be 0.015 mg per sample. (The LOD is defined as the smallest amount of analyte which can be distinguished from background.[12])

   Respirable crystalline silica dust content (alpha quartz and cristobalite) was analyzed by NIOSH Method 7500, using X-ray diffraction with the following modifications: (1) Filters were dissolved in tetrahydrofuran rather than being ashed in a furnace. (2) Standards and samples were run concurrently and an external calibration curve was prepared from the integrated intensities rather than using the suggested normalization procedure.[12] The LOD and the Limit of Quantification (LOQ) for these samples for quartz were determined to be 0.015 mg and 0.03 mg per sample, respectively. (The LOQ is defined as the mass of analyte equal to 10 times the standard error of the calibration graph; or approximately the mass of analyte for which the relative standard error, s_r, equals 0.10.[8])

3. Real-time sampling was performed in several areas. The techniques for this have been described in the literature.[13] The instrument used to measure dust concentration was a Hand-held Aerosol Monitor (HAM) manufactured by PPM, Inc., Knoxville, Tennessee. This instrument is a light scattering device and its response is dependent upon the optical characteristics of the dust being measured. The HAM responds to respirable dust, but does not differentiate between crystalline silica and other dusts. For these reasons, concentrations are reported as relative concentrations (rather than absolute levels); as a result, this instrument was used only in comparisons between similar operations (i.e., spout loading); identification of a profile of concentration over a cycle of a given operation (i.e., truck loading); and identification of dust sources.

   In the continuous mode, real-time samples were taken at the controlled loading spout for trucks, the controlled loading spout for railroad cars, and uncontrolled loading spout for railroad cars. The sample sites were near the spout's discharge. When the instrument was used to measure dust levels during several loading cycle operations, it was operated in a continuous mode and its analog output was connected to a data logger (Rustrak Ranger, Gulton, Inc., East Greenwich, Rhode Island). When the collection was completed, the data logger was downloaded to a portable computer (Compaq Portable III, Compaq Computer Corporation, Houston, Texas) for analysis.

The HAM was also used in a short-term mode to survey the drying and loading area to identify dust sources. Measurements were taken only for a few moments at each sample site until the readings stabilized. Relevant events were also noted that could account for the different dust levels.

4. Ventilation rates and airflow pattern evaluations were made to determine the effectiveness of the controlled (exhausted) spouts. Velocity measurements were made with a hot wire anemometer (Model 1650 Air Velocity Meter, TSI, Inc., St. Paul, Minnesota).

B. Observational Evaluations

Other control measures, such as the environmental monitoring program, the respirator protection program, housekeeping, and equipment maintenance were also observed, in addition to a review of these areas with the Plant Superintendent and Manager of Safety/Health.

V. RESULTS AND DISCUSSION

A. Environmental Evaluations

1. Bulk Sand Sample Analyses

Quantitative analyses of two bulk samples, collected at the time of this survey, indicated that the quartz content of the sand ranged from 75% to 81%. No cristobalite was detected in either sample. (The Limit of Detection for both quartz and cristobalite was 0.75% and the Limit of Quantitation was 1.5%.)

2. Air Sample Analyses

Of the nine personal samples, none exceeded the REL or the PEL; of the 22 area samples, two exceeded the REL and one exceeded the PEL. All 31 air samples collected contained quantifiable masses of respirable dust (greater than the analytical LOQ of 0.01 mg per sample). Ten of the samples contained quantifiable masses of respirable quartz (greater than the analytical LOQ of 0.015 mg per sample). Fifteen samples contained no detectable respirable quartz, four contained trace quantities of respirable quartz and were semi-quantitative estimates falling between the LOD (0.015 mg) and LOQ (0.03 mg) per sample. No cristobalite or tridymite was detected in any of the samples. Locations of the air samples are identified in Table I. Table II contains the results of each airborne sample; Table III summarizes these results.

Table I. Identification of Air Sampling Sites

Sample Code	Operator and/or Location, as shown in Figures 8 and 9.
	A. Personal (Sampled at 1.7 lpm)
10	Front-end Loader Operator
11	Sand Loading Operator - Trucks and Railroad Cars
16	Dryer Operator
	B. Area Samples (Sampled at 1.7 lpm)
21	Controlled Loading Spout Control Room for Trucks
22	Controlled Loading Spout Control Room for Railroad Cars
23	Near Controlled Loading Spout above Truck
24	Near Controlled Loading Spout above Railroad Car
25	Uncontrolled Loading Spout on Top of Railroad Car
26	Dryer Enclosed Control Room
	C. Area Hi-Vol Samples (Sampled at 9-10 lpm)
33	Near Controlled Loading Spout above Truck
34	Near Controlled Loading Spout above Railroad Car
37	Near Screens
38	Outside Area near Warehouse (about 200' east Drying/Loading Area)

a. General Dryer/Loader Plant Area

Air samples and real-time measurements detected dust sources in the screen area and along the dried sand conveyor lines.

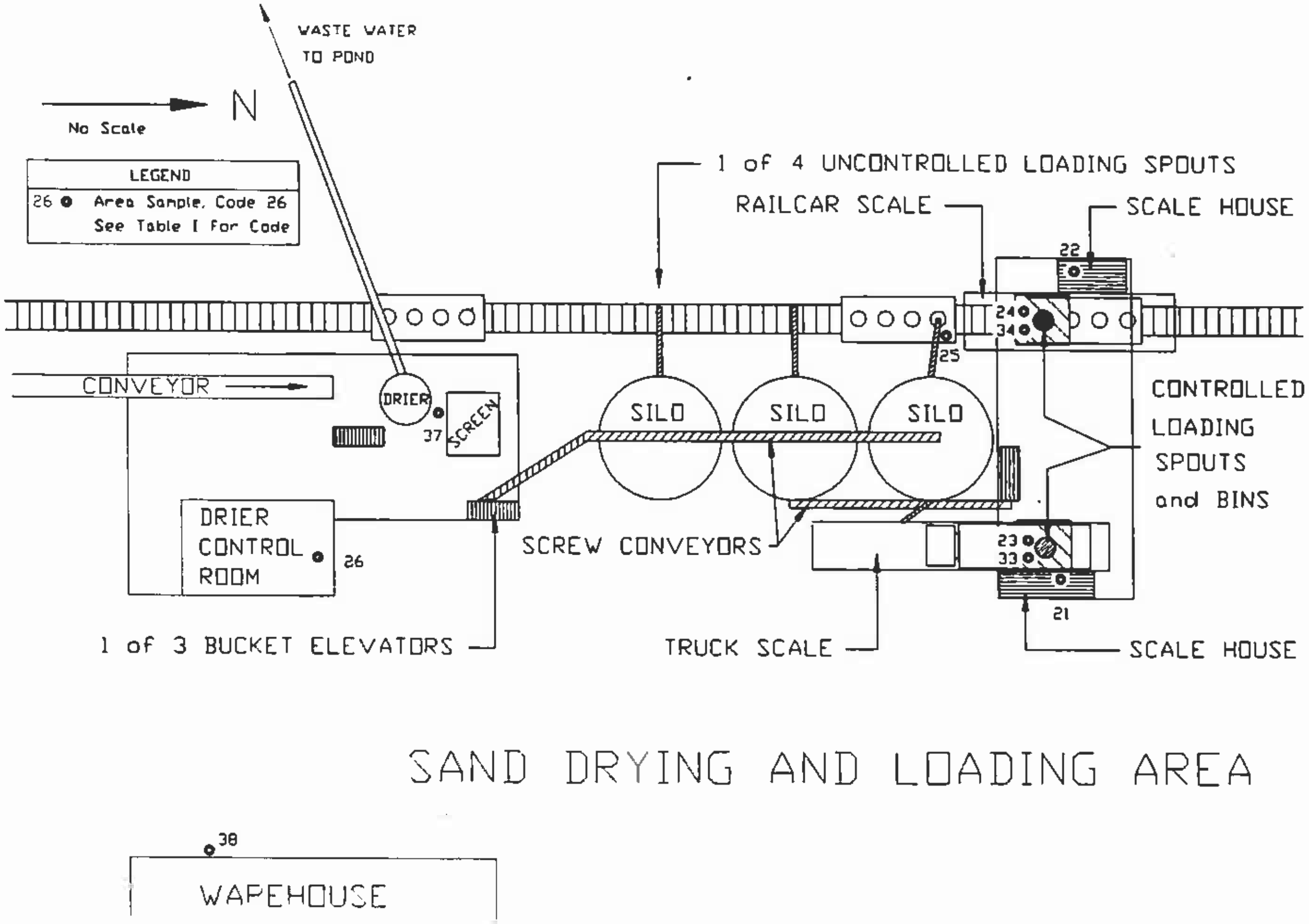


Figure 8. Air Sample Location Sites.

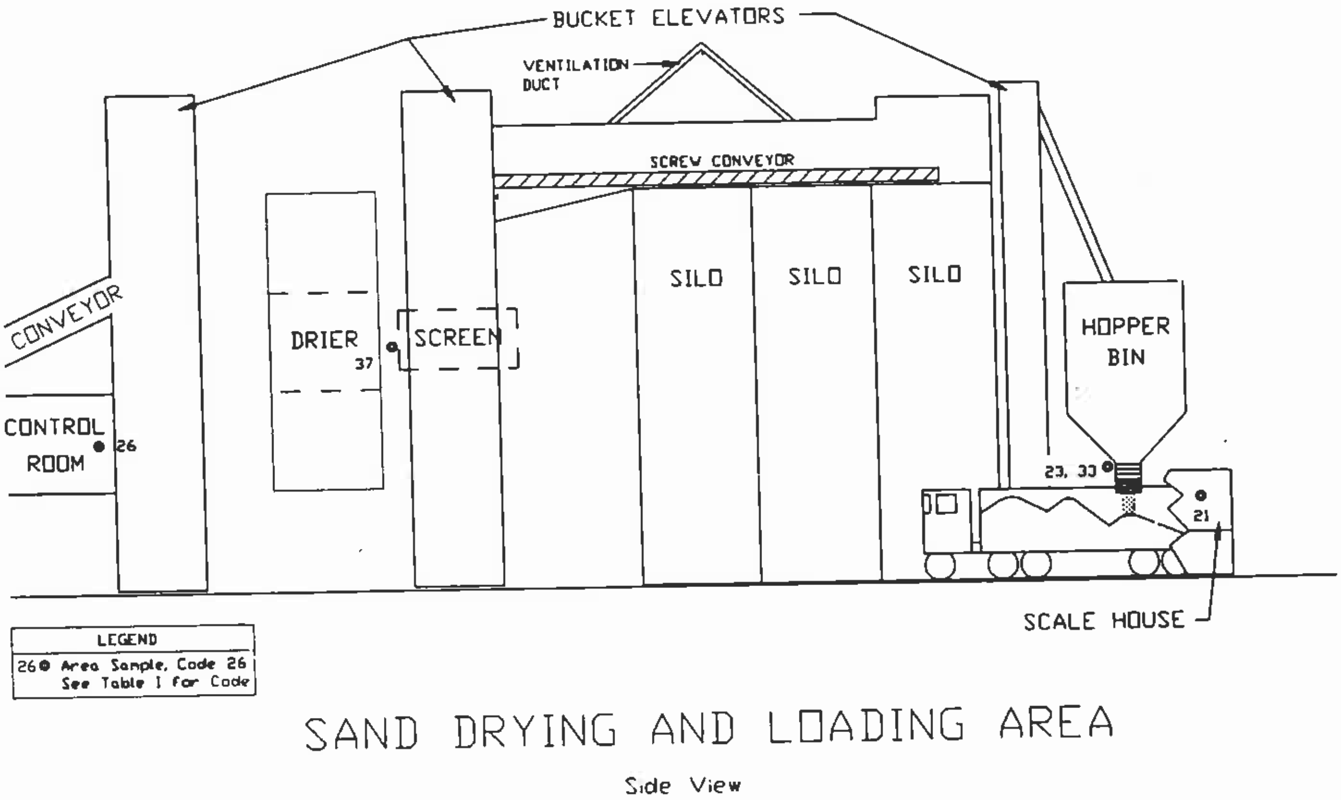


Figure 9. Air Sample Locations (Side View of Plant).

Table II. Respirable Airborne Dust Measurement Results

Day	Shift	Sample Code	Type of Sample	Dust (mg/m^3)		%	% of	% of
				Resp	Quartz	Quartz	PEL	REL
13	1	10	Personal	0.14	<0.02	< 17	< 26	<40
14	3	10		0.04	<0.02	< 50	< 21	<40
15	3	10		0.08	<0.02	< 25	< 22	<40
13	1	11		0.24	<0.02	< 8	< 24	<40
14	3	11		0.05	(0.03)	50	26	60
15	3	11		0.11	(0.03)	25	30	60
13	1	16		0.05	<0.02	< 38	< 20	<40
14	3	16		0.09	0.04	43	40	80
15	3	16		0.15	0.05	36	58	100
13	1	21	Area	0.03	<0.02	< 75	< 23	<40
14	3	21		0.06	<0.02	< 30	< 19	<40
15	3	21		0.03	<0.02	< 75	< 23	<40
14	3	22		0.01	<0.02	<100	< 10	<40
15	3	22		0.01	<0.02	<100	< 10	<40
15	3	23		0.07	0.04	60	43	80
15	3	24		0.07	<0.02	< 30	< 22	<40
14	3	25		0.90	0.77	85	787	1540
13	1	26		0.08	<0.02	< 25	< 22	<40
14	3	26		0.04	<0.02	< 50	< 21	<40
15	3	26		0.01	<0.02	<100	< 10	<40
13	1	33	Area (Hi-Vol)	0.07	0.015	22	4	30
13	2	33		0.07	0.021	28	6	42
15	3	33		0.05	0.031	59	19	62
15	3	34		0.05	<0.004	< 8	< 1	<7
13	1	37		0.05	(0.005)	11	1	10
14	3	37		0.09	0.065	76	51	131
15	3	37		0.09	0.049	55	28	99
13	1	38		0.04	<0.004	< 9	< 1	<8
13	2	38		0.04	0.008	20	2	16
14	3	38		0.02	<0.003	< 17	< 1	<7
15	3	38		0.03	(0.005)	17	1	10

REL - NIOSH Recommended Exposure Limit: 0.05 mg/m^3 (quartz).
PEL - MSHA Permissible Exposure Limit: (see text).

Table III. Average Respirable Dust Concentration (mg/m^3) of Air Samples

Code, Personal or Area, Location	No. of Samples	Average Conc.		No. of Samples	
		Resp	Quartz	>PEL	>REL
A. Personal					
10. Front-end Loader Operator	3	0.09	<0.02	0	0
11. Loading Operator	3	0.13	<0.03	0	0
16. Dryer Operator	3	0.10	<0.04	0	0
B. Area Samples					
21. Cnt'd Ld'g Spout Room, Trucks	3	0.04	<0.02	0	0
22. Cnt'd Ld'g Spout Room, RR Cars	2	0.01	<0.02	0	0
23 & 33. Cnt'd Ld'g Spt for Trucks	4	0.06	0.03	0	0
24 & 34. Cnt'd Ld'g Spt for RR Cars	2	0.06	<0.02	0	0
25. Uncnt'd Ld'g Spout, Top RR Car	1	0.90	0.77	1	1
26. Dryer Control Room	3	0.04	<0.02	0	0
37. Screens	3	0.08	<0.04	0	1
38. Outside Area near Warehouse	4	0.03	<0.01	0	0

REL - NIOSH Recommended Exposure Limit: 0.05 mg/m^3 (quartz).
PEL - MSHA Permissible Exposure Limit: (see text).

Note: Arithmetic average calculation based on assumption that nondetectable samples contained silica at the level corresponding to the limit of detection.

(1) Personal Samples

Three personal samples were collected on three different dryer operators (sample code 16 in Tables I, II, and III). The average respirable quartz dust exposure was <0.04 mg/m^3 (range <0.02 to 0.05 mg/m^3). The exposures were between 20% and 50% of the MSHA PEL; one sample equalled the NIOSH REL for respirable silica dust. The operator spends part of the shift in the dryer control room and the remainder of the shift in the general plant area of the dryer, screens, and conveyor line. On the day the personal sample was 100% of the REL, the area sample measured near the screens was at 99% of the REL.

(2) Area Samples

Area samples were collected in the dryer control room (sample code 26) and near the sand screens (sample code 37). In the dryer control room, the respirable quartz dust levels of all three samples were below the LOD (0.02 mg/m^3). In the screen area, the average respirable dust concentration of three samples was <0.04 mg/m^3 (range 0.015 to 0.0657 mg/m^3). The concentrations ranged between 7% and 70% of the PEL. One sample exceeded the REL (131%).

(3) Real-Time Measurements

In the plant area between where the damp sand enters and the dried finished sand is loaded into trucks and railroad cars, real-time measurements (in the short-term mode) identified several dust sources. (Figures 10, 11, and 12 show the sample sites and Table IV shows the dust levels measured at these sites.) Dust sources were located near the screen, the top of the dryer, at the bucket elevator discharge into the screw conveyor at the top of the silos, and on top of the hopper bin above the truck scales.

The highest real-time measurements were in the area of the screens (0.31 mg/m^3); this area appears to be the greatest potential continuous source of dust exposure. Improved maintenance of the screen enclosure covers and exhaust ventilation of the screens should reduce this dust source.

A second potential dust exposure is on top of the hopper bin above the truck scales (0.30 mg/m^3). This appears to be mainly where the sand enters the hopper bin. Since this is an isolated area with minimal worker interaction, this dust source does not present as great as hazard as the screens. Improved maintenance of the dust seals near the transfer points of the conveyor system and increased ventilation from the bin would reduce this source.

A third potential dust exposure is located near the top of the dryer (0.06 mg/m^3). Dust may be migrating from the screen area rather than leaking from the dryer. Additional measurements are needed in this area to determine if this source is from the dryer or from the screens.

A fourth potential dust exposure is at the top of the bucket elevator leading to the silos (0.10 mg/m^3). This is an isolated area requiring minimal worker interaction and the source does not present as great as hazard as the one at the screens. The elevators act as chimneys for the dust. Improved maintenance of the conveyor enclosures and exhaust ventilation from the enclosures would reduce the dust level.

(4) Ventilation Evaluation

Several examples of poor design in the exhaust duct system were observed. First, all elbows in the system were right angles (mitred elbows). This type of bend produces excessive pressure drop and reduces the effectiveness of the ventilation system. Duct elbows should have a center line radius of at least 2 duct diameters, as shown in Appendix B, taken from the ACGIH Ventilation Manual.[14]

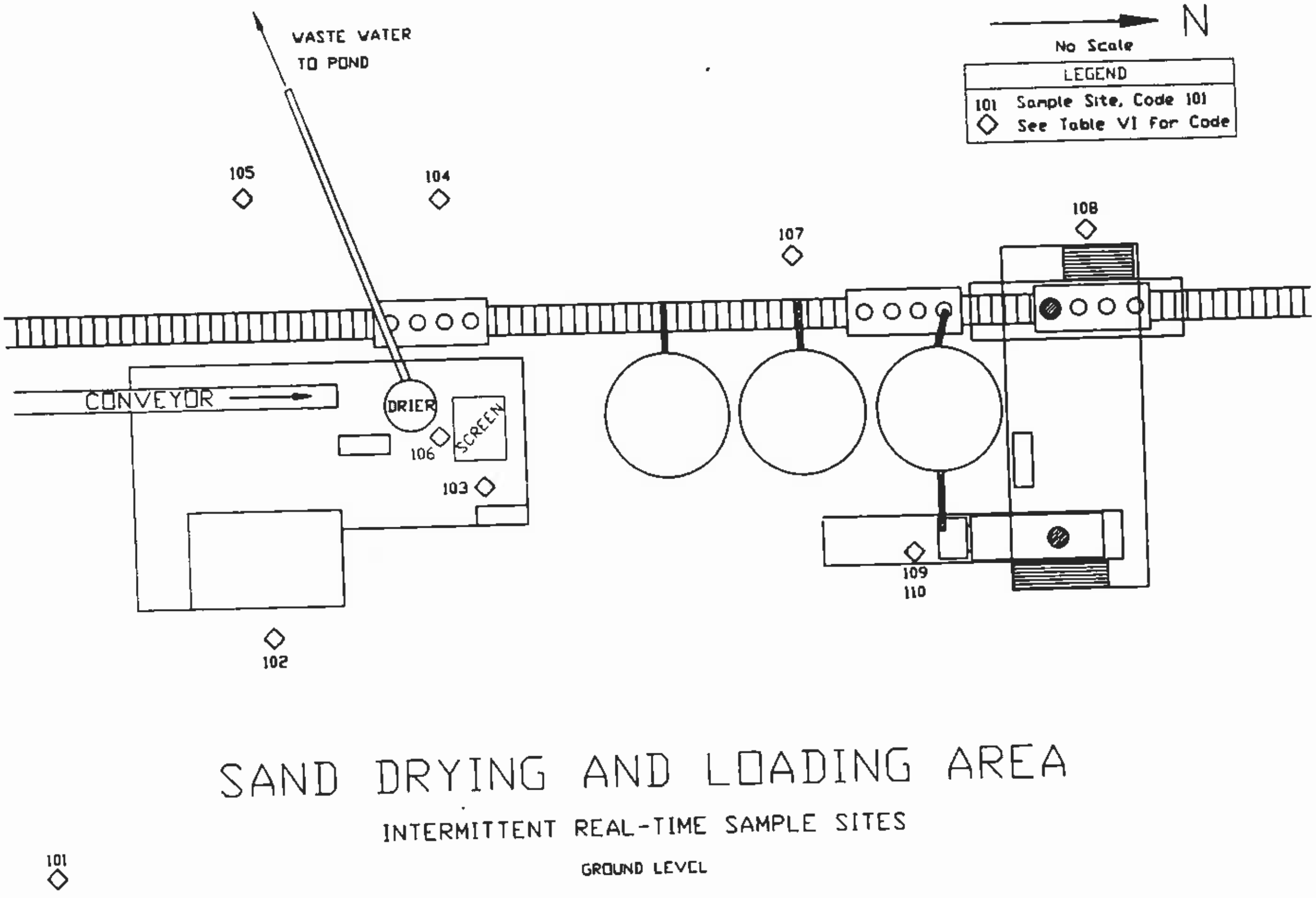


Figure 10. Real-Time Sampling Sites, Ground Level.

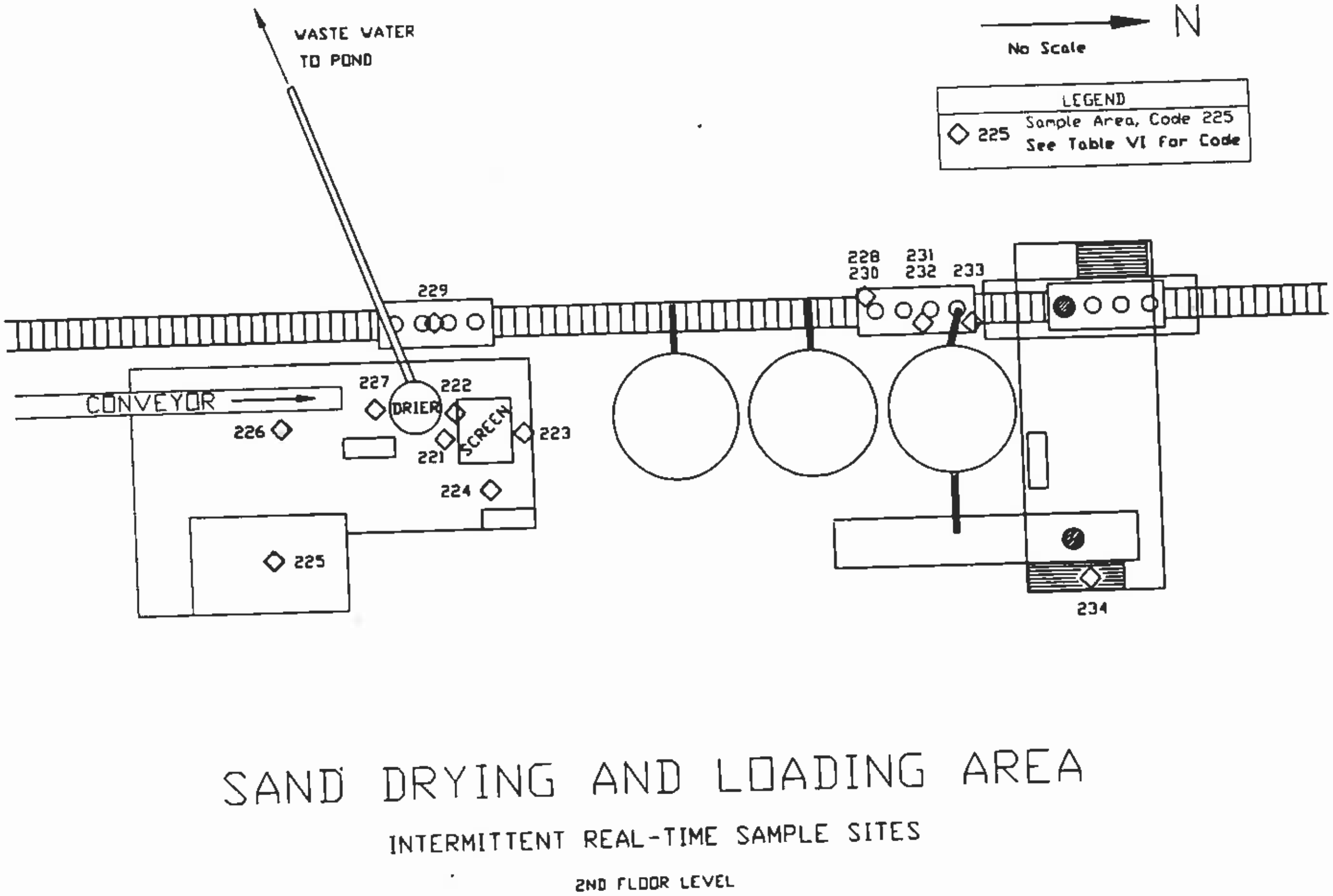


Figure 11. Real-Time Sampling Sites, 2nd Floor Level.

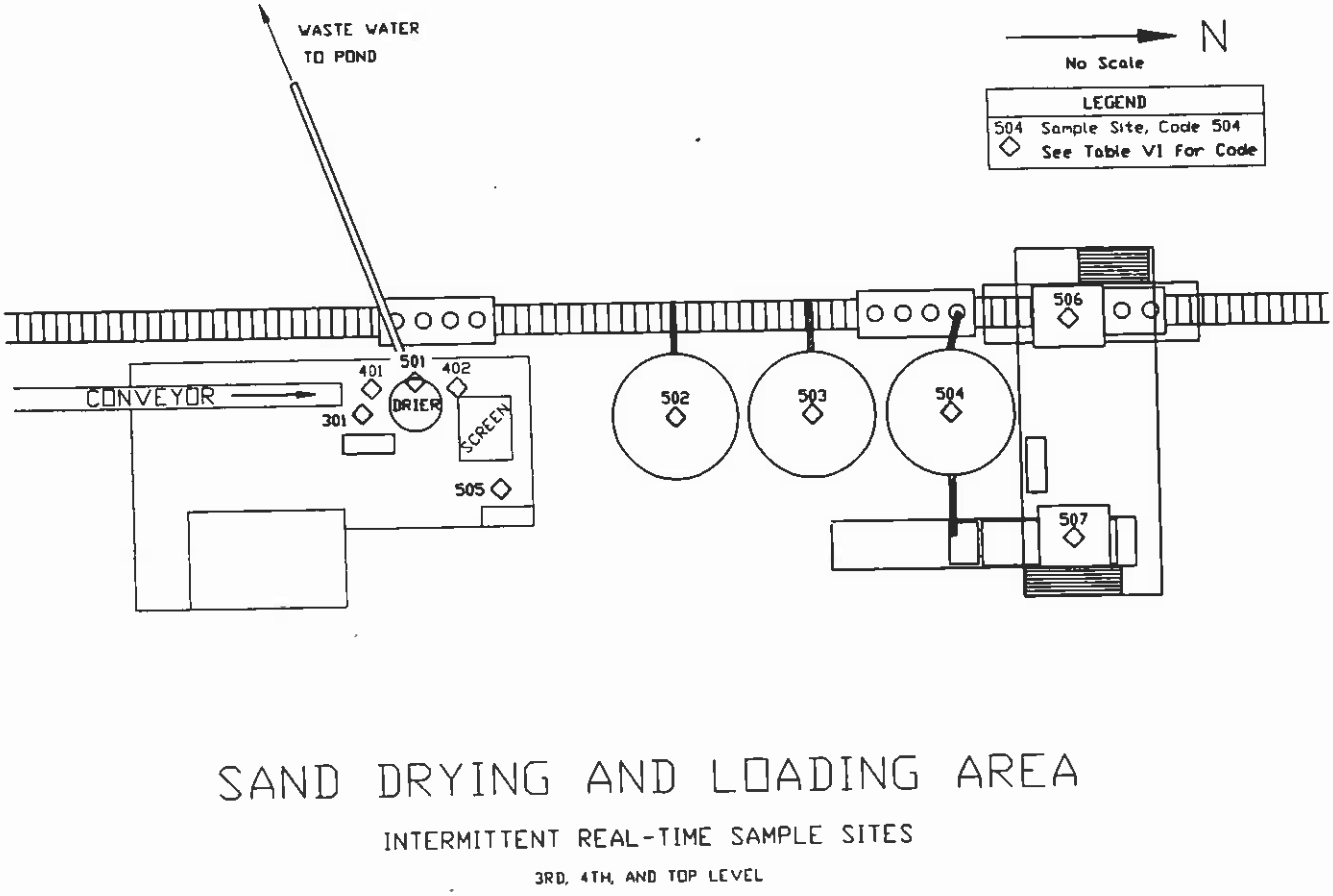


Figure 12. Real-Time Sampling Sites, 3rd, 4th, and Top Level.

Table IV. Short-term, Real-time Respirable Dust (mg/m^3) Survey of 9/15/88

Sample Site**	Site Description Sample Locations, as shown in Figures 10, 11, and 12.	Est'd % of PEL*	Dust Level (mg/m^3)
	GROUND LEVEL (BREATHING ZONE)		
101	Area near Warehouse (Ambient Dust Level)	16	0.05
102P	Below Dryer Control Room	25	0.03
103P	Base of Bucket Elevator to Silos	25	0.03
104P	Upwind of Waste Water Pipe Discharge from Dryer	10	0.03
105P	Downwind of Waste Water Pipe Discharge from Dryer	20	0.06
106P	Downwind of Screen Oversize Discharge	160	0.1-0.5
107P	Downwind of Railroad Car Being Filled with Sand	85	0.10
108R	Beside Loading Spout Control Room for Railroad Car	60	0.07
109T	Downwind of Truck Before Being Loaded with Sand	25	0.03
110T	Downwind of Truck during Loading (5 mph Breeze N-S)	950	0.03-1.1
	2ND FLOOR LEVEL		
221P	South Side of Screens beneath Hi-Vol Sampler	25	0.03
222P	South Side of Screens by Hi-Vol Sampler	260	0.31
223P	North Side of Screens	40	0.05
224P	East Side of Screens	85	0.10
225P	Inside Dryer Control Room	70	0.04
226P	Beneath Belt Conveyor Discharge	35	0.04
227P	Bottom of Dryer on South Side	50	0.06
228R	Top of RR Car by Silo # 2, (NOT Loading)	25	0.03
229R	Top of RR Car by Dryer, (NOT Loading)	35	0.04
230R	Top of RR Car, Downwind (Loading into Car)	1650	0.9-2.0
231R	Top of RR Car, Downwind (Loading near Top of Car)	290	3.5
232R	Top of RR Car, Downwind (Sand Flowing on Cross Member)	700	3.0-8.2
233R	Top of RR Car, Upwind (Sand Flowing on Cross Member)	16500	20
234T	Inside Control Room for Truck Loading Spout, (AC, off)	50	0.06
	3RD FLOOR LEVEL		
301P	Between Dryer and Damp Sand Bucket Elevator	100	0.12
	4TH FLOOR LEVEL		
401P	South of Dryer	100	0.12
402P	North of Dryer	25	0.03
	TOP LEVEL		
501P	Top of Dryer, West Side	50	0.06
502P	Top of Silo # 1 (South Silo)	40	0.05
503P	Top of Silo # 2 (Middle Silo)	35	0.04
504P	Top of Silo # 3 (North Silo)	35	0.04
505P	Top of Bucket Elevator to Silos Screw Conveyor	85	0.10
506T	Top of Hopper Truck Bin	250	0.30
507R	Top of Railroad Hopper Car Bin	25	0.03

* PEL based on average % quartz in air samples.

** P - Measurements taken in the general plant area processing dry sand.

** R - Measurements taken in the railroad car loading area.

** T - Measurements taken in the truck loading area.

Second, the duct system was constructed using a single duct size for both mains and branches. This does not provide for proper exhaust air distribution. In addition, it does not permit the maintenance of material conveying velocity in the branch duct without excessively high velocity in the main duct.

A third example of poor design is the use of the bucket elevator (leading to the hopper bins) as a plenum to the loading spout's exhaust ventilation system. The enclosure of the bucket elevator is not sufficiently tight (nor is it likely to be made so) to allow it to serve as an exhaust plenum. The loading spouts should be connected directly to the dust collector.

b. Truck Loading (Controlled Spout)

(1) Personal Samples

Three personal samples were collected on three different workers' loading trucks and railroad cars, with one operator performing both jobs (sample code 11). The average exposure to respirable quartz was <0.03 mg/m^3 (range <0.02 to 0.03 mg/m^3) and the average respirable dust exposure was 0.13 mg/m^3 (range 0.05 to 0.24 mg/m^3). These levels are about 25% of the PEL for silica (none exceeded the REL). These exposures are the average during the loading of both trucks and railroad cars.

(2) Area Samples

Four samples were collected in the area of the truck loading spout (sample codes 23 and 33). The average respirable quartz concentration was 0.02 mg/m^3 (range 0.015 to 0.03 mg/m^3) and the respirable dust level was 0.06 mg/m^3 (range 0.05 to 0.07 mg/m^3). These levels are about 20% of the PEL (none exceeded the REL).

(3) Real-Time Measurements

Continuous real-time measurements made near the loading spout during the loading of 13 trucks is shown in Figure 13 and summarized in Table V. Over a 5-hour period, the average respirable dust levels between truck loading ranged from 0.03 to 0.04 mg/m^3. The dust levels during loading varied with the construction of the trailer. During the loading of a cross rib truck with a longitudinal rib and some cross rib trucks, these dust levels increased 20 times over ambient (0.72 mg/m^3). During loading of open-type trucks, these levels averaged 0.26 mg/m^3. For hopper-type trucks, the dust levels averaged 0.08 mg/m^3.

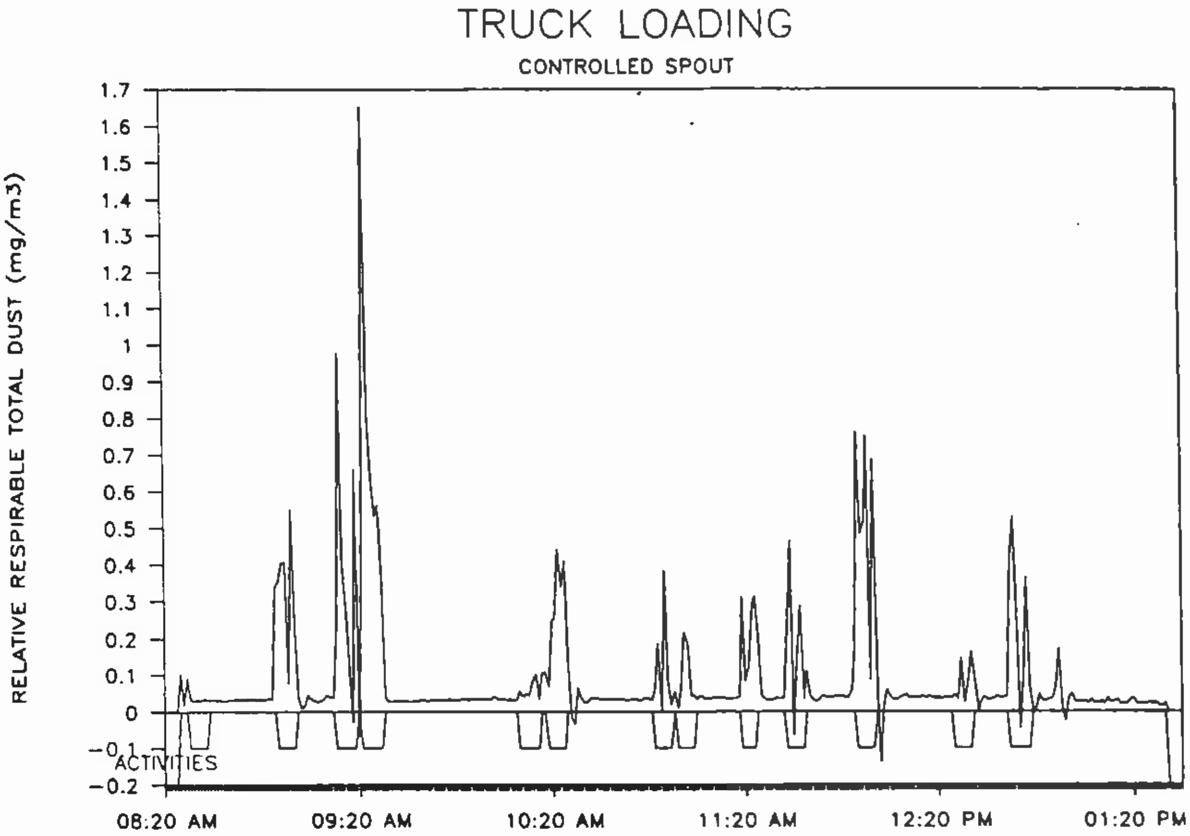


Figure 13. Truck Filling from a Controlled Spout.

This is the continuous real-time plot of the respirable dust levels measured during the loading of 13 trucks. A description of this plot follows:

0 line:	Reference line. Also "0" values indicate when no sand flowed from the spout into trucks.
Minus values:	Designate events; "-0.1" for 5 or more minutes indicates one truck being loaded. Table V shows the type of truck being loaded.
Plus values:	Relative respirable dust levels measured during and in-between truck loadings. Table V shows the maximum and average dust levels during truck filling and between truck fillings.
Comments:	The greatest dust level measured was for the fourth truck, a cross rib truck (maximum of 1.65 mg/m^3 and an average of 0.72 mg/m^3). When there was 5 or more minutes between truck fillings, the dust level dropped to 0.03 mg/m^3.

Table V. Summary of Continuous Real-time Data, Respirable Dust Levels during Truck Loading, 9/13/88

Truck No.	Types of Truck	Tons of Sand	Real-Time Readings (mg/m^3)*					
			During Loading			Between Loadings		
			Minutes	Max.	Avg.	Minutes	Max.	Avg.
1	Open	80	7	0.06	0.04			
						20	0.04	0.03
2	Cross Ribs	50	7	0.55	0.34			
						12	0.05	0.03
3	Open	53	8	0.97	0.32			
4	Cr Lo Ribs	53	7	1.65	0.72			
						42	0.04	0.03
5	Hopper (4)	51	7	0.10	0.06			
						3	0.11	0.10
6	Open	53	6	0.44	0.32			
						26	0.07	0.03
7	Cross Ribs	49	7	0.39	0.11			
8	Hopper (2)	50	5	0.22	0.11			
						14	0.05	0.04
9	Open	53	6	0.32	0.22			
						8	0.04	0.04
10	Open	52	7	0.47	0.18			
						14	0.06	0.04
11	Open	53	7	0.76	0.50			
						24	0.06	0.03
12	Cross Ribs	50	7	0.16	0.08			
						10	0.04	0.03
13	Open	53	7	0.53	0.24			
						42	0.17	0.03
Total		700	88			215		

Summary	Types of Trucks	Total Trucks	% of		Avg Dust Level			Avg Dust Level
			Trucks	Dust				
Avg's	All	13	100	100	0.25			0.03
	Open	7	54	21	0.26			
	Cross Ribs	3	23	14	0.18			
	Cr Lo Ribs	1	8	58	0.72			
	Hopper	2	15	7	0.08			

*Respirable dust concentration based on factory calibration with an aerosol of density = 1.5 g/cm^3.
"Types of Trucks", see Figure 4, types of truck openings.
"Cr Lo Ribs" are cross ribs with a longitudinal rib.
"Hopper (4)", a hopper-type truck with 4 hatches.
Comments: For 13 trucks; 29% of time was for filling, 71% between fillings.

Short-term real-time measurements identified work practices that could effect dust exposure in the truck loading area. (The sample sites are shown in Figures 10 and 11 and the dust levels are summarized in Table IV.) Higher measurements were recorded for rib-type trucks when the sand was allowed to flow over a rib and fall 5 to 6 feet into the truck (up to 1.1 mg/m^3). For open trucks where the spout was lowered to the bottom of the truck, dust levels were only 0.03 mg/m^3. Measurements inside the control room, with the air conditioner off, averaged 0.06 mg/m^3.

Real-time measurements show that the proper use of the spout can greatly reduce the amount of dust generated during truck filling. The type of truck being filled is a major factor in the effectiveness of the spout. Trucks with longitudinal ribs defeat the purpose of the loading spout by not allowing it to be lowered past the ribs to the bottom of the truck. As a result, sand flows over the rib, is dispersed, and entraps air as it free falls into the truck, thus increasing the amount of dust generated. This can also be a factor in cross rib-type trucks when the spout is positioned over a rib. When the spout is lowered to the bottom of the truck and maintained near the top of the sand pile as it discharges into the truck, the free fall distance through open air is reduced to a few inches, thus reducing the amount of air entrapped and the resultant dust generated. When loading hopper trucks, sand free falls up to 8 feet inside an enclosed container which contains most of the dust generated.

(4) Ventilation Evaluation of the Controlled Spout

The enclosed-type loading spout, as shown in Figure 4, is designed to fill enclosed vehicles such as hopper trucks. The outer diameter of the fabric sleeve is 28 inches and the diameter of the product outlet is 9.25 inches. The diameter of the donut-shaped exhaust surrounding the product spout is 15 inches. Sand flows by gravity through the spout at a rate of 10,000 pounds (100 cubic feet) of sand per minute. The measured air velocity through the spout averaged 130 fpm which corresponds to a volumetric flow rate of approximately 400 cfm. The manufacturer recommends an exhaust flow rate of 800 to 1,000 cfm when sand loading capacity is 200 cfm. The spout functions by removing the air flow induced by the falling sand. Thus, the existing flow rate is probably marginal. If increased product flow is contemplated, the exhaust flow rate should be increased to the spout manufacturer's recommendation.

For loading open-type trucks, an open-type loading spout is needed, as shown in Figure 4. This spout is similar in design to the closed loading spout except it has a double layered skirt around the spout. The sand discharges from the spout within the area of the confining skirt and then flows out from under the skirt while at the same time the spout is slowly retracted to permit sand flow. There are automatic raising sensors available that retract the spout as the stockpile rises to ensure that the sand discharge remains within the confines of the skirt. The airborne dust is contained within the curtained area and can be easily exhausted.

The enclosed loading spout is not designed to fill open vehicles and still effectively contain the dust. Ventilation rates would need to be much greater to slightly improve the effectiveness of the spout's dust containment. The main disadvantage of using an open-type loading spout to fill rib-type trucks and especially longitudinal rib trucks is the difficultly of lowering the spout past the ribs to within a few inches of the top of the sand pile in the truck. The greater the distances between the spout discharge and the top of the sand pile, the less effective is the dust containment of the spout.

As was discussed in section a.(4), the loading spout was connected to the dust collector via a constant diameter duct system containing mitred elbows and using the bucket elevator as an exhaust plenum. Proper methods of duct design could provide additional exhaust for the loading spout.

c. Railroad Car Loading (Uncontrolled Spout)

(1) Personal Samples

Results of these samples are reported in section b.(1).

(2) Area Samples

One sample was collected in the area of the loading spout (sample code 25, Figures 8 and 9). The respirable quartz concentration was 0.77 mg/m^3 and the respirable dust level was 0.90 mg/m^3. This exceeded the PEL by approximately 800% and the REL by 1,540%. (Workers spend very little time in this area during loading operations.)

(3) Real-Time Measurements

Continuous real-time data during the loading of five railroad cars are shown in Figure 14, and summarized in Table VI. Over a 4½-hour period, the average respirable dust level between car loadings was approximately 0.04 mg/m^3. During the filling of hatch-type (4-, 6-, and 10-hatch) cars, average levels ranged from 1.8 to 5.1 mg/m^3 near the open hatch used for filling. When the uncontrolled spout was in use, peak

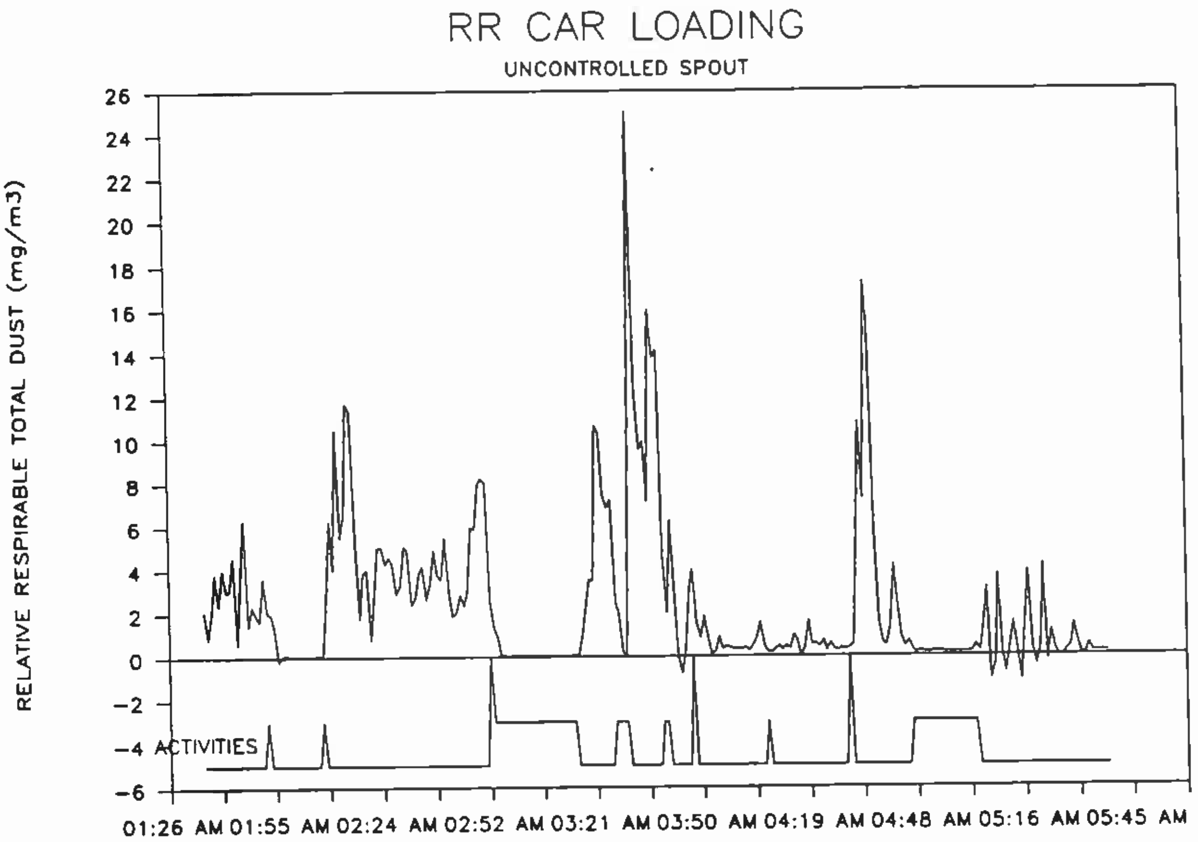


Figure 14. Railroad Car Filling from an Uncontrolled Spout.

Above is the real-time plot of the respirable dust levels measured during the loading of four railroad cars. A description of this plot follows:

0 line	Reference line.
Minus values	Designate events. The span between two "0s" designates one car being filled at the uncontrolled spout. A "-0.3" indicates no sand flowing. A "-0.3" for a 1- to 3-minute period also indicates a car being moved to the next open hatch. Table VI shows the type of car being loaded with car #1 being from 1:26 a.m. to 2:52 a.m. This table shows data for four cars at the uncontrolled spout.
Plus values	Relative respirable dust levels measured as cars were being filled. Table VI shows the maximum and average dust levels during the filling of five cars at the uncontrolled spout and three cars at the controlled spout.
Comments	The highest dust level measured was during the filling of the third car, a 6-hatch car (maximum of 16 mg/m^3 and an average of 5.1 mg/m^3). When no sand flowed into the car for periods of 10 or more minutes, the dust level dropped below 0.1 mg/m^3. The ambient dust level in the area was near 0.05 mg/m^3.

Table VI. Summary of the Continuous Real-time Data, Respirable Dust, during Railroad Car Loading, 9/13/88

Railroad Car			Uncontrolled Spout			Controlled Spout		
Car No.	Car Description	Sampler Location	Minutes	Max.	Avg.	Minutes	Max.	Avg.
1	4 Hatches	by Silo	14	4	2.7	100	0.1	0.04
-	-	on Scale	-	-	-	-	-	-
2	4 Hatches	by Silo	78	11	3.3	40	0.2	0.04
-	-	on Scale	-	-	-	-	-	-
3	6 Hatches	by Silo	30	16	5.1*	27	0.2	0.04
2	4 Hatches	on Scale	3	25	16.3	5	1.5	0.57
4	2 Coffin Lid	by Silo	42	2	0.5	38	0.2	0.05
3	6 Hatches	on Scale	2	1	0.8	3	0.3	0.23
5	10 Hatches	by Silo	51	17	1.8*	61	0.1	0.05
5	10 Hatches	on Scale	-	-	-	3	0.1	0.12
Total		by Silo	215					
		on Scale				11		

Summary	Sampler by Silo			Sampler on Scale		
	% of Total		Avg. Dust Level	% of Tot.		Avg. Dust Level
	Cars	Dust Level		Cars	Dust Level	
All Cars	100	100	2.6	100	100	0.26
4 Hatch	40	30	3.2	33	62	0.57
6 Hatch	20	48	5.1	33	25	0.23
10 Hatch	20	17	1.8	33	13	0.12
2 Coffin Lid	20	5	0.5	-	-	-

* Average dust concentrations of periods of active loading only.

measurements between 10 and 25 mg/m^3 were common near the open hatch. These are approximately 10 times higher than those measured near the controlled spout for truck loading.

Short-term real-time dust measurements were used to identify dust sources during loading from the uncontrolled spout and are summarized in Table IV. Measurements were taken prior to loading, while sand flowed into a car, and when sand flowed over a cross member of a coffin-hatch-type car. Ambient levels averaged 0.04 mg/m^3. Dust levels during the filling of hatch-type cars ranged from 0.9 to 3.5 mg/m^3. The highest levels were measured during filling of a coffin-lid-type car (20 mg/m^3) when the sand flowed over a cross rib in the hatch.

As a car fills, the amount of visible dust increases and dust levels often are a 100 times above the ambient. Sand, flowing by gravity, free falls approximately 8 feet from the spout to the bottom of the car generating large volumes of dust inside the car. As the car fills, this dust is displaced and escapes from the open hatches. Effects of this dust could be detected (0.1 mg/m^3) over 50 feet from the car.

d. Railroad Car Loading (Controlled Spout)

(1) Personal Samples

Results of these samples are reported in section b.(1).

(2) Area Samples

Two samples were collected in the area of the loading spout above the railroad car (sample codes 24 and 34, Figures 8 and 9). Neither exceeded the PEL nor the REL.

(3) Real-Time Measurements

Continuous real-time data during the loading of three railroad cars is shown in Figure 15, and Table VI. (At the same time, five railroad cars were being loaded at the uncontrolled spout.) Over a 6-hour period, the average ambient respirable dust level (when the spout was not in use) was 0.04 mg/m^3. During loading from this spout, the average levels increased 3 to 13 times above the ambient level reaching levels of 1.5 mg/m^3. Only hatch-type cars (4-, 6-, and 10-hatch cars) were loaded from the controlled spout.

(4) Ventilation Evaluation at the Controlled Spout

The enclosed-type loading spout, as shown in Figure 4, is designed to fill enclosed vehicles such as hopper cars. The outer diameter of the fabric sleeve is 28 inches and the

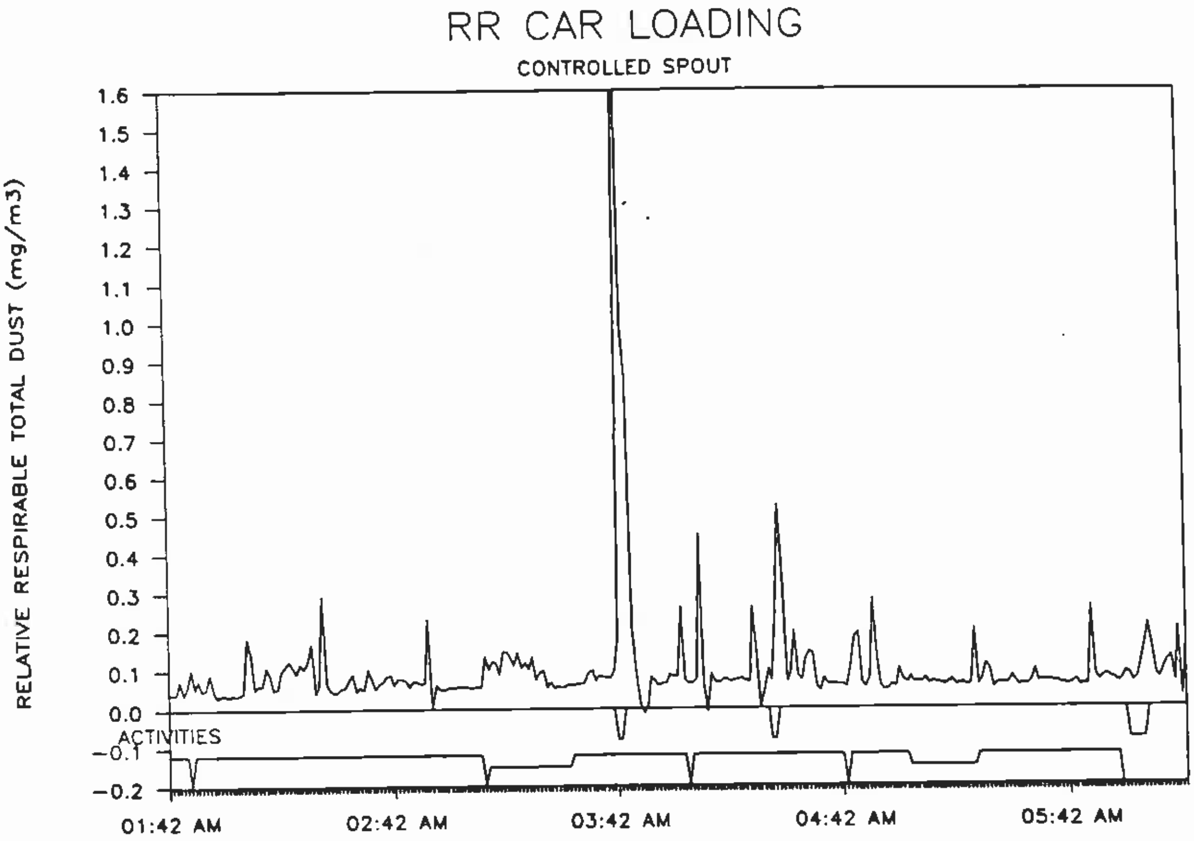


Figure 15. Railroad Car Loading with a Controlled Spout.

Above is the real-time plot of the respirable dust levels measured during the loading of five railroad cars. A description of this plot follows:

0 line	Reference line.
Minus values	Designate events. The span between two "-0.2s" denotes one car at the uncontrolled loading spout. A "-0.12" for over 30 minutes is a car being filled at the uncontrolled spout. A "-0.15" denotes no sand flow at the uncontrolled spout. A "-0.07" for 1 to 5 minutes indicates a car being filled at the controlled spout (three cars filled). Filling taking about one minute. Table VI shows the type of car being loaded; car #3, between 3:05 a.m. to 4:01 a.m., is being filled at the uncontrolled spout and car #2, at 3:45 a.m., is being filled at the controlled spout.
Plus values	Relative respirable dust levels measured near the controlled spout during and in-between car fillings at both the controlled and uncontrolled spouts. The maximum and average dust levels during loading are shown in Table VI.
Comments	The greatest dust level measured was when a 4-hatch car (Car #2) was being filled at the controlled spout and at the same time, a 6-hatch car (Car #3) was filling at the uncontrolled spout. The maximum level at the controlled spout was 1.5 mg/m^3, averaging 0.57 mg/m^3. The ambient dust level in the area was near 0.04 mg/m^3.

diameter of the product outlet is 9.25 inches. The diameter of the donut-shaped exhaust surrounding the product spout is 15 inches. Sand flows by gravity through the spout at a rate of 10,000 pounds (100 cubic feet) of sand per minute. The measured air velocity through the spout averaged 70 fpm, which corresponds to a volumetric flow rate of approximately 220 cfm. The manufacturer recommends an exhaust flow rate of 800 to 1,000 cfm when the sand loading capacity is 200 cfm. The spout functions by removing the air flow induced by the falling sand. Thus, the existing flow rate is inadequate, particularly if other hopper doors are left open. The exhaust flow rate should be increased to the spout manufacturer's recommendation.

The ventilation rate on this enclosed-type controlled spout needs to be increased to improve the effectiveness of its dust containment. This spout shares an exhaust system with the truck loading spout. As was discussed in section a.(4), the spout was connected to the dust collector via a constant diameter duct system containing mitred elbows and using the bucket elevator as an exhaust plenum. Proper methods of duct design could provide additional exhaust for the loading spout. Also, there is considerable leakage of sand at the

slide gate as it opens, closes, and while in use. This appears to be the main dust source in this area.

e. Front-End Loader Operator

(1) Personal Samples

Three personal samples were collected on two different workers operating the front-end loader (sample code 10). The average respirable quartz concentration was <0.02 mg/m^3 and the average respirable dust exposure was 0.09 mg/m^3 (range 0.04 to 0.14 mg/m^3). These levels are about 25% of the PEL (none exceeded the REL).

f. Ambient Dust Concentrations

(1) Area Samples

Four samples were collected near the warehouse to determine the ambient respirable dust and respirable quartz concentrations (sample code 38, Figure 8). The average respirable quartz concentration was <0.01 mg/^{3} and the average respirable dust concentration was 0.03 mg/m^3. This is about 10% of the PEL (none exceeded the REL). (The night prior to the start of the study, rain dampened the ground. The ground remained damp during the morning of the first day, drying out in the afternoon, and was dry on the second and third day. This appeared to have little noticeable effect on the ambient respirable dust levels, these being nearly the same all three days.)

B. Observational Evaluations

1. Respiratory Protection Program

Safety shoes, glasses, and hard hats are required in all areas of the plant. There are also posted areas where respirators (North 7700 series) must be worn. A safety brochure outlining essential safety and health requirements is mandatory reading for all plant personnel and visitors.

2. Medical Monitoring Program

Routine monitoring of silica exposure is performed twice yearly by the Mining Safety and Health Administration (MSHA). The corporate safety and health manager has a MIE Real-time Aerosol Monitor available for spot surveys. Medical Monitoring Programs have been developed by and are available from NIOSH[15] and the National Industrial Sand Association.[16]

3. Environmental Monitoring Program

The plant routinely monitors using the MIE Real-Time aerosol monitor; annually, a complete set of area and personal samples are collected. Also, the Corporate Safety Health Director makes routine visits, and Unitec, the company's internal technical group, annually reviews capital spending for environmental controls.

VI. RECOMMENDATIONS AND CONCLUSIONS

A. General Recommendations and Conclusions

1. Continue the ongoing comprehensive program of medical surveillance to validate the effectiveness of the dust control program. Unimin's program incorporates most of what is in the Medical Surveillance Program developed by NIOSH for Exposure to Crystalline Silica Flour,[16] which is also relevant to other crystalline silica dust exposures:

> "Preplacement and annual medical examinations should be made available to all workers who manufacture, use, or handle silica (flour) or materials containing silica (flour). These examinations should include at least:
>
> a. Comprehensive work and medical histories to evaluate exposure and signs and symptoms of respiratory disease;

b. A 14- by 17-inch posteroanterior chest radiogram, preferably interpreted using the 1971 ILO U/C classification (1980 ILO classification when available); and

c. Pulmonary function tests including forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV_1), with calculation of the FEV_1/FVC ratio.

Workers with radiographic evidence of silicosis should be given the opportunity to transfer to jobs without silica exposures (defined as exposure at concentrations less than half of the NIOSH-recommended standard)."

Unimin has a complete written policy/procedure manual on this subject.

2. Cases of silicosis have been noted by the New Jersey Health Department in the sand mining and processing industry in New Jersey. Although overexposure to respirable silica dust is less likely in wet processing operations, drying and loading operations remain areas of potential overexposure.

3. Both uncontrolled (nonventilated) spouts and controlled (ventilated) spouts are used at this operation. A comparison of the two types of spouts indicates that potential dust exposures during loading operations could be reduced by 90% with the elimination of the nonventilated spouts. (The company intends to eliminate the nonventilated spouts.)

4. Dust measurements inside the sand loading control rooms (sheet metal structures equipped with air conditioners) indicate that there is adequate protection for the operator while inside these rooms. For truck loading, this room is raised several feet above the ground to provide the operator with an unhampered view of the loading operation and the only time he leaves this room during loading operation is to take a grab sample of the sand. At the control room for railroad cars, the operator leaves the room only after loading has been completed.

5. Truck drivers hauling the sand could be exposed to potentially high silica dust concentrations. Often, they stand outside of their trucks during loading in order to see the signal to move the truck forward, to collect a sample of sand, or simply to stretch their legs. It would be better if they stayed inside the trucks with the windows up and a signal installed to indicate when to move forward. Where the driver actively participates in the loading of the sand or hauls several loads each day, high exposures are possible (not only at the mine but at the destination as well). Personal air samples are needed to determine what these exposures are if exposure controls are needed. The New Jersey Department of Health may want to undertake this evaluation.

6. It has been reported that outside areas can contribute significantly to dust contamination problems in work areas.[17] Ambient dust sources, which contain approximately 20% crystalline silica, can be reduced by

surfacing frequently used haul roads (which has been done at this facility), planting vegetation, keeping bulk sand piles damp or covered (with shrouds or sealants), and wetting road surfaces (with water, salt water, or other suitable agents). Ambient dust levels were low during the study which could have been due to rain on the first day of the survey. But over prolonged dry spells, dust from roadways and the surrounding land could become an increasingly significant problem during normal traffic conditions and windy periods.

B. Recommendations Warranting Immediate Attention with Relatively Low Cost

1. A list of resource materials, and where they may be obtained, is presented in Appendix C. These materials should be obtained by the plant management and reviewed.

2. There are several areas of potential overexposure to silica dust in the dryer/loader operation. Observed respirator use by the dryer operator was good and the respirator program comprehensive. Respirators were not required for the loader operator. (Aspects of a respiratory program are discussed in the resource materials, given in Appendix C.) Respirator use should continue to be vigorously enforced for the dryer operator until silica dust exposure levels can be reduced to at least below the MSHA PEL or, preferably, below the NIOSH REL. Respirator use by maintenance personnel working on sand handling equipment in the area should also continue to be vigorously enforced.

3. Good work practices during sand loading operations should be developed for using the controlled loading spouts. When filling open-type trucks, it is important to keep the spout discharge near the top of the accumulating sand pile, retracting the head of the spout as the truck fills so as to minimize dust generation. When filling any vehicle having ribs, trucks or coffin-lid-type railroad cars, the sand should never be allowed to flow from a spout over a rib into the vehicle. For trucks with ribs, the controlled spout can be lowered between the ribs to maintain the spout near the top of the sand pile. If the spout cannot be lowered between or past the ribs, the ribs should be removed prior to loading. For coffin-lid cars, care should be taken to position the spout so as to avoid sand flowing over the rib. (Hatch-type hopper vehicles do not have cross members and do not present this problem.) When filling hopper-type trucks, the controlled spout head should be lowered as close to the hatch as possible, yet that flow of sand can still be seen so that the fill can be stopped before overflow occurs. Also, all hatches on hopper-type vehicles should be kept closed except the one being used.

4. Scheduled maintenance and repair of dust control systems and of the bulk material handling equipment would improve their overall effectiveness and reduce known dust sources. Since the structure housing most of this operation is fairly open, normal air currents may increase dust concentrations in nearby downwind work areas. The routine use of a small air velocity meter can be effective in

determining the status of ventilation systems such as the spout. Also, the use of direct-reading dust monitors can help locate major dust sources in need of control.

C. Recommendation Warranting Immediate Attention with Greater Cost Involved

1. The controlled spouts' exhaust ventilation rates are inadequate. The manufacturer of these spouts recommends an exhaust volume of 800 to 1,000 cfm for a sand loading capacity of 200 cfm. (Unimin's sand loading capacity is about 100 cfm.) The measured air volume of the controlled spout for truck filling was 400 cfm and 220 cfm for the railroad car loading spout. A new duct system connecting these units directly to the existing dust collector should be installed.

D. Recommendations Involving Larger Expense

1. A horizontal positioner added to the truck spout (that would travel in the direction along the length of the truck) would allow this spout to be more effectively used in filling rib-type trucks (except those with longitudinal ribs). This would permit the spout to be lowered between the ribs without moving the truck.

2. Replace the uncontrolled spouts with a controlled enclosed-type spout. From air samples and real-time measurements, a controlled spout could reduce dust emissions by about 90%. This reduction could be even greater when the exhaust volume of the spout is increased to the manufacturer's recommendation and good operating practices are used. Controlled loading spouts for enclosed railroad cars are available and could be adapted to this operation, as is shown in Figure 16.

3. As an alternative to 2, redesign the sand transport system to convey the sand directly from the dryer and screens to the hopper bins equipped with controlled spouts, and fill all vehicles from these spouts thus eliminating the uncontrolled spouts.

4. Another alternative to 2 or 3 would be the exhaust hood arrangement shown in Figure 17. This would require modifying work practices so that only two hatches are open during loading: the one being filled through and the one being exhausted from. An unventilated shroud or hood would be placed around the uncontrolled fill spout that will cover the open hatch used for loading. An exhaust hood would sit on a second open hatch of the railroad car and capture the dust at this point. The exhaust rate of the hood should be sufficient to develop 150 to 200 fpm capture velocity around the open hatch being filled through. [According to the guidelines in the ACGIH Industrial Ventilation Manual (excerpted in Appendix B), the capture velocity at the spout should be from 100 to 200 feet per minute when intermittently filling containers and the product is released at low velocity into moderately still air. However, since silica dust is considered to be toxic, production use is high, at times there are disturbing air currents, and the hood on the

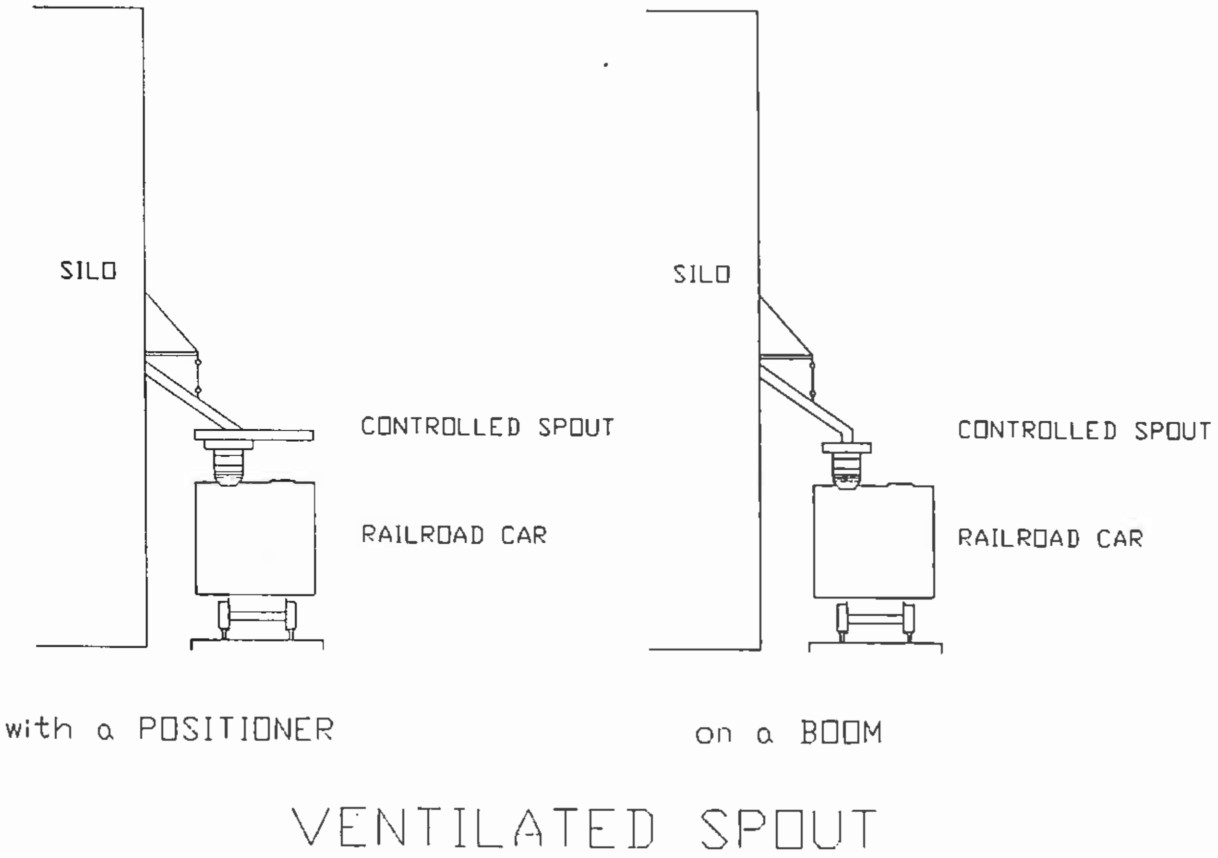
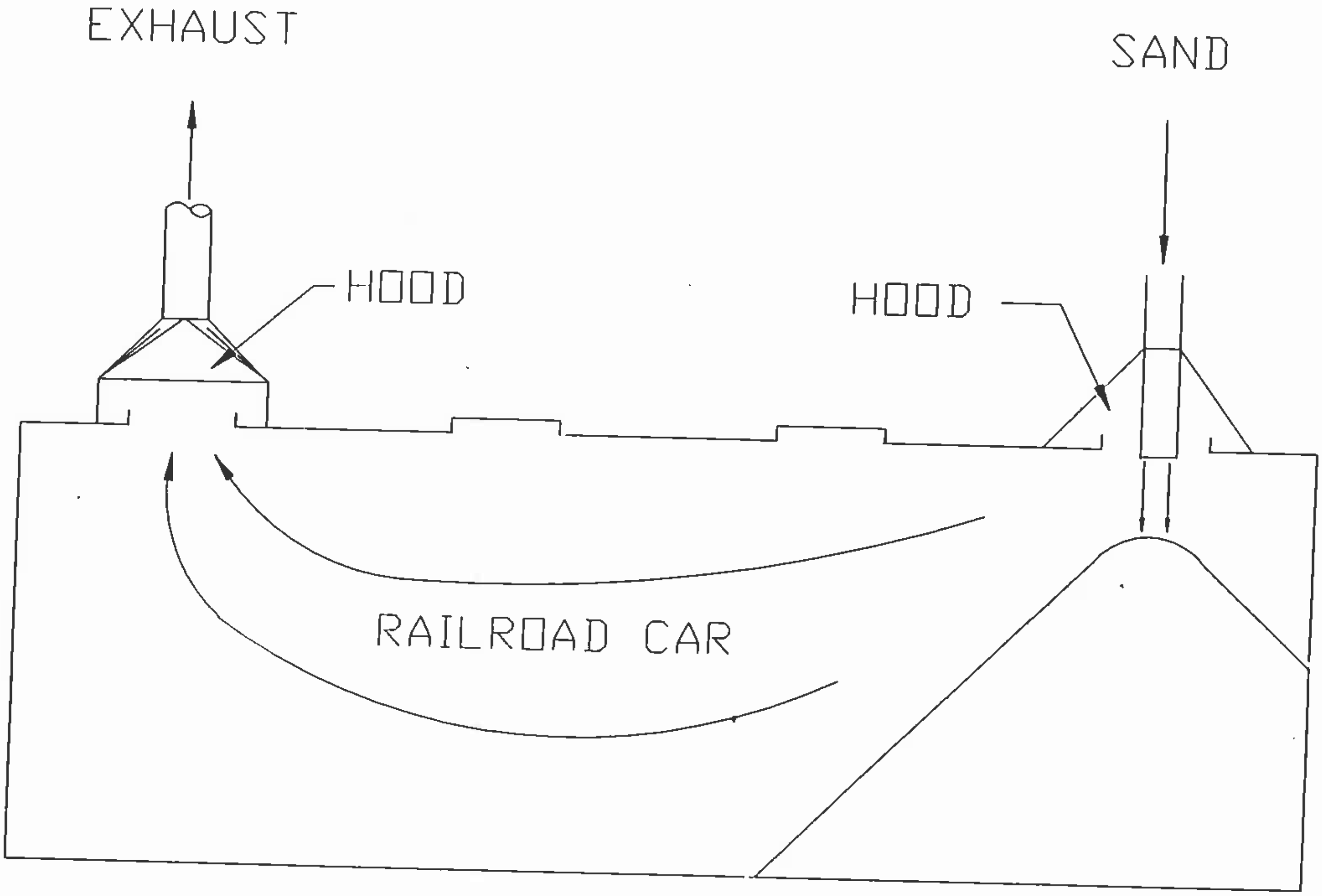


Figure 16. Controlled (Ventilated) Spouts From a Silo.



EXHAUST HOOD OVER OPEN HATCH

Figure 17

spout is small for local control only, the velocity should be nearer 200 fpm.]

The information in this report is intended for use by the Unimin Corporation to improve the working environment at the Dividing-Creek facility. These recommendations are believed to be both specific and feasible. These recommendations should also be implemented, as appropriate, at other facilities operated by Unimin, and by any other sand mining operations which may have problems similar to those observed in this study.

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APPENDIX A-1: ENVIRONMENTAL DATA – UNIMIN DIVIDING CREEK SAND MINE

DATE	SAMPLE		OP	JOB	JOB	PUMP	START	STOP	RUN	PUMP	FILTER	PUMP	ANALYSIS (mg)		%	OSHA	CONCENTRATION (mg/m3) RESPIRABLE		%	%	AVERAGE CONC. FOR JOB/LOCATION (mg/m3) RESPIRABLE	
	NO.	TYPE		CODE	TITLE/LOCATION	NO.	TIME	TIME	TIME (min)	FLOW (lpm)	NO	VOL (l)	MASS	QUARTZ	QTZ	PEL (mg/m3)	DUST	QUARTZ	OF PEL	OF REL	DUST	QUARTZ
13-Sep-88	3926	PERS.	5	10	FRONTEND LOADER	444	09:13 AM	03:36 PM	383	1.7	3926	651	0.09	< 0.015	< 17%	> 0.54	0.14	< 0.02	< 26%	< 40%	0.09	< 0.02
14-Sep-88	3911	PERS.	3	10	FRONTEND LOADER	410	12:20 AM	07:44 AM	444	1.7	3911	755	0.03	< 0.015	< 50%	> 0.19	0.04	< 0.02	< 21%	< 40%		
15-Sep-88	3939	PERS.	3	10	FRONTEND LOADER	445	12:06 AM	07:27 AM	441	1.7	3939	750	0.06	< 0.015	< 25%	> 0.37	0.08	< 0.02	< 22%	< 40%		
13-Sep-88	3924	PERS.	4	11	TRUCK TRLR LOADER	451	08:18 AM	03:57 PM	459	1.7	3924	780	0.19	< 0.015	< 8%	> 1.01	0.24	< 0.02	< 24%	< 40%	0.13	< 0.03
14-Sep-88	3910	PERS.	2	11	TRUCK TRLR LOADER	415	12:08 AM	07:52 AM	484	1.7	3910	789	0.04	(0.02)	(50%)	0.19	0.05	(0.03)	26%	60%		
15-Sep-88	3927	PERS.	1	11	TRUCK TRLR LOADER	429	12:02 AM	07:14 AM	432	1.7	3927	734	0.08	(0.02)	(25%)	0.37	0.11	(0.03)	30%	60%		
13-Sep-88	3925	PERS.	3	16	DRYER OPERATOR	413	08:13 AM	03:56 PM	463	1.7	3925	787	0.04	< 0.015	< 38%	> 0.25	0.05	< 0.02	< 20%	< 40%	0.10	0.04
14-Sep-88	3916	PERS.	1	16	DRYER OPERATOR	406	12:11 AM	07:50 AM	459	1.7	3916	780	0.07	0.03	43%	0.22	0.09	0.04	40%	80%		
15-Sep-88	3904	PERS.	2	16	DRYER OPERATOR	434	11:59 PM	07:11 AM	432	1.7	3904	734	0.11	0.04	36%	0.26	0.15	0.05	58%	100%		
																AVG:	0.11	< 0.03				
13-Sep-88	3921	AREA		21	TRK WGH ROOM	429	09:26 AM	03:54 PM	388	1.7	3921	660	0.02	< 0.015	< 75%	> 0.13	0.03	< 0.02	< 23%	< 40%	0.04	< 0.02
14-Sep-88	3915	AREA		21	TRK WGH ROOM	450	12:23 AM	08:01 AM	458	1.7	3915	779	0.05	< 0.015	< 30%	> 0.31	0.06	< 0.02	< 19%	< 40%		
15-Sep-88	3932	AREA		21	TRK WGH ROOM	451	12:11 AM	07:04 AM	413	1.7	3932	702	0.02	< 0.015	< 75%	> 0.13	0.03	< 0.02	< 23%	< 40%		
14-Sep-88	3908	AREA		22	RAILCAR WGH ROOM	409	12:23 AM	08:10 AM	467	1.7	3908	794	0.01	< 0.015	< 100%	> 0.10	0.01	< 0.02	< 10%	< 40%	0.01	< 0.02
15-Sep-88	3938	AREA		22	RAILCAR WGH ROOM	421	12:13 AM	07:08 AM	415	1.7	3938	705	0.01	< 0.015	< 100%	> 0.10	0.01	< 0.02	< 10%	< 40%		
15-Sep-88	3931	AREA		23	TRK LOADING SPOUT	444	12:45 AM	07:52 AM	427	1.7	3931	726	0.05	0.03	60%	0.16	0.07	0.04	43%	80%		
15-Sep-88	3907	AREA		24	RR LOADING SPOUT	426	11:53 PM	06:54 AM	421	1.7	3907	716	0.05	< 0.015	< 30%	> 0.31	0.07	< 0.02	< 22%	< 40%		
14-Sep-88	3914	AREA		25	RR LOADG NC SPT	422	12:01 AM	06:00 AM	359	1.7	3914	610	0.55	0.47	85%	0.11	0.90	0.77	787%	1540%		
13-Sep-88	3920	AREA		26	DRYER CONTRL ROOM	445	08:25 AM	03:59 PM	454	1.7	3920	772	0.06	< 0.015	< 25%	> 0.37	0.08	< 0.02	< 22%	< 40%	0.04	< 0.02
14-Sep-88	3912	AREA		26	DRYER CONTRL ROOM	439	12:15 AM	07:58 AM	463	1.7	3912	787	0.03	< 0.015	< 50%	> 0.19	0.04	< 0.02	< 21%	< 40%		
15-Sep-88	3933	AREA		26	DRYER CONTRL ROOM	413	12:07 AM	07:09 AM	422	1.7	3933	717	0.01	< 0.015	< 100%	> 0.10	0.01	< 0.02	< 10%	< 40%		
																AVG:	0.12	< 0.09				
13-Sep-88	3923	HI-VOL		33	TRK LOADING SPOUT	390943	09:00 AM	03:47 PM	407	9.98	3923	4062	0.27	0.08	22%	0.41	0.07	0.015	17%	30%	0.06	0.02
13-Sep-88	3906	HI-VOL		33	TRK LOADING SPOUT	390943	03:49 PM	12:37 AM	528	9.98	3906	5269	0.39	0.11	28%	0.33	0.07	0.021	21%	42%		
15-Sep-88	3943	HI-VOL		33	TRK LOADING SPOUT	390955	11:48 PM	06:50 AM	422	10	3943	4220	0.22	0.13	59%	0.16	0.05	0.031	31%	62%		
15-Sep-88	3936	HI-VOL		34	RR LOADING SPOUT	390943	11:52 PM	06:49 AM	417	9.98	3936	4162	0.19	< 0.015	< 8%	> 1.01	0.05	< 0.004	< 5%	< 7%		
13-Sep-88	3919	HI-VOL		37	SCREENS	390968	08:45 AM	03:41 PM	416	9.26	3919	3852	0.18	(0.02)	(11%)	0.76	0.05	(0.005)	7%	10%	0.08	< 0.04
14-Sep-88	3950	HI-VOL		37	SCREENS	390968	12:48 AM	07:41 AM	413	9.26	3950	3824	0.33	0.25	76%	0.13	0.09	0.065	70%	131%		
15-Sep-88	3930	HI-VOL		37	SCREENS	390968	12:08 AM	06:42 AM	394	9.26	3930	3648	0.33	0.18	55%	0.18	0.09	0.049	51%	99%		
13-Sep-88	3918	HI-VOL		38	WAREHOUSE AREA	880	09:12 AM	04:02 PM	410	9.56	3918	3920	0.17	< 0.015	< 9%	> 0.92	0.04	< 0.004	< 4%	< 8%	0.03	< 0.01
13-Sep-88	3905	HI-VOL		38	WAREHOUSE AREA	880	04:03 PM	12:32 AM	509	9.56	3905	4866	0.2	0.04	20%	0.45	0.04	0.008	9%	16%		
14-Sep-88	3944	HI-VOL		38	WAREHOUSE AREA	880	12:32 AM	08:04 AM	452	9.56	3944	4321	0.09	< 0.015	< 17%	> 0.54	0.02	< 0.003	< 4%	< 7%		
15-Sep-88	3942	HI-VOL		38	WAREHOUSE AREA	880	11:41 PM	06:38 AM	417	9.56	3942	3987	0.12	(0.02)	(17%)	0.54	0.03	(0.005)	6%	10%		
																AVG:	0.06	< 0.024				

LIMIT OF DETECTION = 0.015 MG (quartz)

NUMBERS IN () BELOW LOQ

BLANK CORRECTION +0.001 MG (MASS)

APPENDIX B - 1

Specific Operation

TABLE 4-1

RANGE OF CAPTURE VELOCITIES (7,24)

Condition of Dispersion of Contaminant	Examples	Capture Velocity, fpm
Released with practically no velocity into quiet air.	Evaporation from tanks; degreasing, etc.	50-100
Released at low velocity into moderately still air.	Spray booths; intermittent container filling; low speed conveyor transfers; welding; plating; pickling	100-200
Active generation into zone of rapid air motion	Spray painting in shallow booths; barrel filling; conveyor loading; crushers	200-500
Released at high initial velocity into zone of very rapid air motion.	Grinding; abrasive blasting, tumbling	500-2000

In each category above, a range of capture velocity is shown. The proper choice of values depends on several factors:

Lower End of Range	Upper End of Range
1. Room air currents minimal or favorable to capture.	1. Disturbing room air currents.
2. Contaminants of low toxicity or of nuisance value only.	2. Contaminants of high toxicity.
3. Intermittent, low production.	3. High production, heavy use.
4. Large hood—large air mass in motion.	4. Small hood—local control only.

Hood Design Procedure

Effective control of a contaminant producing process is brought about by first eliminating or minimizing all air motion about the process and then capturing the contaminated air by causing it to flow into the exhaust hood. Flow toward the suction opening must be sufficiently high to maintain the necessary capture velocity and to overcome opposing air currents.

Elimination of sources of air motion as a first step in hood design is an important factor in cutting down the required air volume and the corresponding power consumption. Important sources of air motion are:

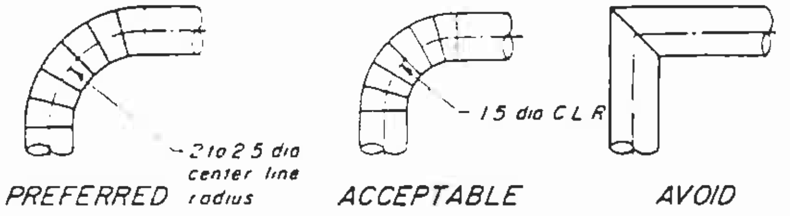
1. Thermal air currents, especially from hot processes or heat-generating operations.
2. Motion of machinery, as by a grinding wheel, belt conveyor, etc.
3. Material motion, as in dumping or container filling.
4. Movements of the operator.
5. Room air currents (which are usually taken at 50 fpm minimum and may be much higher).
6. Spot cooling and heating equipment.

The shape of the hood, its size, location and rate of air flow are important design considerations.

The hood should enclose the operation as much as possible. If enclosure is not practicable, the hood should be located as close as possible to the source and shaped to control the area of contamination.

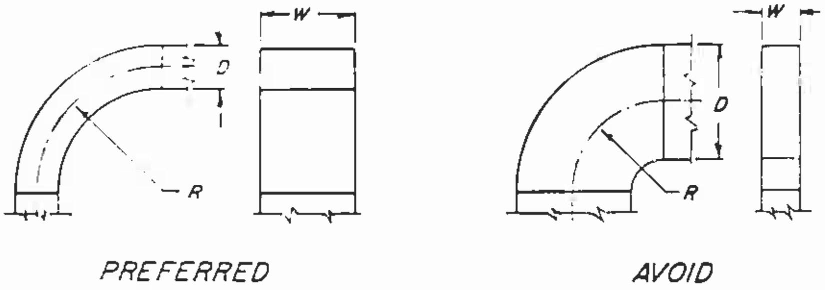
APPENDIX B - 2

Specific Operation



ELBOW RADIUS

Elbows should be 2 to 2.5 diameter centerline radius except where space does not permit. See Fig 6-11 for loss factor.



ASPECT RATIO $\left(\frac{W}{D}\right)$

Elbows should have $\left(\frac{W}{D}\right)$ *and* $\left(\frac{R}{D}\right)$ *equal to or greater than (1). See Fig. 6-11 for loss factor.*

Note Avoid mitre elbows. If necessary, use only with clean air and provide turning vanes. Consult mfg. for turning vane loss factor.

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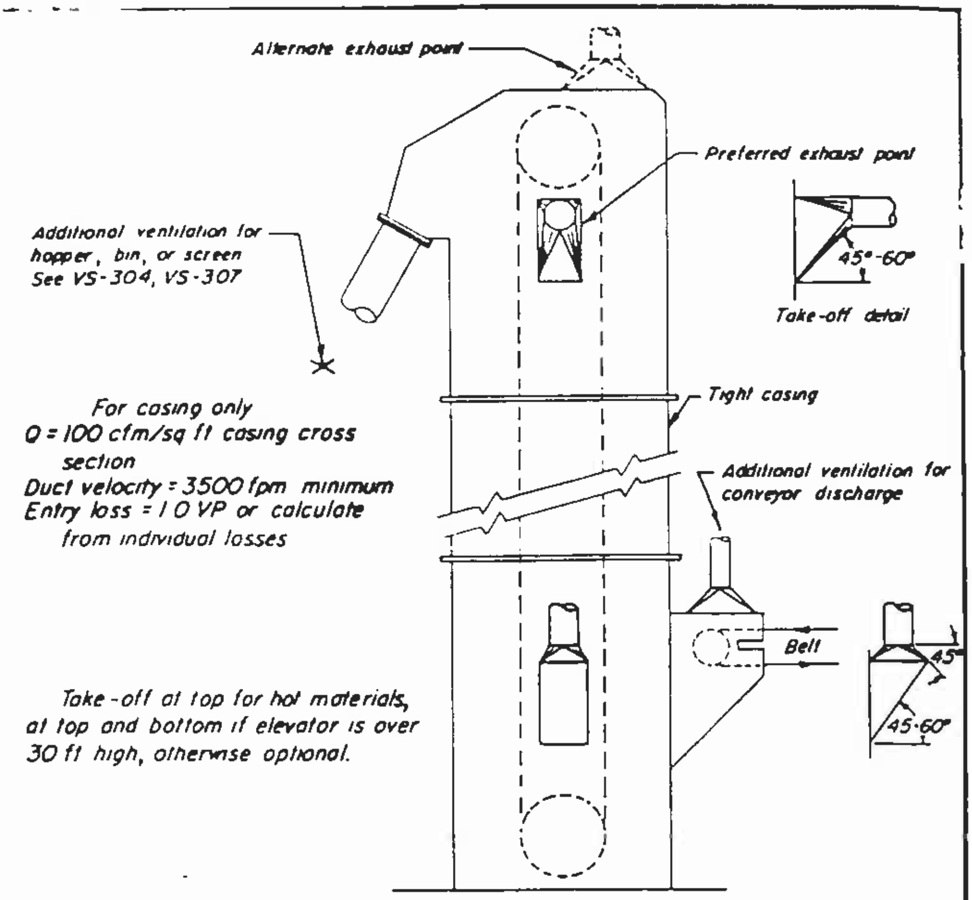
PRINCIPLES OF DUCT DESIGN
ELBOWS

DATE 1-86	Fig. 6-25

APPENDIX B - 3

Specific Operation



For casing only
Q = 100 cfm/sq ft casing cross section
Duct velocity = 3500 fpm minimum
Entry loss = 1.0 VP or calculate from individual losses

Take-off at top for hot materials, at top and bottom if elevator is over 30 ft high, otherwise optional.

Belt speed	Volume
Less than 200 fpm	— 350 cfm/ft of belt width. Not less than 150 cfm/ft of opening
Over 200 fpm	— 500 cfm/ft of belt width. Not less than 200 cfm/ft of opening

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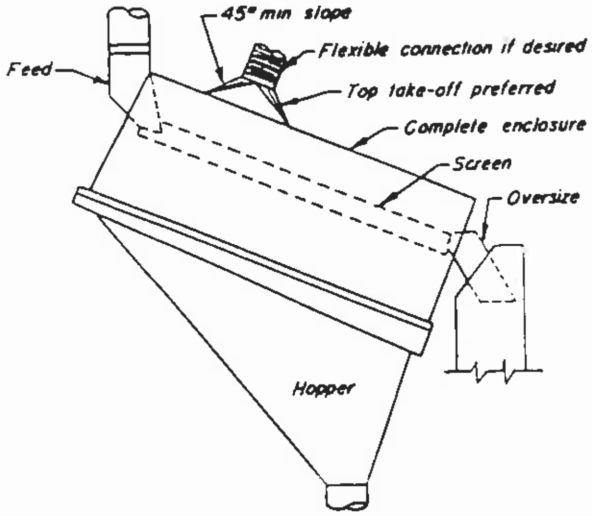
GOVERNMENTAL INDUSTRIAL HYGIENISTS

BUCKET ELEVATOR VENTILATION

DATE 1-66 VS-305

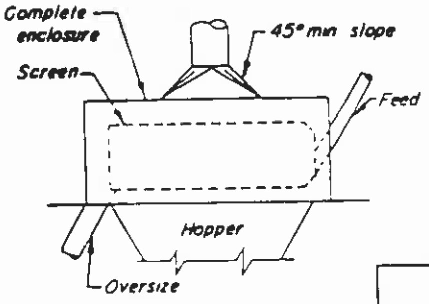
APPENDIX B - 4

Specific Operation



FLAT DECK SCREEN

Q = 200 cfm/sq ft through hood openings, but not less than 50 cfm/sq ft screen area. No increase for multiple decks
Duct velocity = 3500 fpm minimum
Entry loss = 0.50 VP



CYLINDRICAL SCREEN

Q = 100 cfm/sq ft circular cross section of screen; at least 400 cfm/sq ft of enclosure opening
Duct velocity = 3500 fpm minimum
Entry loss = 0.50 VP

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SCREENS

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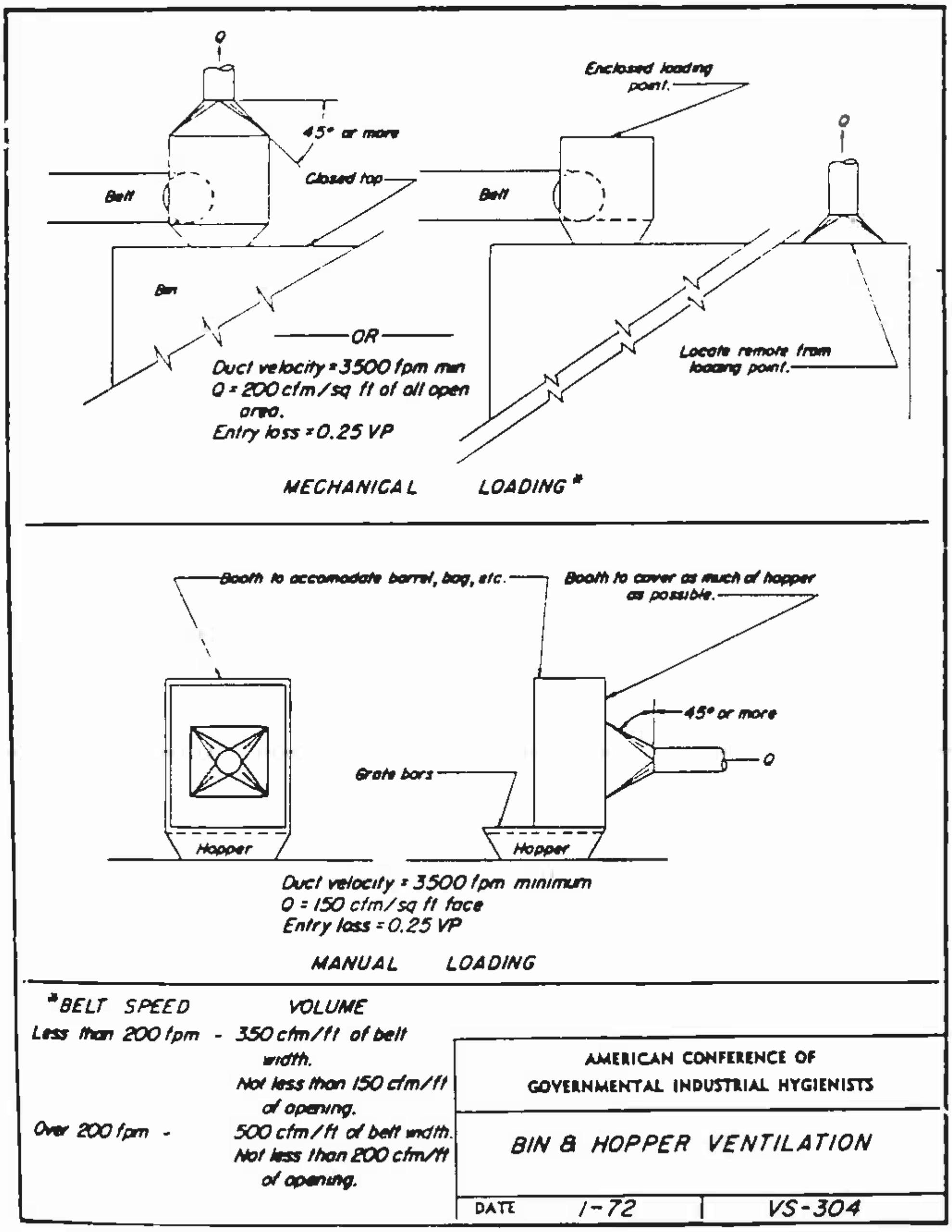
APPENDIX B - 5

Specific Operation



Duct velocity = 3500 fpm min
Q = 200 cfm/sq ft of all open area.
Entry loss = 0.25 VP

MECHANICAL LOADING *

Duct velocity = 3500 fpm minimum
Q = 150 cfm/sq ft face
Entry loss = 0.25 VP

MANUAL LOADING

*BELT SPEED	VOLUME
Less than 200 fpm -	350 cfm/ft of belt width. Not less than 150 cfm/ft of opening.
Over 200 fpm -	500 cfm/ft of belt width. Not less than 200 cfm/ft of opening.

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BIN & HOPPER VENTILATION

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APPENDIX C

Health and Safety Resource Publications

1. "Occupational Exposure to Crystalline Silica - Criteria for a Recommended Standard." U.S. Department of HEW, PHS, CDC, National Institute for Occupational Safety and Health, 1974. HEW Pub. No. (NIOSH) 75-120. National Technical Information Center (NTIS) No. PB 246-697/A07. Tel. (703) 487-4650.

2. "Silica Flour: Silicosis (Crystalline Silica)." NIOSH Current Intelligence Bulletin 36. June 1981. DHHS (NIOSH) Pub. No. 81-137, NTIS No. PB 83-101-758/A02. Ibid.

3. "Occupational Health Guidelines for Crystalline Silica." Sept. 1978. NIOSH/OSHA Occupational Health Guidelines for Chemical Hazards. U.S. Depts. HHS/DOL, Jan. 1981. DHHS (NIOSH) Pub. No. 81-123, NTIS No. PB 83-154-609/A99. Ibid.

4. "Threshold Limit Values and Biological Exposure Indices 1988-89." American Conference of Governmental Industrial Hygienists (ACGIH), 6500 Glenway, Bldg. D-7, Cincinnati, OH 45211. (513) 661-7881.

5. "Occupational Health Program for Exposure to Free Crystalline Silica." 1977. National Industrial Sand Association, 900 Spring Street, Silver Spring, MD 20910. (202) 587-1400.

6. "NIOSH Guide to Respiratory Protection." 1987. DHHS (NIOSH) Pub. No. 87-116. NIOSH Publication Dissemination, 4676 Columbia Parkway, Cincinnati, OH 45226-1998. (513) 533-8287.

7. General Industry Standards, Part 1910. OSHA 2206, Rev. March 8, 1983. USDOL/OSHA Sub Part I - Personal Protective Equipment, pg. 270-276; and Sub Part Z - Toxic and Hazardous Substances, pg. 598-604. NTIS. Ibid.

8. "Practices for Respiratory Protection." ANSI Z 88.2, 1980. American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018. (212) 354-3300.

9. "Key Elements of a Sound Respiratory Protection Program." Bulletin 1000-16. Mine Safety Appliances Company, 600 Penn Center Boulevard, Pittsburgh, PA 15235. (416) 967-3000.

10. "Industrial Ventilation - A Manual of Recommended Practice." 20th Ed. 1988. ACGIH. Ibid.

11. "Industrial Ventilation Workbook." 1988. D. Jeff Burton, DJBA Inc., P.O. Box 520545, Salt Lake City, UT 84152.

12. "An Evaluation of Control Technology for Bag Opening, Emptying, and Disposal. The Self-Contained Filter/Bag Dump Station - Manufactured by the Young Industries, Inc., Muncy, PA 17756" by William Heitbrink et al.

Nov. 1983. Report No. 114-19. NIOSH-DPSE, 4676 Columbia Parkway, Cincinnati, OH 45226-1998. (513) 841-4221.

13. "Work Practices Guide for Manual Lifting." NIOSH Technical Report. March 1981. DHHS (NIOSH) Pub. No. 81-122. NTIS No. PB 82-178-948/A09. Ibid.

14. "An Evaluation of the NIOSH Guidelines for Manual Lifting, with Special Reference to Horizontal Distances" by Arun Garg. AIHAJ. 50(3):157-164(1989).

15. "Analysis of Manual Lifting Tasks: A Qualitative Alternative to the NIOSH Work Practice Guide" by W. Monroe Keyserling. Ibid.

16. Dust Control Handbook" by V. Mody and R. Jakhete. (Pollution Technology Review, ISSN 0090-516X; No. 161.) Noyes Data Corporation, Mill Road, Park Ridge, NJ 07656.

17. OSHA Safety and Health Standards (29 CFR 1910) US Dept. of Labor, OSHA 2206 1910.1000; Air Contaminants, Permissible Exposure Limits, Table Z-3, p 2951, Rev. January 19, 1989.