SENTINEL EVENT NOTIFICATION SYSTEM FOR OCCUPATIONAL RISKS (SENSOR):

RECOMMENDATIONS FOR CONTROL OF SILICA EXPOSURE

AT

Woodbridge Sanitary Pottery Corporation
Woodbridge, New Jersey

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PLANT SURVEYED:	Woodbridge Sanitary Pottery Corporation 500 Green Street Woodbridge, New Jersey 07095 (201) 634-3950
SIC CODE:	3261 Vitreous China Plumbing Fixtures
SURVEY DATE:	June 6-9, 1988
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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 Woodbridge Sanitary Pottery Corporation, Woodbridge, New Jersey, as part of this effort. Environmental, engineering, and ergonometric evaluations were conducted in June 1988.

The environmental evaluations included the collection of ten bulk/material samples, which were analyzed for crystalline silica content; and 66 personal and area atmospheric samples, which were analyzed quantitatively for respirable crystalline silica dust and respirable dust. Respirable crystalline silica dust personal exposures averaged between 0.12 and 0.18 mg/m^3 for 43 collected samples. At least 50% of all the personal samples exceeded the NIOSH Recommended Exposure Limit (REL) of 0.05 mg/m^3 for crystalline silica; and at least 44% of the personal samples exceeded the OSHA Permissible Exposure Limit (PEL), which is based on the silica content of the respirable dust in the samples. Highest exposures were in the Slip House, where area concentrations averaged 0.38 mg/m^3 of silica dust. In the other three areas (casting, glaze spraying, and glaze preparation), highest personal exposures were found in the glaze spraying area, where at least 67% of the personal air samples exceeded the calculated OSHA PELs for respirable dust. In the glaze preparation area, at least 50% of the samples exceeded the PEL; and in the casting department, at least 26% of the measurements exceeded the PEL for respirable dust.

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

ABSTRACT

Excessive exposures to respirable silica dust and respirable dust were documented in this plant. Overexposures were most prevalent in the Slip House, Glaze Spraying, and Glaze Preparation areas. High risk of lost time injuries due to manual handling of heavy materials was also noted. Recommendations are presented to reduce these risks by modification of engineering controls, work practices, and workstations. These recommendations include the use of nonsilica mold release parting compounds; the strict enforcement of a comprehensive respiratory protection program; the minimization of dry sweeping; the cleaning of castings in the green phase rather than the white phase; and the reduction of compressive forces on workers' backs by modification of materials handling operations. These and other recommendations are contained in Section VI of this report.

Keywords: SIC 3621; Vitreous china plumbing fixtures; china bathroom fixtures; silica; respirable dust; vitreous china; pneumoconiosis; silicosis; manual materials handling (MMH).

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 (DPSE) 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 exist 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 at the Woodbridge Sanitary Pottery Corporation, Woodbridge, New Jersey, as a part of this federal-state effort. Since the NJDOH has shown the pottery industry to be a high silicosis risk industry, this plant study was initiated to demonstrate the feasibility of effective intervention in reducing the silicosis risk; to develop effective risk reduction programs for use in this and in similar type plants; and, thereby, to reduce the incidence of silicosis in this industry.

The specific 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.

During the course of this survey, a review of the Workers' Compensation Log for injuries, from May 1986 to November 1987, indicated that lost time injuries were a significant problem in this plant. These injuries were probably due to the manual lifting of heavy objects. Therefore, ergonometric evaluations, based on videotapes of operations taken during the survey, were conducted at several workstations to estimate lifting hazards in these operations. Recommendations to reduce these hazards were also developed, which are intended to reduce, thereby, the incidence of back and muscular injuries.

Plant Description

The Woodbridge Sanitary Pottery Corporation manufactures vitreous china products, such as lavatories and toilet bowls. The work force at this plant consists of approximately 150 employees, including 30 salaried and 120 hourly workers. The hourly employees work in the following departments:

Slip Preparation	3	Packaging	13
Casting	57	Shipping	3
Glazing	2	Refiring	5
Spraying	9	Maintenance	6
Kiln	10	Labor	9
Molding	3		

The plant capacity is approximately 9,500 product units per (5-day) week. (A product unit may be a toilet tank with a lid, a lavatory, or a toilet bowl.)

Vitreous china, a specialized type of ceramics, is made as follows: first, various amounts of raw materials are combined to form a clay slip. After the slip is cast, the casting is shaped, dried, glazed, and fired. The three main types of raw materials are clay (hydrated aluminum silicates), feldspar (alkaline aluminum silicates), and flint (crystalline silica). One or more glaze coats (containing crystalline silica) are sprayed onto the molded greenware prior to firing in a tunnel kiln. The operations, processes, and materials used to produce these products are shown in Figure 1.

All production work is carried out in one building (Figure 2). Fired, blemished products are repaired and refired in the new annex housing, the Refire Department. All production areas operate during one 8-hour shift per day, 5 days per week. The kiln is fired continuously, 24 hours per day, 7 days per week. Production areas having a potential for silica exposure include the Slip House, Cast Shop, Mold Shop, Spray Area, and the Kiln, Glaze, and Refire Departments.

Detailed descriptions of the operations, processes, and work procedures in the various departments are presented in Section V.

III. POTENTIAL HEALTH AND SAFETY HAZARDS AND EVALUATION CRITERIA

A. Crystalline Silica

1. Effects of Exposure

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), as well as 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 atmospheric or bulk material samples. In this study, only significant amounts of alpha quartz were determined to be present in any of the raw materials, final products, or 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:

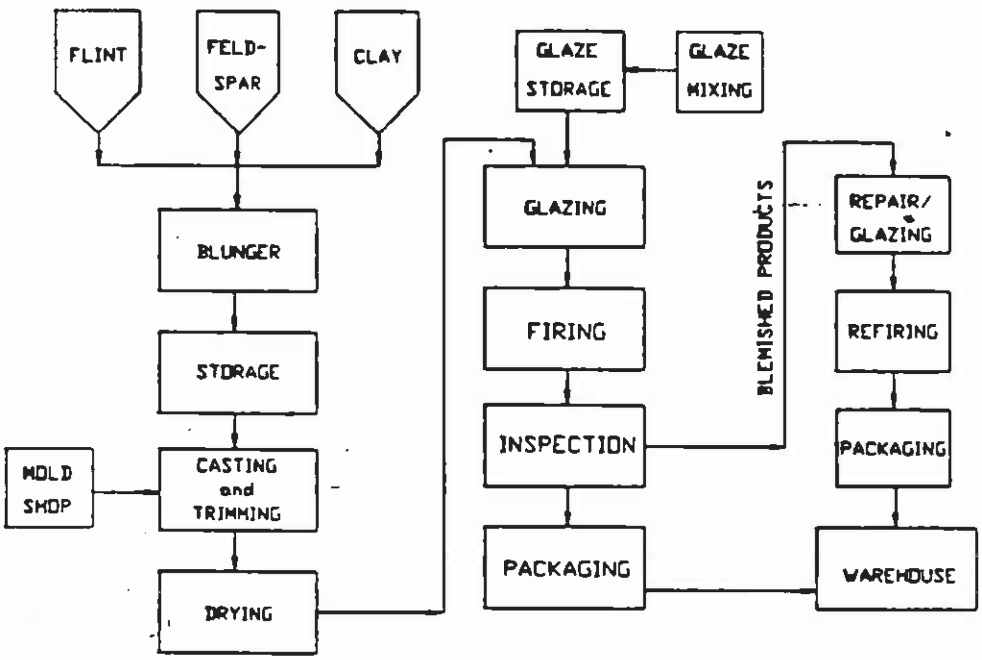

Figure 1. Woodbridge Sanitary Pottery Flow Chart.

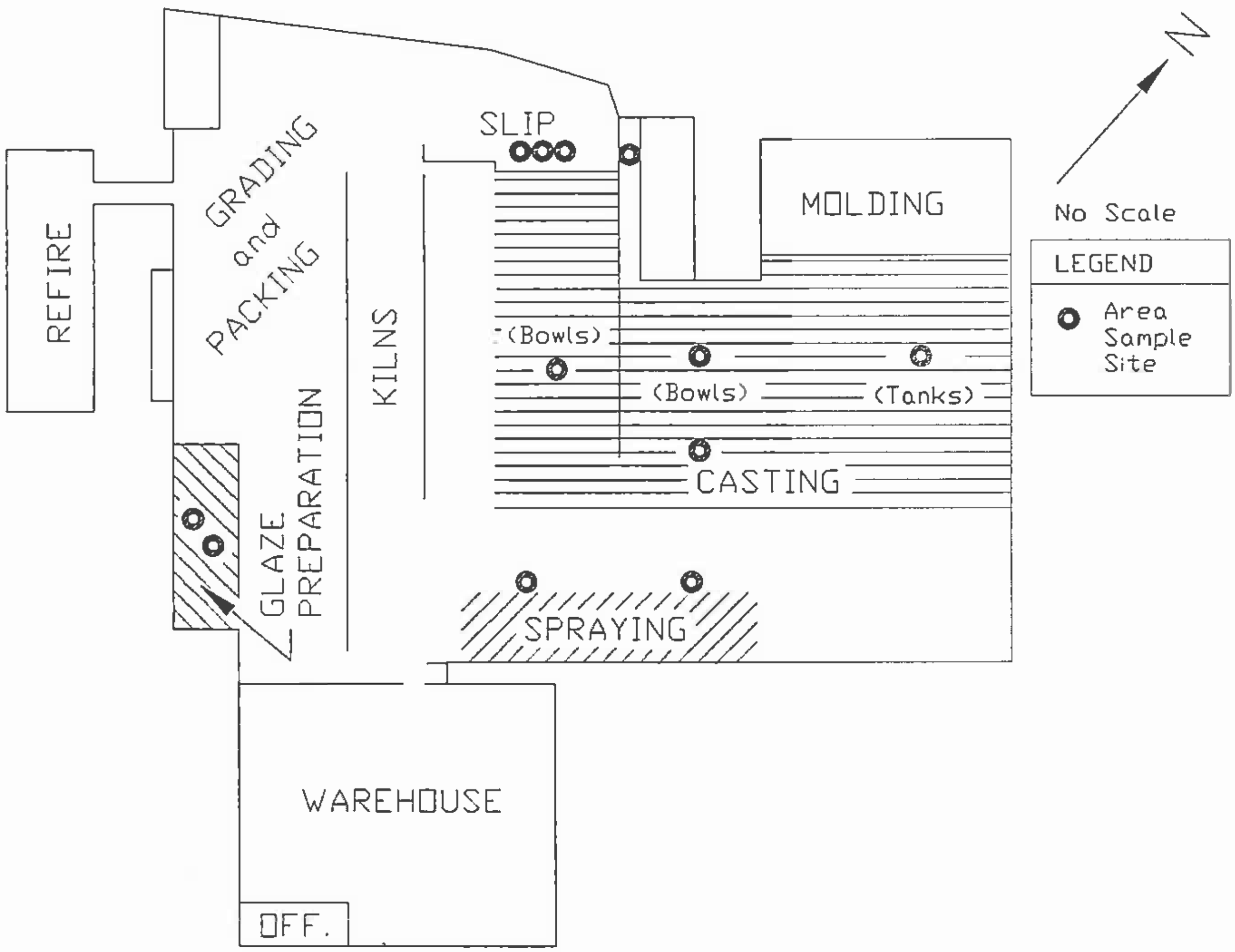

Figure 2. Floor Plan.

"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 silicas 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

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 work day, 40-hour work week.[8]

The OSHA Permissible Exposure Limit (PEL): At the time of this study, the OSHA PEL for respirable dust containing silica 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:

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

The OSHA PEL is now in a transitional period. The new PEL is 0.1 mg/m^3 as a TWA for an 8-hour day.[10] This new standard is effective on March 1, 1989, and enforceable on September 1, 1989. Unless otherwise noted, employers in general industry ,that is those covered by 29 CFR 1910, may use any combination of controls to achieve this limit for a period not to exceed 4 years from the effective date of this standard.

B. Hazards Involving Manual Materials Handling (MMH)

1. Effects of Exposure

As discussed earlier, the focus of this study is to recommend ways to prevent silicosis in this and other similar sanitary ware facilities. Since lifting also proved to be an issue of concern in this facility, information on the effects of exertion and on recommended standards for lifting is presented in this section. Overexertion in the workplace accounts for a large number of disability injuries. Most of these injuries involve the act of manually handling materials. There are both short- and long-term effects. Short-term effects include traumatic injury, such as lacerations, bruises or fractures, and fatigue. The effects of long-term exposures may include fatigue, postural stress, or musculoskeletal injury. However, the main long-term health effects concern injury to the spine. These problems are discussed in the NIOSH Technical Report "Work Practices Guide for Manual Lifting."[24]

2. Recommended Lifting Standards

The NIOSH "Work Practices Guide for Manual Lifting"[24] was used in the ergonometric evaluations performed on lifting tasks in the Glaze Spray and Cast Shop areas. Based on epidemiologic, psychophysical, and biomechanical studies, NIOSH has determined that workers may be at an increased risk for back injuries when the back compressive forces exceed 770 pounds for average-size males and 500 pounds for average-size females. These levels are called the <u>Action Limit</u>. When material handling tasks exceed these forces, NIOSH recommends that administrative controls be applied. The <u>Maximum Permissible Limit</u> is exceeded, however, when material handling tasks show back compressive forces greater than 1,430 pounds and 1,000 pounds for average males and females, respectively. In this case, NIOSH recommends engineering controls be implemented to decrease and prevent musculoskeletal injury.

Both the Action Limit and the Maximum Permissible Limit are based on the horizontal and vertical location of the load, the vertical travel distance of the load, and the average frequency of the lift.

The formulas are:

For the Action Limit:

$$AL\ (lb) = 90(6/H)(1-.01[V-30])(.7+3/D)(1-F/F_{max})$$

For the Maximum Permissible Limit:

$$MPL\ (lb) = 3\ (AL)$$

where H = horizontal location in inches forward of midpoint between ankles at origin of lift
V = vertical location at the origin of lift
D = vertical travel distance between origin and destination of lift
F = average frequency of lift (lifts/minute)
F_{max} = maximum frequency which can be sustained (23)

Note that frequency of lifting may become a factor if the worker is lifting heavy objects (i.e., 50-pound objects) more than once per minute.

IV. STUDY PLAN/METHODOLOGY

A. Quantitative Evaluations

NIOSH/NJDH investigators conducted environmental evaluations in several work areas of the plant including the Slip House, Casting Department, Glaze

Department, and Spray Department. Bulk samples of raw materials and slip mixtures were collected and analyzed for crystalline silica content.

Air exposures to dust were evaluated in several ways:

1. Personal samples, for the estimation of respirable 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, 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 3.5 to 8.5 hours depending on individual work schedules).

2. Area samples, collected in general work areas, were evaluated using the same type of preweighed PVC filters and portable, battery-operated pumps. All air samples were analyzed for respirable dust and crystalline silica dust content. Determinations of respirable dust content were made gravimetrically according to NIOSH Method 0600,[11] with a Limit of Detection (LOD)* considered to be 0.01 mg of respirable particulates per portion.

   Crystalline silica (alpha quartz and cristobalite) was analyzed by NIOSH Method 7500, using X-ray powder diffraction.[11] Most of the samples contained varying amounts of minerals, such as feldspars, clays, and other aluminosilicates, which interfere with the primary quartz region used in X-ray diffraction analysis for quartz. Since the analytical laboratory reported that these large interferences could not be removed (nor were the samples prewashed to remove interferences), the secondary quartz peaks were used to quantify the results of a majority of the samples. The LOD and the Limit of Quantification (LOQ)**, for the samples using the primary quartz peak, were stated to be 0.015 mg and 0.03 mg per portion, respectively; whereas, for those samples using the secondary peak, the LOD and LOQ were stated to be 0.08 mg and 0.15 mg per portion, respectively. Many of the samples contained less than the LOD for silica, 0.08 mg per sample.

3. Real-time sampling was performed in several areas. The techniques for this have been described in the literature by NIOSH researchers.[13]

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* The Limit of Detection (LOD) is defined as the smallest amount of analyte which can be distinguished from background.[11]

** The Limit of Quantitation (LOQ) is defined as the mass of analyte equal to ten 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.[11]

The instrument used to measure the exposures 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 silica and other dusts. For these reasons, concentrations are reported as relative exposures (rather than absolute levels), which resulted in comparisons only between similar operations and in the identification of a profile of concentrations over the cycle of a given operation. The HAM's analog output was connected to a data logger, called the Rustrak Ranger, manufactured by Gulton, Inc., East Greenwich, Rhode Island. When data collection was completed, the data logger was downloaded to a portable computer, Compaq Portable III, manufactured by Compaq Computer Corporation (Houston, Texas), for analysis. As the real-time data were being collected, the operation was simultaneously videotaped, and the clock on the video camera, Panasonic Model WV-3245, manufactured by Panasonic Industrial Company (Secaucus, New Jersey), was synchronized with the data logger. This allowed the recorded activities to be matched with the exposure data, so that the work practices contributing to increased exposures could be determined.

The real-time sampling was done at several areas to determine not only activities causing exposures, but also the effectiveness of some of the controls. These areas included the bowl casting area, where the cleaning of green and white castings were compared; and the glaze preparation area, where the effectiveness of a charged fogger in reducing dust levels was evaluated.

4. Ventilation rates and airflow pattern evaluations were made to determine the effectiveness of locally exhausted spray booths. Velocity measurements were made with an Air Velocity Meter, Model 1650, manufactured by TSI, Inc., St. Paul, Minnesota. Additionally, airflow patterns were evaluated using smoke tubes, manufactured by the National Draeger Corporation, Pittsburgh, Pennsylvania.

B. Evaluations of Lifting Stress

Ergonometric evaluation of videotaped operations was made to help recommend improved work practices and workstation designs for reduced biomechanical stress during job performance operations.

C. Observational Evaluations

Other control measures, such as the medical monitoring program, 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 Manager of Industrial Relations and Safety Coordination and with the Plant Engineer.

V. RESULTS AND DISCUSSION

A. Environmental Evaluations

1. Material Sample Analyses

Quantitative analyses of bulk samples, collected at the time of this survey, indicated that the crystalline silica content of raw materials and mixes ranged from nondetectable to 98%, as shown in Table I. The major materials used in the main working area (the cast shop) are clay slip and glaze. These materials contain approximately 15 to 25% crystalline silica. These compositions were substantiated by analyses of airborne area samples (approximately 21% silica) and personal samples (approximately 15% silica) in the casting area.

2. Air Sample Analyses

All of the collected samples contained quantifiable masses of respirable dust; that is, more than the analytical Limit of Quantitation (LOQ) of 0.01 milligrams (mg) per sample. However, since most of the collected samples contained minerals such as clay and feldspar that interfered with the primary quartz region used in X-ray diffraction analysis for quartz, it was necessary to use the secondary quartz peaks to quantify many of the samples for crystalline silica (quartz) content. The Limit of Detection (LOD) of crystalline silica for these samples is around 0.08 mg per sample, using the secondary peak; and around 0.015 mg per sample using the primary peak.

Five of the air samples contained trace quantities of cristobalite, between the LOD (0.015 mg) and the LOQ (0.03 mg) per sample.

a. Slip House

Activities in the slip house (Figure 3) are a major source of silica emissions. In this area, raw materials, including flint powder (98% crystalline silica) and feldspar (approximately 15% crystalline silica), are received in bulk shipments weekly, and pneumatically loaded into adjoining silos.[17] Two types of clay containing 5 to 30% crystalline silica are received in dry bulk or slurry shipments. Other production materials used in the plant contain less than 1% silica, as shown in Table I.

At the time of this study, these powders were transferred manually from the silos to the blungers (slurry mixing tanks) by means of a front end skip loader (Figures 4 and 5). After the powders, slurries, and recycled slip are mixed in a blunger, the slip is pumped through pipes for use in the cast shop. Planned construction modifications for this area include the replacement of the manual transfer of powders by a new automated batching system, such as the one shown in Figure 6 and Appendix D.

Table I

Crystalline Silica (Quartz) Content of Bulk Samples[a]

Material	Crystalline Silica[a] (quartz) %
A. Slip House	
1) Flint	98
2) Feldspar	15
B. Casting Area	
1) Parting Compound-Tank Area	25
2) Dried Clay Slip	20
C. Glaze Mix Area	
1) Silcosil®	55
2) Feldspar NK4	7.6
3) Whiting ($CaCo_3$)	n.d.[b]
4) Pyrax® H.S.	66
5) China Clay (F.C.)	n.d.[b]
6) TDM-Talc	1.6
Average Silica Content of Glaze Mix (calculated)	22.7

a All samples contained no detectable cristobalite (<3.8%).

b n.d. = None Detected (<0.75%)

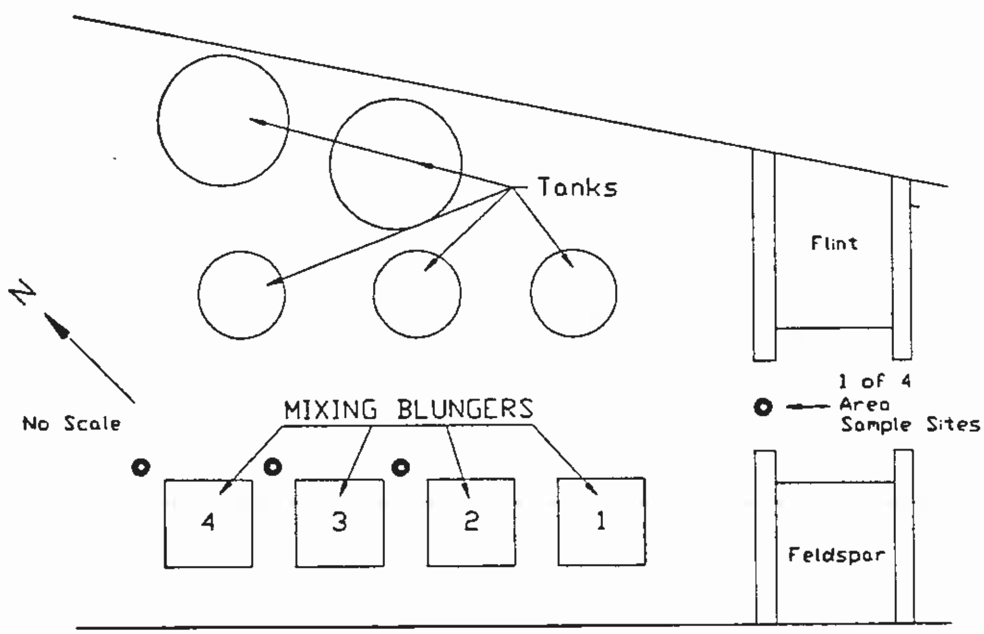

Figure 3. Slip House.

Figure 4. Slip House - Filling Skip Loader.

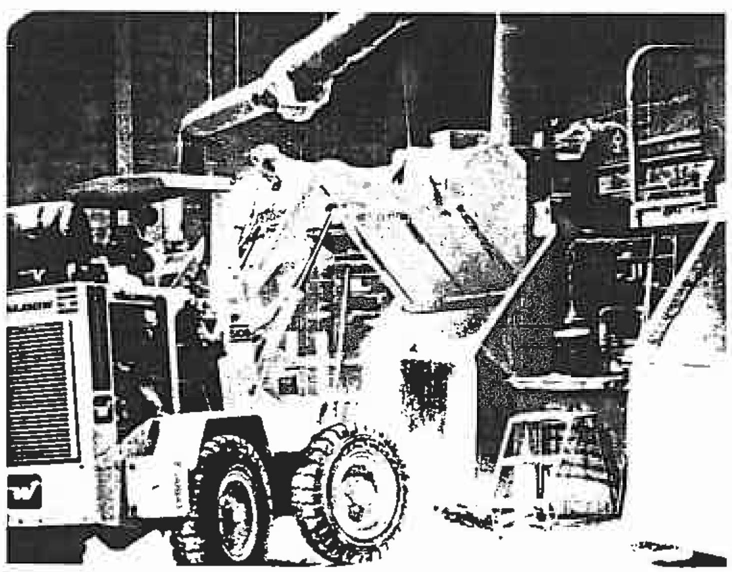

Figure 5. Slip House - Filling Blunger.

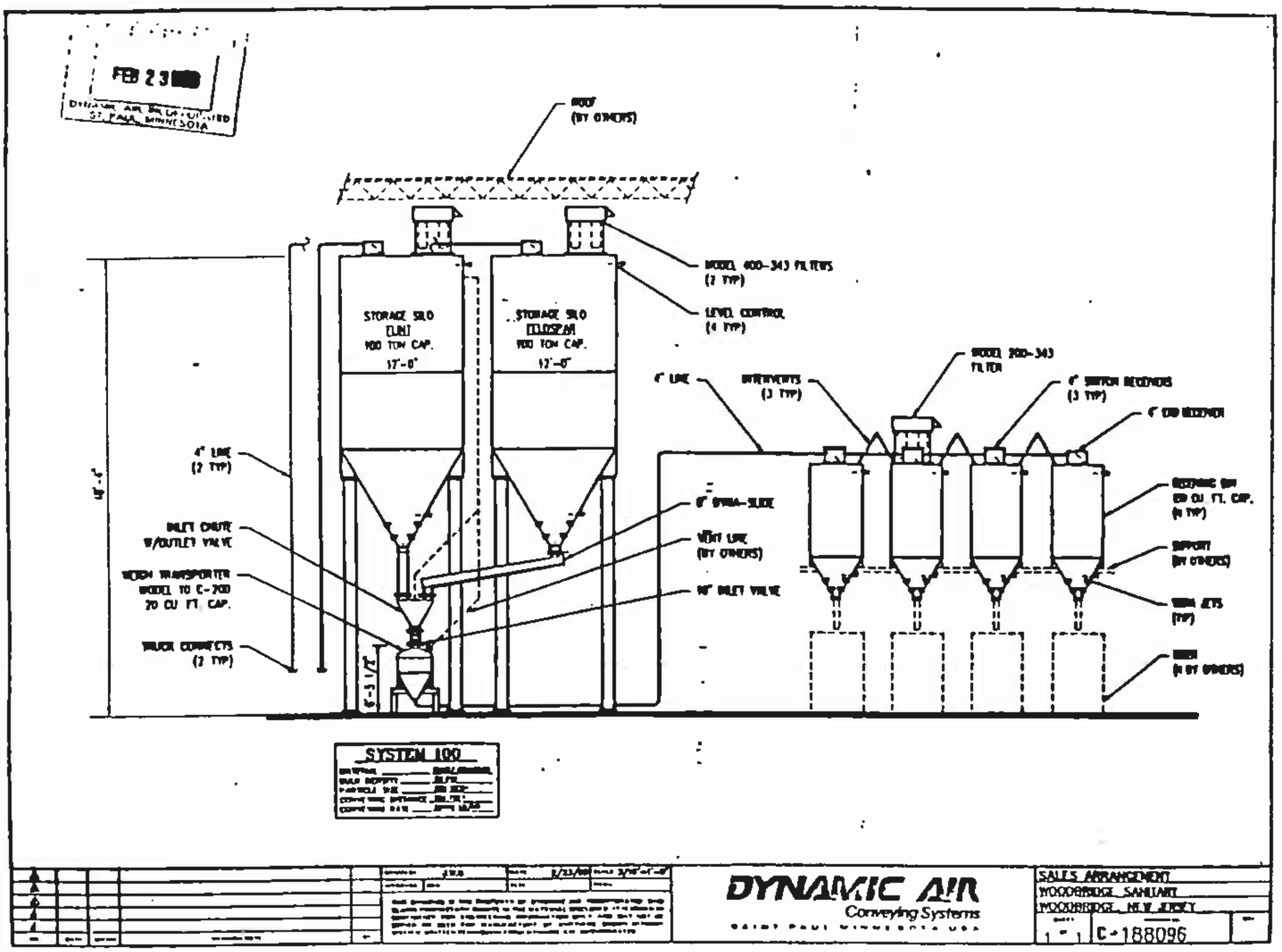

Figure 6. Dynamic Air Conveying Systems.

(1) Area Samples

Area samples were collected in the slip house near the storage bins and mix tanks (blungers), numbers 3 and 4 as shown in Table II and Figure 3. The silica dust concentration of six area samples averaged 0.38 mg/m^3 (range 0.06 to 1.16 mg/m^3). The silica content of the respirable dust samples averaged approximately 33% (range 20 to 43%).

Thus, these levels are from approximately 200 to 300% above the OSHA PEL's. These results are consistent with the personal exposure levels found by Clayton Environmental Consultants in their survey of November 1987, when silica concentrations ranged from 0.20 to 0.55 mg/m^3, and respirable dust concentrations ranged from 1 to 2 mg/m^3.[14]

The new system, proposed by Dynamic Air Conveying Systems, will be closed to minimize atmospheric dust dispersion. It will be designed so that the filling rate capacity of the storage silo will easily accommodate the truck's unloading capability. Thus, dust generation during silo loading should be substantially reduced. A programmable logic controller (PLC) will then automatically weigh and pneumatically convey both materials to four receiving bins above the blungers.

b. Cast Shop

The cast shop (Figure 7) consists of approximately 50 workstations with one worker per station. Each caster starts the shift by pouring the slip through a hose into several rows of plaster molds, which had been set up the previous day. Each worker's production quota may vary, depending on his negotiated work schedule and the type of fixture being cast, e.g., tanks - 80 per day, lavatories - 52 per day, and bowls - 24 to 32 per day. After casting, the slip is allowed to harden long enough (typically an hour or more) for the molds to be removed (Figure 8). The pieces are dried for several hours (or 1 or 2 days); initially smoothed and trimmed using an assortment of hand tools (minor repairs and removal of large mold marks); and dried further for 1 to 2 days. Then the pieces undergo final smoothing and finishing; are loaded onto carts; and allowed additional drying time in the casting area prior to being taken to the glazing department for subsequent glazing and firing. After the molds are removed, they are dusted with a parting compound in preparation for the next day's work. This parting compound is made from reclaimed glaze overspray, which contains about 20 to 25% crystalline silica. The manual operation of dusting molds (where no dust control exists) causes a visible cloud in the casting area (Figure 9). Prior to firing, the castings have to dry for several days to reduce the water content to a relatively low level. Limitations in plant size dictate that the castings are stored on carts in and around the casting area while they are drying. The entire casting area may, therefore, be

Table II

Slip House - Respirable Dust and Respirable Silica Dust Concentrations

Location	No. of Samples n	Resp. Dust (av.[a]) mg/m^3	Silica Dust (av.[a]) mg/m^3	Samples >PEL[b] %	Samples >REL[c] %
		Area Samples			
1. Mix Tanks 3-4	2	2.00	0.75	100	100
2. Mix Tank 3	2	0.66	0.14	50	100
3. Between Bins	1	1.27	0.39	100	100
4. Mix Tank 4	1	0.27	0.12	100	100
Average in Slip House	6	1.14	0.38	83	100

a Arithmetic Average

b PEL = OSHA Permissible Exposure Limit for Respirable Dust
= $10/(\% \ SiO_2 + 2)\ mg/m^3$.

c REL = NIOSH Recommended Exposure Limit for Respirable Silica Dust
= $0.05\ mg/m^3$.

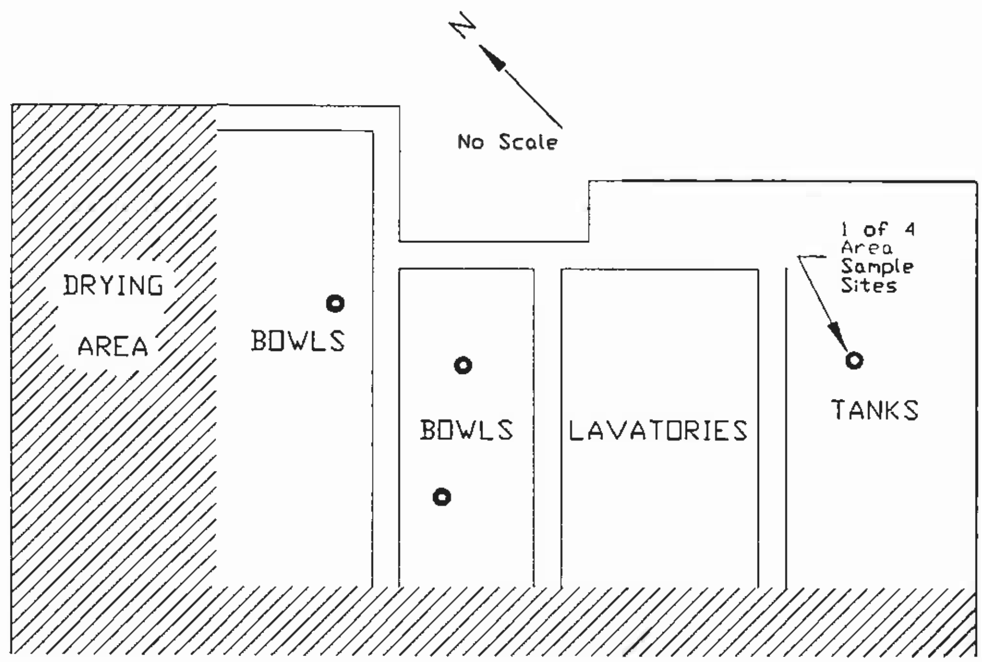

Figure 7. Cast Shop.

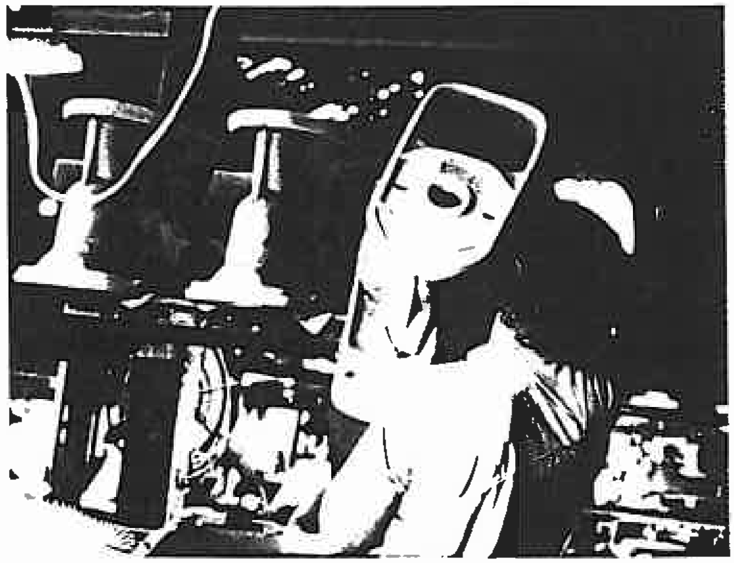

Figure 8. Cast Shop - Removing Molds.

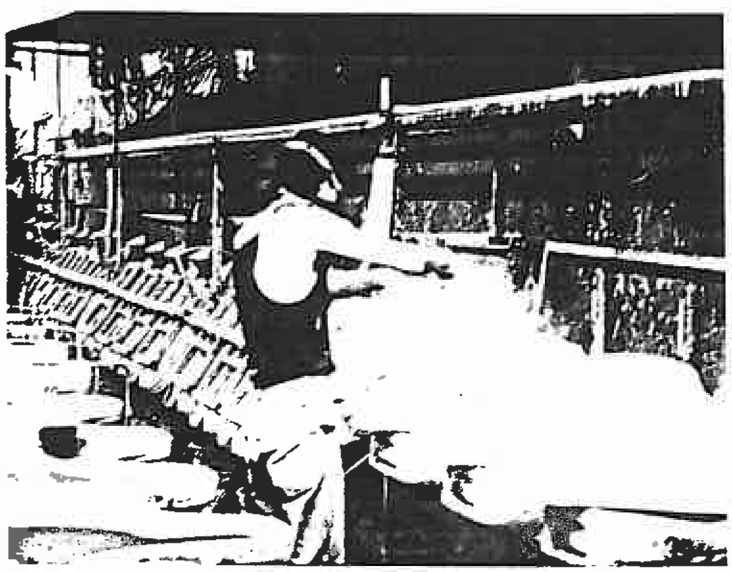

Figure 9. Cast Shop - Dusting Molds.

considered to be a large drying area, prior to firing in the kilns. Particularly at night, waste heat from the kilns is directed to this area. In addition to drying greenware, dust and pieces of scrap clay on the floor become thoroughly dry, presenting an opportunity for reentrainment into the air and adding appreciably to the likelihood of a high background dust level.

(1) Area Samples

Table III contains the results of seven area samples, which were collected at four locations in the tank/bowl/lavatory casting area. The silica content of these samples was quite variable, ranging from 7 to 23%, with an average of approximately 16%. The average dust concentrations in this area were 0.34 mg/m^3 of respirable dust and <0.10 mg/m^3 of silica dust. Since the average silica content of these area air samples was 16%, the average calculated air concentration of silica dust was 0.054 mg/m^3. Two of the seven samples contained detectable quantities of silica, but were below the REL for silica dust.

(2) Personal Samples

As shown in Table III, 19 personal samples were collected on ten different workers involved in casting tanks, bowls, and lavatories. The range of silica content of these personal samples was from 8 to 28%, with an average content of 16%. The average exposure in this area was 0.71 mg/m^3 of respirable dust, which contained an average of <0.13 mg/m^3 of silica dust. Detectable levels of silica were found in 7 of the 19 samples. It is estimated that at least 26% (5) of the exposures exceeded the PEL and at least 37% (7) exceeded the REL of 0.05 mg/m^3 for silica dust.

(3) Work Practices

Two work practices were evaluated in this department to determine their effects on atmospheric dust exposure levels.

<u>Dusting of Molds and Cleaning of Castings</u>

The first of these work practices was the dusting of molds using dried glaze material as the mold release parting compound; and the cleaning of the removed castings. The glaze material contained approximately 20% crystalline silica. Personal samples were collected on six workers in the tank and bowl casting areas on two successive days. On the first day, several of the six workers dusted/cleaned the molds and castings normally, with dried glaze material, while the others did not. On the second day, the workers reversed their procedure of dusting/cleaning or not dusting/cleaning. The workers who did not dust or clean stayed in the work area and

Table III

Casting Department - Respirable Dust and Respirable Silica Dust Concentrations.

A. Area Samples

Dust Location/Operation	No. of Samples n	Resp. Dust conc.(av.)[a] mg/m^3	Silica Dust conc.(av.)[a] mg/m^3	Samples[d] >PEL[b] %	Samples[d] >REL[c] %
1. Bowl/Tank Casting	7	0.34	<0.10	0 to 86	0 to 86

B. Personal Samples

Location/Operation	No. of Samples n	Resp. Dust conc.(av.)[a] mg/m^3	Silica Dust conc.(av.)[a] mg/m^3	Samples[d] >PEL[b] %	Samples[d] >REL[c] %
1. Tank Casting	5	0.74	<0.12	20 to 80	40 to 100
2. Bowl Casting	13	0.71	<0.13	31 to 92	38 to 100
3. Lavatory Casting	1	0.23	<0.18	0 to 100	0 to 100
Average in Casting Area	19	0.71	<0.13	26 to 89	37 to 100

[a] Arithmetic Average

[b] PEL = OSHA Permissible Exposure Limit for Respirable Dust
$= 10/(\% \ SiO_2 + 2)\ mg/m^3$

[c] REL = NIOSH Recommended Exposure Limit for Respirable Silica Dust
$= 0.05\ mg/m^3$

[d] Lower percentage based on assumption nondetectable (ND) level of silica in samples = 0 mg; higher percentage based on assumption ND level of silica in samples = 0.08 mg, the Limit of Detection.

performed other tasks, such as lifting and filling the plaster molds. The results of this work are shown in Table IV.

Since the mass of crystalline silica on 12 of the 18 personal samples was below the limit of detection (0.08 mg per sample), the effect of dusting/cleaning on exposure levels was based only on the respirable dust analyses. The average exposure for the workers who included dusting/cleaning was approximately 1.19 mg/m^3; whereas, the average exposure for workers who did not dust/clean was approximately 0.58 mg/m^3. The exposures for the other workers are judged to be mainly from background, since their respirable dust levels were similar to the background levels shown on Table III. Thus, the procedure of dusting/cleaning molds and castings with the dried glaze material approximately doubled the exposure level as shown in Table IV. This increase in exposure was significant at the .02 level of confidence using a paired t-test.

Further analysis of these exposure levels indicates that during dusting/cleaning all six of the personal exposure levels exceeded the OSHA PEL for respirable dust; whereas, during nondusting/cleaning, only two of the six exceeded the PEL. These operations not only increased the personal exposures to the mold/casting operator, but also may have contributed significantly to the general background level of dust, since the dust that was generated could have been reentrained by air currents, etc.

Thus, dusting with dried glaze overspray from the bag house, which contains approximately 20% crystalline silica, may be a major potential source of silica dust exposure. At present, respiratory protection is needed, particularly during these operations.

<u>Casting/Cleaning Procedures on White or Green Castings</u>

Since the castings were done in two-piece plaster molds, some finishing was required on each piece to remove mold marks and to leave a smooth finish prior to glaze application. This finishing was done with hand-held scrapers. The pieces had to dry for at least a day before this finishing could be done. Scraping at this point required a lighter touch, since the casting was softer; but it did not seem to be as dusty, since the casting was less dry. Most workers finished the pieces the next day, but some preferred to let the castings set for another day before finishing.

The Hand-held Monitor (HAM) and the video camera were used to provide real-time exposure data to evaluate the casting cleaning operation in the bowl casting area. Here, the worker cleaned four "green" castings (castings made the previous day)

Table IV

Comparison of Respirable Dust Exposures With and Without Mold Dusting and Cleaning of Castings in the Bowl/Tank Casting Area.

Worker	Location/Operation	Respirable Dust Concentration mg/m^3		Reduction
		Normal Work Procedure	Not Dusting and Cleaning	Reduction %
A-1	Tank Casting	1.319	0.622	53
A-3	Tank Casting	1.859	0.534	71
A-5	Bowl Casting	1.053	0.266	75
A-6	Bowl Casting	1.286	0.974	24
A-8	Bowl Casting	0.859	0.529	38
A-9	Bowl Casting	0.790	0.558	29
	AVERAGE[a]	1.194	0.581[b]	48[b]

[a] Arithmetic average

[b] Significant at the .02 level, using the Student paired t-test.[15]

and four "white" castings (castings that had dried for two or more days). The experiment was designed to determine if the moisture in the casting affected the workers' exposures. At the same time, the effects of the different work activities were also evaluated. The worker cycle for cleaning a casting began by placing the casting on a pedestal. The rough edges and mold parting lines were removed by scraping the casting with a metal blade. The casting was dusted off using a brush (which produced a visual cloud of dust) and was then wiped off with a wet sponge to smooth the casting. The casting was turned over and the process repeated to clean the other side. When the cleaning was finished, the casting was placed on a rack and another casting was retrieved for cleaning. For analysis of the data, the cleaning operation was broken down into four basic functions: scraping the casting; wiping the casting with a wet sponge; brushing the dust from the casting; and carrying the castings to and from the racks. Relative exposure levels for each casting type and activity are shown in Figure 10 and Table V.

These results showed that cleaning the white castings resulted in exposures which were 4.5 times higher than the exposures during the cleaning of green castings. Brushing the castings resulted in higher (than background) exposures for the white castings, but not for the green castings. Here, the dust was displaced from the casting, causing it to become airborne. In this case, it is thought that the dust on the green castings does not become airborne as readily, because of the additional water in the casting. With the white casting, the dust becomes airborne more easily. The wiping of the casting with the sponge also seemed to result in increased exposures for both the white and the green castings, possibly because the thin layer of dust left on the casting was displaced. However, it is difficult to tell the exact contribution of specific work procedures, since the dust cloud that was evolved by the brushing was observed to hang around the worker's breathing zone for some time.

c. Glaze Spray Department

The dried, hand-finished pieces are hand carted from the Casting Department to the Spray Department, where 9 to 12 employees are involved in piece inspection and glaze spraying. One or more coats of glaze (depending on the type of fixture) are applied in the ventilated spray booths by means of a compressed-air spray system.

As shown in Figure 11, area and personal atmospheric samples were collected at two area locations and on nine operators in this area. The local hood exhaust ventilation control systems were also evaluated to determine their effectiveness.

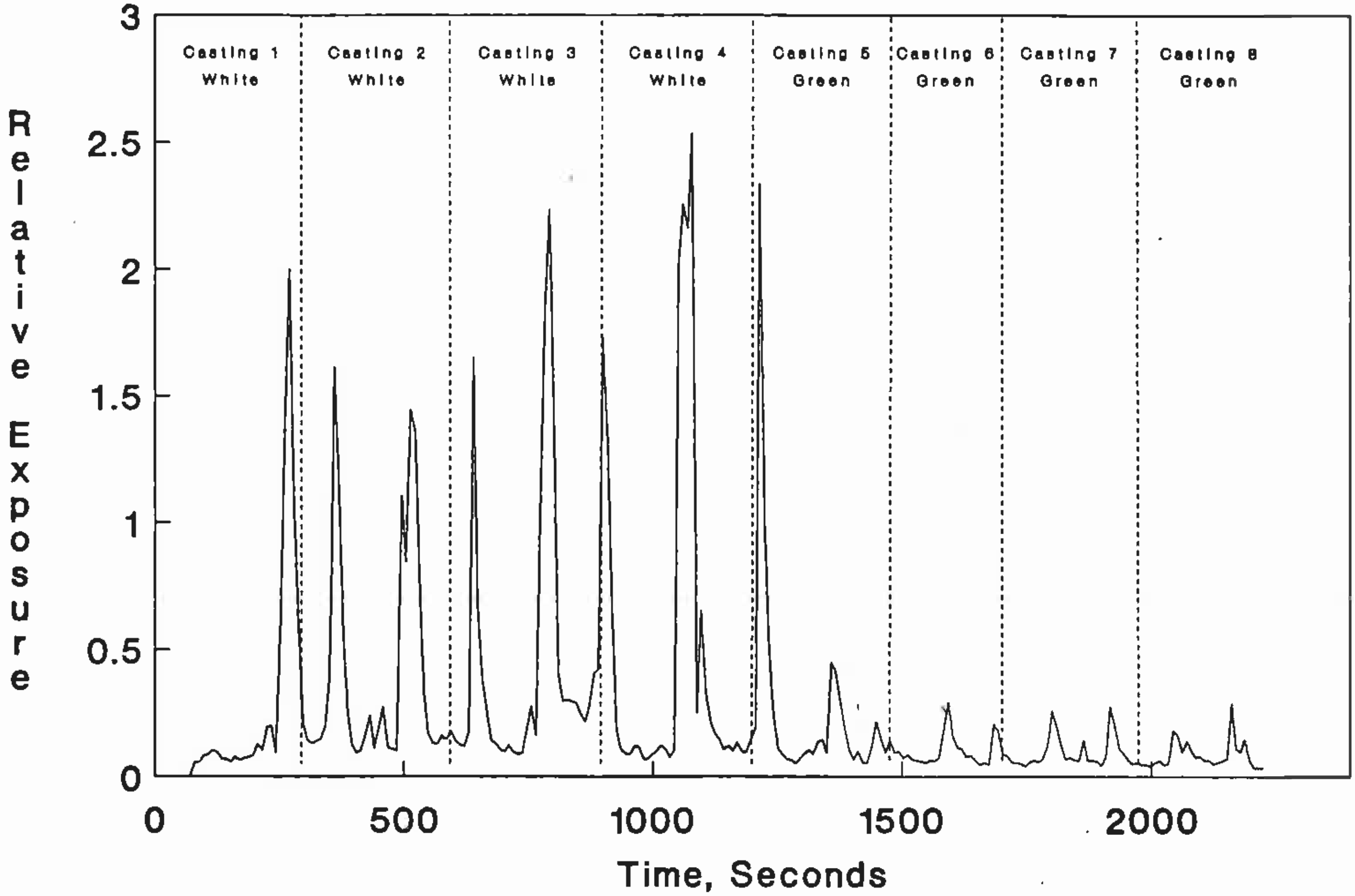

Figure 10. White vs. Green Casting Cleaning.

Table V

Relative Exposures for the Cleaning of Green and White Castings.

	Air Concentration Index[a]			
Casting Type/Activity	A Mean	Standard Deviation	B Operating Time (seconds)	C Relative Dose A x B
GREEN CASTINGS OVERALL	0.10	0.07	923	92
Green Castings Scraping	0.07	0.02	300	21
Green Castings Brushing	0.07	0.03	69	5
Green Castings Wiping	0.13	0.09	486	63
Green Castings Carrying	0.06	0.03	68	4
WHITE CASTINGS OVERALL	0.45	0.59	1115	502
White Castings Scraping	0.16	0.07	380	61
White Castings Brushing	0.58	0.70	99	57
White Castings Wiping	0.69	0.71	530	366
White Castings Carrying	0.11	0.05	106	12

[a] Levels are reported as an "Index," since the instrument was not calibrated directly for response to this dust.

(1) Area Samples

At the time of this study, nine employees were working in the glaze spray area during two shifts. Six area samples were collected at two locations in the department (see Figure 11 and Table VI). Analyses of these area samples indicated an average silica content of <16%. General area exposures to respirable dust averaged 0.44 mg/m^3, with a range of 0.03 to 0.92 mg/m^3. Silica dust area samples averaged <0.07 mg/m^3 and ranged from 0.02 to 0.14 mg/m^3. One area sample of silica dust exceeded the silica dust PEL. The average of the respirable dust levels on the east side of the department (0.77 mg/m^3) was higher than the average level on the west side (0.10 mg/m^3) (significant at the .05 level). At least one sample (on the east side) exceeded the respirable dust PEL; and at least two area samples equaled or exceeded the REL.

(2) Personal Samples

Eighteen personal samples were collected in the breathing zone of the operators and inspector at the manual spray, semiautomatic spray, automatic spray, and inspection booths. The results are shown on Table VI. The average silica content of these personal samples was <11%. The average exposure in this area was 2.39 mg/m^3 of respirable dust and <0.25 mg/m^3 of silica dust. Thus, average personal exposures were from 130 to 180% above the OSHA PEL's for this dust (approximately 0.77 mg/m^3). Furthermore, at least 12 of the 18 personal samples were at or above the PEL for respirable dust and the REL for silica dust.

(3) Local Exhaust Ventilation Systems

As shown in Figure 11, glaze is applied at five ventilated spray booth stations. Some pieces, mostly bowls, are inspected at a ventilated inspection booth prior to having glaze applied to them. The effectiveness of the ventilation systems was evaluated at three of the five spray booths and at the inspection station. Recommended control face velocities for these types of booths range from 100 to 150 feet per minute (fpm), depending upon whether the operator works inside the booth or outside the booth.[16]

(3.1) Automatic Tank Spray Booth

At this booth, the opening is 8 feet wide by 4 feet high (Figure 12). Pieces are placed on a rotating table and rotated for even spraying. The average face velocity of this booth was measured to be approximately 90 fpm (ranging from 30 fpm on sides to 140 fpm near the center). Personal exposures to respirable dust

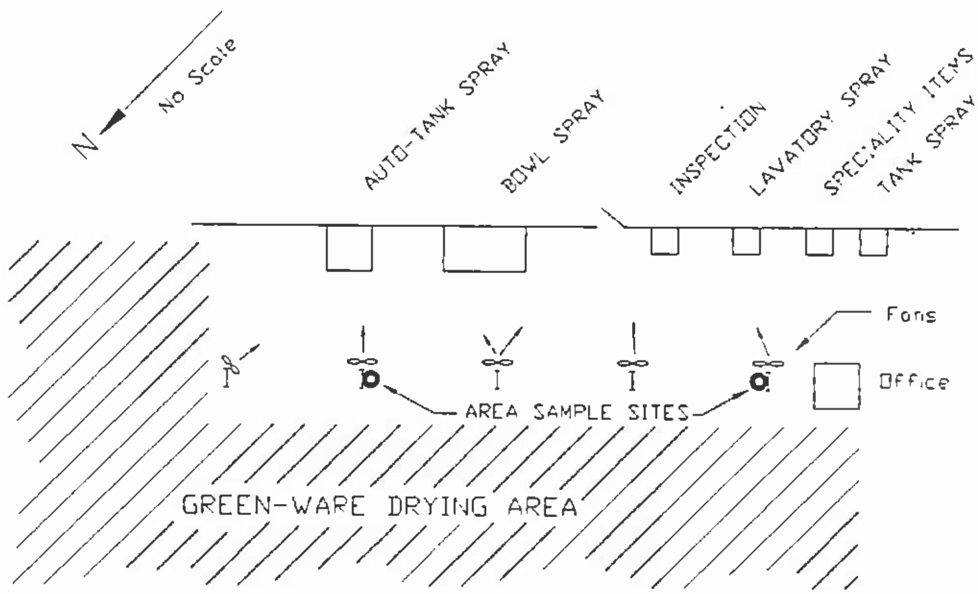

Figure 11. Glaze Spraying Area.

Table VI

Glaze Spray Department - Respirable Dust and Respirable Silica Dust Concentrations.

A. Area Samples

Location/Operation	No. of Samples n	Resp. Dust conc. (av.)[a] mg/m^3	Silica Dust conc. (av.)[a] mg/m^3	Samples[d] >PEL[b] %	Samples[d] >REL[c] %
1. West Side	3	0.10	<0.03	0	33 to 100
2. East Side	3	0.77	<0.10	33 to 100	33 to 100
Average in Glaze Spray Area	6	0.44	<0.07	17 to 50	33 to 100

B. Personal Samples

Location/Operation	No. of Samples n	Resp. Dust conc. (av.)[a] mg/m^3	Silica Dust conc. (av.)[a] mg/m^3	Samples[d] >PEL[b] %	Samples[d] >REL[c] %
1. Inspection	3	1.20	<0.19	33 to 100	33 to 100
2. Auto-Tank Spray	3	1.08	<0.20	0 to 100	0 to 100
3. Semiautomatic Bowl Spray	9	2.53	<0.23	89 to 100	89 to 100
4. Manual Spray	3	4.48	0.45	100	100
Average in Glaze Spray Area	18	2.39	<0.26	66 to 100	66 to 100

[a] Arithmetic Average

[b] PEL = OSHA Permissible Exposure Limit for Respirable Dust
$= 10/(\%SiO_2+2)\ mg/m^3$

[c] REL = NIOSH Recommended Exposure Limit for Respirable Silica Dust
$= 0.05\ mg/m^3$

[d] Lower percentage based on assumption nondetectable (ND) level of silica in samples = 0 mg; higher percentage based on assumption ND level of silica in samples = 0.08 mg, the Limit of Detection.

were estimated to be close to the PEL. It should be noted, however, that the amounts of crystalline silica in all three samples were below the detectable limit (0.08 mg). In general, exposures to dust at this spray operation appear to be better controlled than at the other spray locations, since the average respirable dust level at this location (1.10 mg/m^3) was the lowest of the workstations tested.

(3.2) Semiautomatic Bowl Spraying Line

At this location, three workers rotate through the workstations: from the loading/unloading station on the west end, to the first spray station, and to the second spray station. The two spray stations are part of a common enclosure. The three stations are described below.

Bowl Loading/Unloading Station

After the conveyor line exits from the second spray station and from the common enclosure, the operator removes the finished, sprayed bowls from the conveyor line and places them on a transport cart. This operation is done in the bowl loading/unloading station booth, which is 3-1/2 feet wide by 2-1/2 feet high. At this same location, the operator places unglazed bowls on the conveyor line. The unglazed bowls then enter the first exhausted booth of the enclosure. The average face velocity at this booth is approximately 65 fpm (ranging from 15 to 220 fpm). No spraying is performed at this booth location.

First Spray Booth

At this location, the operator applies the first coat of glaze by manually spinning the bowl and spraying all exposed surfaces. The opening at this spray booth is 4 feet wide by 4-1/3 feet high (Figure 13). The average face velocity at this booth was approximately 50 fpm (ranging from 10 to 60 fpm). Entry and exit openings for the conveyor line (3 feet wide by 2-1/2 feet high) were also exhausted. The average velocity was 48 fpm into the entry side and 17 fpm at the exit side. Many holes were observed in the sheet metal of this hood, apparently from corrosion/erosion.

Second Spray Booth

At this location, a second coat of glaze is applied as the bowl is manually rotated. This spray booth is 4 feet wide by 4-1/2 feet high. The average face

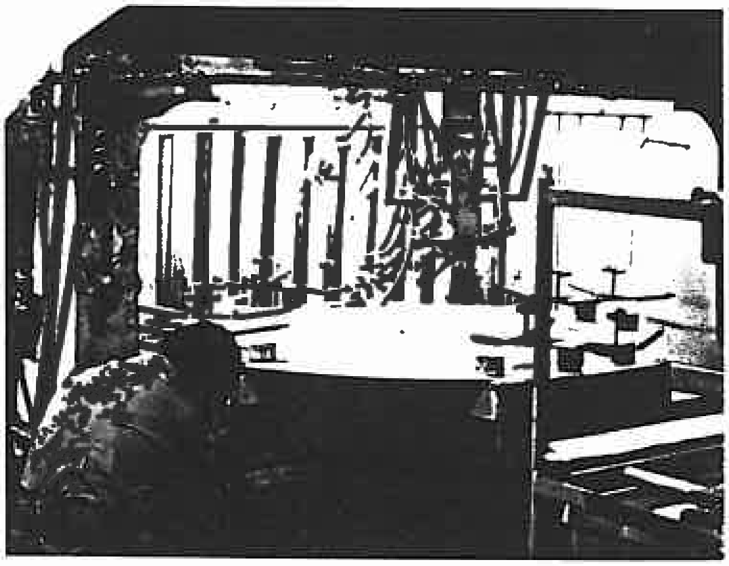

Figure 12. Glaze Spray Area - Automatic Tank Spray Booth.

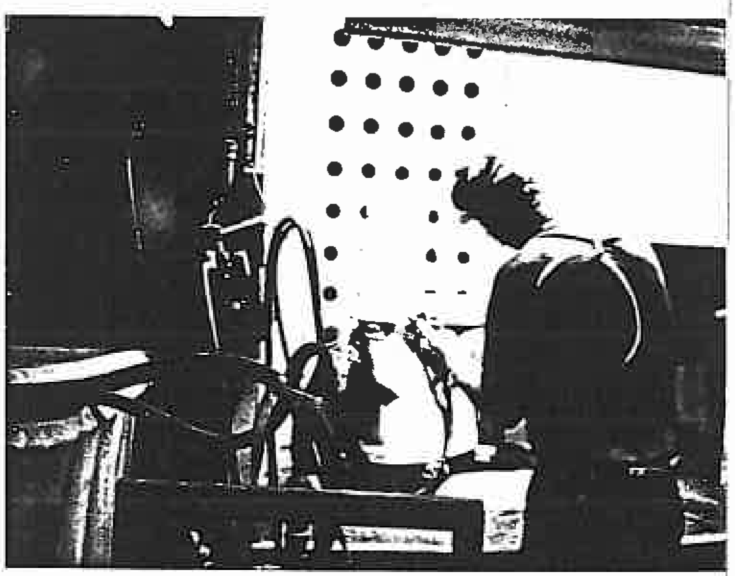

Figure 13. Glaze Spray Area - Semiautomatic Bowl Spray, First Booth.

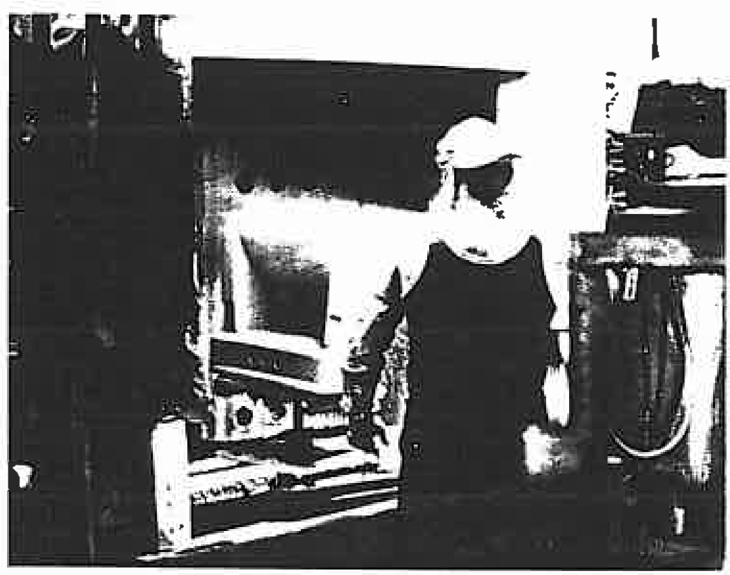

Figure 14. Glaze Spray Area - Manual Lavatory Spray Booth.

velocity at this booth was approximately 40 fpm (ranging from 20 to 80 fpm). Side entry and exit openings (3-1/2 feet wide by 2-1/3 feet high) had average face velocities of 68 fpm (entrance) and 17 fpm (exit) for the conveyor line.

Personal exposures to both respirable dust and silica dust were high in this area. Eight of nine personal exposures not only contained measurable levels of silica, but also indicated exposures above the PEL for respirable dust and the NIOSH REL for silica dust.

(3.3) Manual Lavatory Spray Booth

At this booth (Figure 14) (4-1/2 feet wide by 4-1/4 feet high), the operator removes lavatory sinks from a transport cart and places them on a stand in the booth. He first removes dust from the sink with an air hose. He then spins the sink and sprays glaze on the exposed surfaces. Normally, he points his spray gun down and away from himself toward the booth. Some visible spray can be seen escaping from the hood. Face velocities in this hood were measured both with an area (man-cooler) fan on and with the fan off. With the fan off, the average face velocity was 147 fpm, evenly distributed across the face (ranging from 120 to 170 fpm). With the fan on, the average velocity was 167 fpm, but unevenly distributed (ranging from 80 fpm on the left side to 300 fpm at the lower right side). Although this air movement approximates the recommended average velocity of 150 fpm,[16] air turbulence caused by the use of the area fan is counterproductive for effective spray control. All three of the personal sample exposures were above the PEL for respirable dust, averaging 4.5 mg/m^3 (respirable dust); and the REL for silica dust, averaging 0.45 mg/m^3 (silica dust). Furthermore, all samples contained quantifiable amounts of silica.

(3.4) Inspector's Booth

At this booth (measuring 4 feet high by 4-1/2 feet high), the operator places bowls in the hood and uses compressed air to blow off dust. He then wipes areas with a wet sponge and uses a mirror to inspect the holes inside the rim. He normally stands between the booth and the transport cart during the inspection process. The average face velocity of this hood was 60 fpm (ranging from 40 to 100 fpm). The average dust exposures were 1.20 mg/m^3 for respirable dust; and <0.19 mg/m^3 for silica dust (Table VI). At least one of the three samples exceeded both the PEL and the

REL. Much of this may have been contribution from the general work area environment (which averaged about 0.43 mg/m^3 of respirable dust) and, in particular, from the manual spray and semiautomatic spray operations.

d. Glaze Preparation Area

The liquid glaze is prepared in the Glaze Department (Figure 15) by three workers using bags of Supersil powder (crystalline silica), feldspar, whiting, Pyrax, China clay, talc, and other color producing compounds. Bags are dumped manually into one of several pebble mill blenders (Figure 16). In dumping the bags of material, the operator climbs up a portable ladder. The bags of material are placed on a pallet and elevated behind the operator by a fork lift. The operator turns around, takes one bag at a time, and holds each bag near the manway to the pebble mill (which is at shoulder height, even with the ladder). He then slits the bag with a knife, manually dumps it into the pebble mill, and manually compresses the bag (creating visible dust clouds). The mix is milled overnight, and the glaze is then pumped to holding tanks for final adjustment and storage prior to use in the Spray Department.

(1) Area Samples

Three area samples were collected at one location, site 1, near the office, as shown in Figure 15 and Table VII. The silica content of these samples averaged approximately 39%, ranging from 22 to 65%. The average area dust exposure levels were 0.87 mg/m^3 of respirable dust, which is approximately 150% above the OSHA PEL. On the basis of silica dust concentrations, which averaged 0.23 mg/m^3, all three exceeded the NIOSH REL. Dust levels on the third day of the study were higher than on days one and two.

(2) Personal Samples

Six personal samples were collected on two of the operators in this area. Each operator was evaluated for a full shift on each of the three days of this study. As shown in Table VII, the average silica content of these samples was <32%. The average of the personal exposures in this area was 0.64 mg/m^3 of respirable dust or approximately 80% above the OSHA PEL. At least three of the six exposures exceeded the OSHA PEL. On the basis of silica dust, at least four of the six exceeded the NIOSH REL. Exposures to the operator, dumping the dry batch material into the mixer, were consistently higher than exposures to the operator primarily involved in formulating.

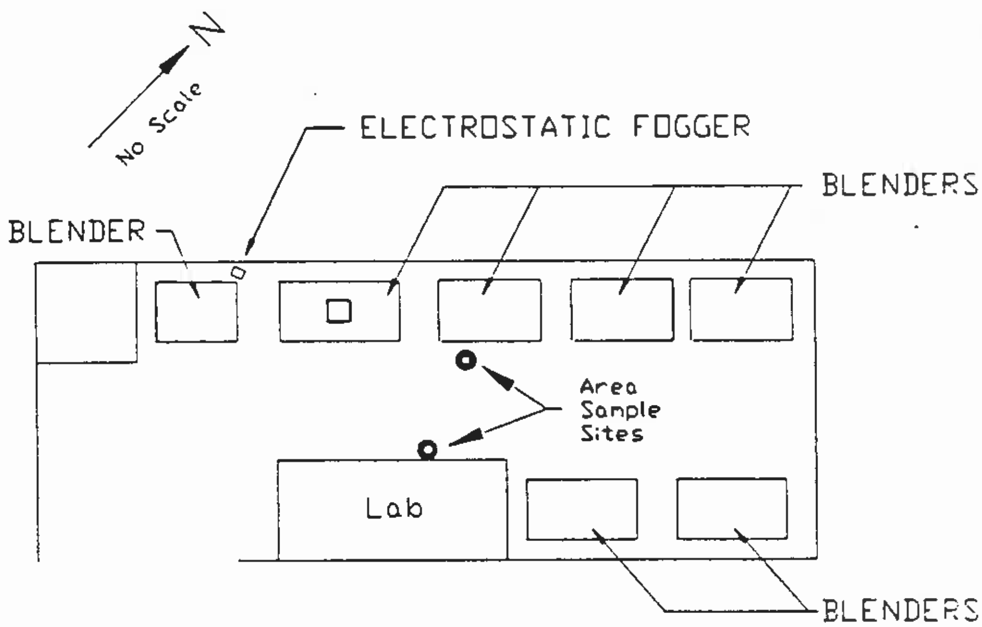

Figure 15. Glaze Area.

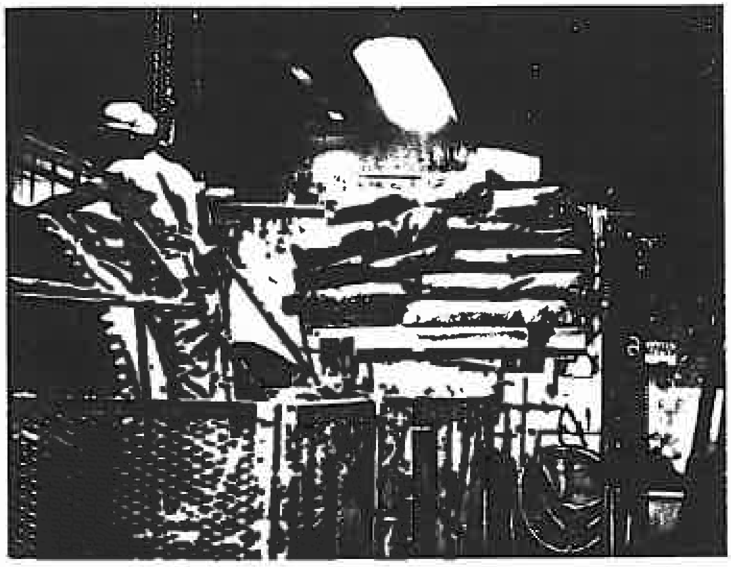

Figure 16. Glaze Preparation Area - Dumping Bags into Mill.

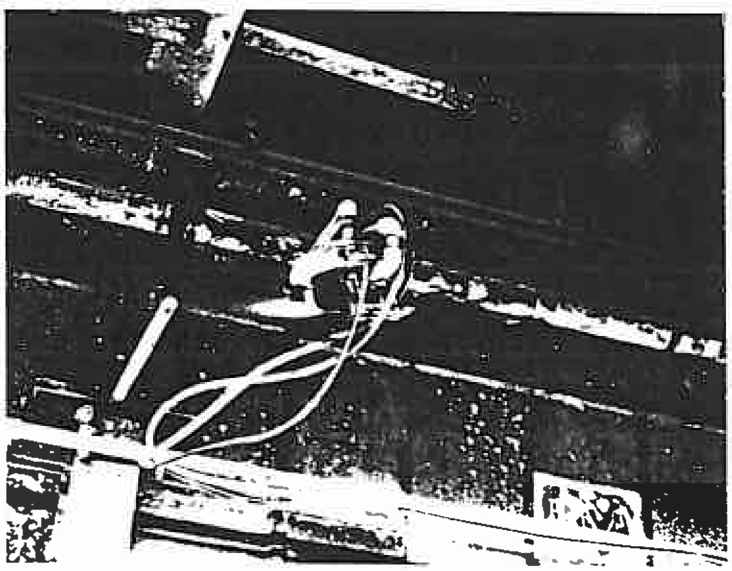

Figure 17. Glaze Preparation Area - Charged Fogger.

Table VII

Glaze Preparation Department - Respirable Dust and Respirable Silica Dust Concentrations.

A. Area Samples

Location/Operation	No. of Samples n	Resp. Dust conc. (av.)[a] mg/m^3	Silica Dust conc. (av.)[a] mg/m^3	Samples[d] >PEL[b] %	Samples[d] >REL[c] %
Near Office	3	0.87	0.23	67	100

B. Personal Samples

Location/Operation	No. of Samples n	Resp. Dust conc. (av.)[a] mg/m^3	Silica Dust conc. (av.)[a] mg/m^3	Samples[d] >PEL[b] %	Samples[d] >REL[c] %
Formulation	3	0.35	<0.12	33 to 67	66 to 100
Mixer Operation	3	0.92	<0.23	66 to 100	66 to 100
Average in Glaze Preparation Area	6	0.64	<0.17	50 to 83	66 to 100

[a] Arithmetic Average

[b] PEL = OSHA Permissible Exposure Limit for Respirable Dust
$= 10/\% \, SiO_2 + 2 \; mg/m^3$

[c] REL = NIOSH Recommended Exposure Limit for Respirable Silica Dust
$= 0.05 \; mg/m^3$

[d] Lower percentage based on assumption nondetectable (ND) level of silica in samples = 0 mg; higher percentage based on assumption ND level of silica in samples = 0.08 mg, the Limit of Detection.

(3) Charged Fogger Evaluation

Crystalline silica exposures in the glaze preparation area have been excessive, as indicated by previous area and personal samples taken there and by sampling results obtained during this study as shown above.[14,17] Exposures to the operator filling the ball mill are among the highest silica exposures in the plant. For these reasons, an attempt was made by plant personnel to control the dust at the loading point of two ball mills. A charged fogger was set up between two ball mills for dual application (Figure 15, site 2, and Figure 17). The charged fogger, model 205, was supplied by Keystone Dynamics Incorporated (Villanova, Pennsylvania).

The charged fogger has two main components, a nozzle and a charge induction ring. The nozzle has an outlet for water, which is supplied under pressure through a pressure regulator, and a particulate filter. The nozzle also has an air outlet. The air is supplied under regulated pressure. It is mixed with the water stream and serves to break the sprayed water droplets into smaller sizes, in addition to aiding the transport of the resulting fog. As the fog exits the air and water nozzle, it passes through the center of an electrified ring which charges the droplets by induction. When the charged drops evaporate, ions are released into the space that is being fogged. These ions are highly mobile. Some of them attach themselves to any aerosol that may be present and create a net charge on the particles. The electric field, which results from the presence of a charge in the space, exerts a force on these charges, including the charged aerosol. This electrostatic force facilitates its deposition on surfaces which bound the space, such as the floors and walls. This is reputed to be the primary mechanism whereby charged foggers control aerosols. If the charged fogger is capable of reducing the respirable aerosol, the charged fogger must be used in such a way that the charged aerosol passes close to a surface that can act as a deposition receptor. The electric field at this point must also be large enough to cause a significant movement of the aerosol toward the surface.

The charger was located about 6 feet from the opening of the ball mills, and directed so that the fog traveled across in front of the worker during the loading operation. The primary purpose of the fogger was to reduce the dust exposure of the workers while they were filling these two ball mills. A secondary purpose was to reduce the overall dust levels in the room. An initial observation by plant personnel was that fogger operation seemed to make the air in the room visibly clearer, and presumably less dusty.

The strategy for the evaluation of the fogger consisted of taking a series of real-time respirable dust concentration measurements during the ball mill filling operation: first, with the charged fogger off; then, with both charge induction ring and air supply on; and finally, with only the fogger air supply on. Measurements of 10 minutes duration were allocated to each of these three conditions for the 30 minutes time span required to fill the ball mill. Fifty-one bags of Supersil powder were emptied into the mill during this time. Simultaneously, worker activities were videotaped for subsequent analysis, to determine correlations between the activities and the dust levels. The inlet to the real-time dust monitor was located in the worker's breathing zone. The details of the real-time sampling apparatus are described in Section III.A.b.3 of this report. During the fogger evaluation runs, all other ventilation and air circulation fans in this area were turned off, so that the results would reflect the effects of the fogger alone. Results of these measurements are shown in Figures 18 and 19 and in Table VIII. (Note: the fogger operation cycle differed for each run, i.e., the order of the first run was: Fogger Off, Fogger On, and Fogger Air Only; the order of the second run was: Fogger On, Fogger Off, and Fogger Air Only.) Simultaneously, real-time dust concentration measurements were taken at a point in the glaze preparation area about 20 feet away from the ball mill.

The primary result of this test is that the activity of the charged fogger had no noticeable effect on the dust concentration levels, either at the worker's position or in the general area of the ball mills. Therefore, the charged fogger was not an effective control measure in this application; and other approaches to the dust control problem are necessary.

The visible clearing effect of the fogger may be due to the fact that charged fogging is more effective for smaller dust particles. Visibility is primarily affected by these smaller particles (less than 0.5 micrometers diameter). The fogger may remove some of the smaller dust particles by deposition on surfaces, improving visibility in the area. However, nearly all of the mass of the dust is contained in the range of dust sizes above 0.5 micrometers. Since the health effects are related to the respirable mass of the toxic component of the dust (silica), removal of the small size component of the dust makes an insignificant improvement to worker exposures in this case.

B. Evaluation of Lifting Stress

Although ergonometric considerations were not the primary concern of this study, a review of the Workers' Compensation Log for injuries, from

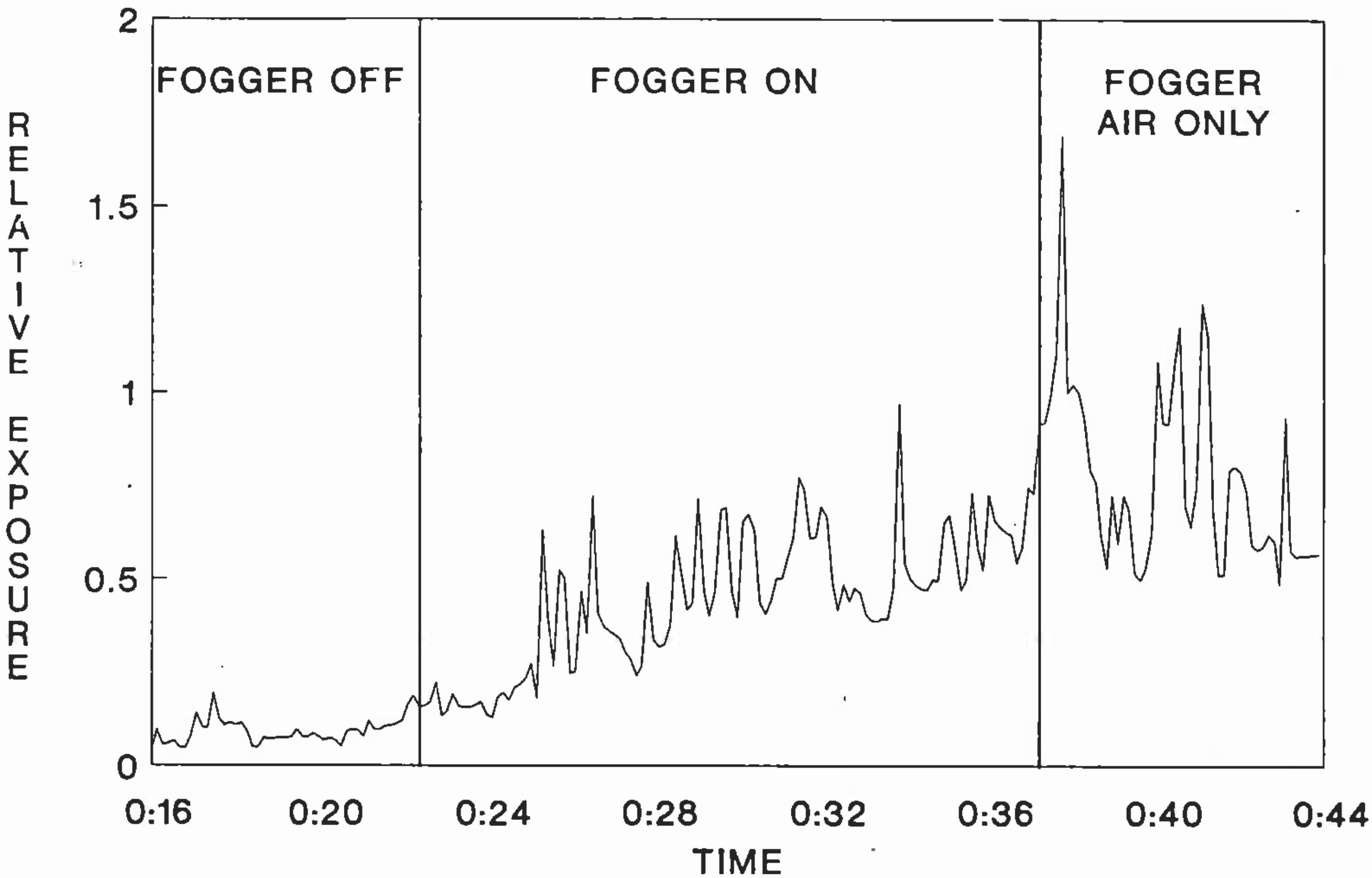

Figure 18. Glaze Preparation Area Real-Time Data, Background.

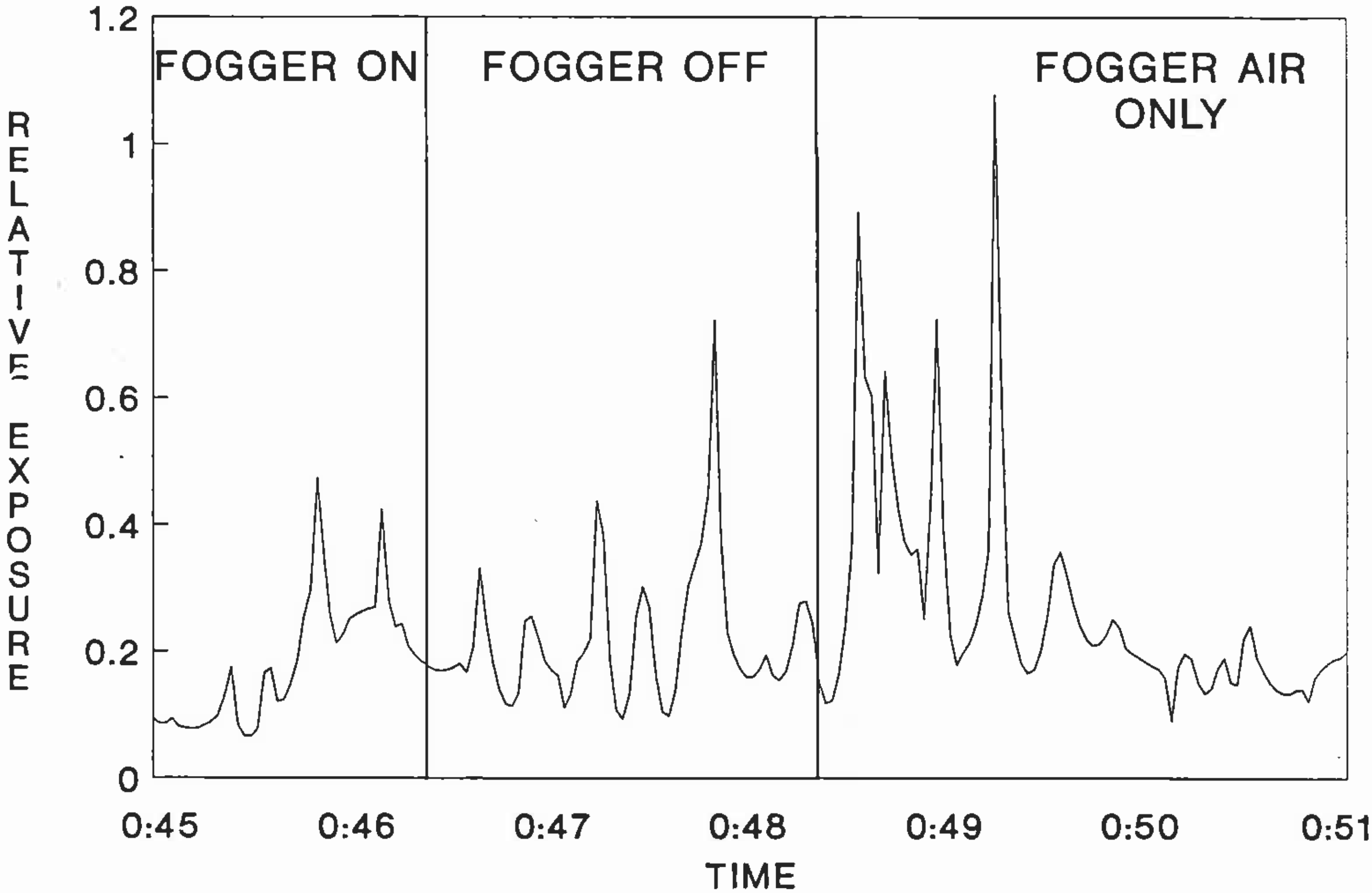

Figure 19. Glaze Preparation Area Real-Time Data, Worker.

Table VIII

Effect of Electrostatic Fogger on Glaze Preparation Exposures

Location	Air Concentration Index Electrostatic Fogger Condition Fogger On	 Fogger Off	 Only Fogger Air On
1. Glaze Worker 2	0.18	0.21	0.25
(standard deviation)	0.09	0.11	0.15
2. Glaze Area (Background)	0.48	0.11	0.76
(standard deviation)	0.18	0.04	0.26

Note - For Run 1, the fogger cycle was: on, off, air only
For Run 2, the fogger cycle was: off, on, air only

May 1986 to November 1987, indicates that lost-time injuries are a significant problem in the plant. A total of 47 work injuries, involving lifting of heavy objects, was reported during this period. A presentation of the incidence of these injuries is shown on Table IX, along with a comparison with the National Injury Incidences reported by the U.S. Bureau of Labor Statistics (U.S. Department of Labor) for 1986.[23] The overall calculated annual incidence for Woodbridge Pottery Company (22.4 cases/100 workers) is consistent with the National incidence for the industry (22.8 cases/100 workers). However, the incidences in specific areas of the plant indicate that high rates of injury occur particularly in the glaze spray, glaze preparation, and casting areas.

In order to perform the calculations for compressive forces on the back, as well as the percent of the population capable of performing such tasks, a computer program, developed by the University of Michigan, Center for Ergonomics, was used.[24] Analysis of work tasks performed in the Glaze Spray and Casting Areas was done for the workers based on videotapes, taken during the survey of workers performing typical tasks. Specific analysis of these jobs is given below.

1. Glaze Spray Inspector

   For the glaze spray inspector in the glaze spray department, the worker was analyzed lifting a 50-pound, precured clay bowl from floor level to knuckle height. The lift was calculated for the worker in the sagittal plane performing a symmetrical lift (Appendix C-1). The worker evaluated was estimated to be in the 50th percentile for height and weight compared to males in the U.S. population. The results showed that during the initial lift of the 50-pound bowl, the compressive forces at the 5th lumbar (L5) and first sacral joint (S1) (the areas where most back injuries occur) was 1,029 pounds. Based on the NIOSH Lifting Manual,[24] this exceeded the Action Limit (AL) of 770 pounds for acceptable lifting conditions.

2. Cast Shop Operator

   In the cast shop, the worker was analyzed lifting a 50-pound, precured clay bowl. The lift was calculated in the same way as the Glaze Spray Inspector. The only difference is that this worker appeared to be in the 95th percentile for height and weight (i.e., only 5% of the population is taller and heavier) compared to U.S. adult males (Appendix C-2). The results showed that during the initial lift of the 50-pound bowl, the compressive forces at the L5/S1 was 1,431 pounds. Based on the NIOSH Lifting Manual, this was in the range of the Maximum Permissible Limit for lifting such loads of 1,430 pounds. Therefore, back injuries should be anticipated, since this calculated compressive force may be underestimated.

Table IX

Occupational Injury Incidence at Woodbridge Pottery by Department (from May 17, 1986, to October 15, 1987) Compared to National Industry Rates[23]

Industry/Company Department	SIC #	Plant/Dept. Population	Total Injuries	Yearly Rate per 100 Workers
1. Woodbridge Pottery (Total Plant)	3261	150	47	22.4
2. Production Department Total Production Area	3261	120	47	28.0
3. Plant Departments	3261			
a. Casting		57	25	31.3
b. Glaze Spray		9	8	63.5
c. Glaze Preparation		2	2	71
d. Kiln		10	4	28.6
e. Inspection, Packaging, Shipping		16	7	31.2
f. Labor, Maintenance		15	1	4.8
4. Vitreous Plumbing Fixtures (General)	3261			22.8

C. Observational Evaluations

1. Respiratory Protection Program

The company maintains a Respiratory Protection Program under the direction of the Manager of Industrial Relations and Safety Coordinator. The requirements for a minimal acceptable program have been prescribed by OSHA.[18] Some of the aspects of the Company's program follow:

a. Respirators, approved for use against pneumoconiosis dusts (by MSHA/NIOSH), are provided in all work areas:

AREA	TYPE RESPIRATOR	MANUFACTURER
Spray Dept.	8710 (single use)	3M
Slip Area	Dust Foe, Mod. 77 or Comfo	MSA
Casting Dept.	Dust Foe, Mod. 78	MSA
Maintenance Workers	Comfo II, Type F	MSA

b. In the slip area, clean respirators are provided to the workers daily. In other areas, workers store their respirators in a bag at their workstation. Maintenance and cleaning of respirators are the responsibility of each individual worker.

c. During the course of this study, respirator usage was observed to be lax in many cases. They were observed to be hanging around workers' necks or not worn at all.

2. Medical Monitoring Program

Management is developing a revised Medical Monitoring Program. Medical protocols have been developed by NIOSH[22] and the National Industrial Sand Association.[19] Medical consultation is provided by a medical group in Woodbridge, New Jersey, who specialize in pulmonary physiology. All new hires are given medical examinations, which include pulmonary evaluations (X-rays and pulmonary function testing). The company plans to provide periodic pulmonary function testing for all employees by contract with a physiological testing service.

3. Health and Hygiene Program

a. A safety committee, representing management and union, meets monthly and conducts monthly inspections. Items covered in this inspection include plant cleanliness, labeling of drums and other containers, and proper storage, condition, and <u>use</u> of respirators. Violation of standing safety procedures are recorded and warnings (verbal followed by written) are issued.

b. Each worker is provided a locker for storage of street clothing/work clothing and a clean bag at his workstation for storage of his respirator. Workers are allowed a 15-minute period for showering, at the end of their work shift.

c. Housekeeping procedures continue to be a major problem. Dust spills and sources are cleaned up at the end of each shift by dry sweeping. No exhaust vacuum systems are available for controlled removal of debris. Many major dust-producing plants indicate that good housekeeping procedures and maintenance of equipment can reduce dust exposures by more than 50%.[21]

4. Environmental Monitoring Program

a. No routine or periodic environmental monitoring program (involving monitoring of both atmospheric exposures and dust control systems) is presently in effect.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. Recommendations Warranting Immediate Attention with Relatively Low Cost

1. A more effective health and safety program should be established at the Woodbridge Pottery Plant. As a start, a specific member of the management or technical staff should be designated as the Health and Safety Coordinator. He should be responsible for the development and implementation of the programs, operations, and procedures directed at the improvement of employee health and safety conditions. Adequate time and training will be necessary for this person to perform necessary health and safety functions.

2. A list of resource materials, and where they may be obtained, is presented in Appendix E. These materials should be obtained and reviewed.

3. There are widespread overexposures to silica dust. On top of this, respirator use was observed to be sporadic. A comprehensive respirator program should be implemented immediately. Aspects of this program are discussed in the resource materials, given in Appendix E. Respirator use should be vigorously enforced until silica dust exposure levels can be reduced to at least below the OSHA PEL of 0.1 mg/m^{3m} or, preferably, below the NIOSH REL of 0.05 mg/m^{3m} for crystalline silica dust.

4. A major source of airborne dust in the cast shop consists of cross contamination from other activities in the plant and reentrainment of dust from scrap and waste on the floor and other surfaces. Other significant sources of dust come from the dusting of molds and the cleaning of castings in the area. The use of glaze overspray as a mold parting compound is a visible source of silica dust exposure, creating clouds of dust. This material not only causes dust exposure, but also can settle and reentrain into the atmosphere.

5. A nonsilica mold release should be substituted for the glaze overspray material.

6. Where possible, green cleaning of castings should be done rather than white cleaning. If feasible, wiping the white pieces with a damp sponge or misting with a sprayer prior to cleaning may help reduce dust generation. A more effective and less dust producing procedure for cleaning castings may be the use of portable vacuum cleaners, with attached High Efficiency Particulate Filters (HEPA), or a centralized vacuum cleaning system.

7. The charged fogger, which was obtained and used during a trial experimental period, is not an effective dust control device in the Glaze Preparation area. It should not be installed for dust suppression purposes.

8. Because of the high exposure levels and number of exposed personnel in the general spray area, high priority should be assigned to this area for improved dust control. The use of a "man-cooler" fan in the Glaze Spray area reduces the effectiveness of the local exhaust ventilation into the spray booth and can also help reentrain settled dust. The directional flow pattern, developed by the hood ventilation system, is disturbed by the man-cooler fan, so that spray mist escapes from the hood. The use of such fans should be curtailed throughout the facility. Smoke tubes can be helpful in defining airflow patterns in and around the hoods.

9. Poor housekeeping can be a major source of dust contamination. The use of dry sweeping should be minimized. Improved methods of cleaning up scrap material, using either a centralized vacuum system or portable vacuum cleaners with HEPA filters, would significantly reduce dust exposures.

10. Scheduled maintenance and repair of dust control systems, including exhaust ventilation systems, would improve their overall effectiveness. The routine use of a small air velocity meter can be effective in determining the status of ventilation systems from the point of view of both maintenance and capacity. Also, the use of direct-reading dust monitors can help locate major dust sources in need of control.

B. Recommendations Warranting Immediate Attention with Greater Cost Involved

1. An improved method for filling the pebble mills is needed. A fixed platform with a ventilated dump station on top of the mills is one option, although the roof height may not allow this. An alternative is to fill reusable semibulk containers on the floor, using a ventilated dump station with built in dust control. The containers could be hoisted up to the mills and dumped in. A dump station, such as those described in Reference 26, Appendix D-3, or Reference 12 in Appendix E, should control the dust during the filling of containers.

2. An ongoing program of medical surveillance should be instituted to validate the effectiveness of the dust control program. The following Medical Surveillance Program, developed by NIOSH for exposures to

crystalline silica flour,[22] 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 exposure (defined as exposure at concentrations less than half of the NIOSH-recommended standard)."

3. The glaze spray booths are not effective in containing the sprayed-on glaze. According to the guidelines in the ACGIH Industrial Ventilation Manual, Appendices D 1-2 and E-10, effective control in small spray booths require from 100 to 150 cubic feet per minute per square foot (cfm/sq. ft.) of open area, depending upon the size and the use of the hood. (cfm/sq. ft. = feet per minute or fpm, velocity.) Average face velocities into the spray booths ranged from 48 to 147 fpm, with most booths having average velocities below 68 fpm. These booths should be reevaluated by your staff, with respect to air distribution, total air capacity, and directional flow patterns. Redesign or modification of the booths, with baffles, should provide for maximum enclosure of the operations and the provision of at least 100 fpm of air velocity at all openings. Reduction of air pressure in the spray guns and the use of extensions on the spray guns may be feasible to reduce the overspray bounce back. The close proximity of the spray operators to the sprayed fixtures and the bounce back of the overspray make this a challenging control problem.

4. The manual handling of plumbing fixtures in several plant areas probably accounts for a large number of lost-time injuries. This occurs particularly in the Cast Shop and the Glaze Spray Area, where compressive forces on the back of workers during lifting can be excessive. A significant reduction in these types of injuries could be achieved by examining all of the lifting operations and determining which operations could be carried out more safely with mechanical aids or by a redesign of the work area.

The compressive forces, calculated according to the NIOSH Model in Appendix C-1, and presented in Appendices C-2 and 3, are based on symmetric (two-handed) lifting in the sagittal plane (directly in front of the body with no twisting during lift). Since most of the lifting in these areas is performed in an asymmetrical, nonsagittal plane, i.e., by rotating or twisting the upper body and lifting to one side, using one arm more than the other, the calculated compressive forces may underestimate the actual compressive forces experienced, and the resultant potential risks of injury.

a. It is recommended that the Cast Shop receive first priority for evaluation, because of the higher calculated compressive forces; since the work cycle time is much shorter; and because material handling is much higher here compared to the Glaze Spray Area. As shown in Appendix C-2, compressive forces on the back of this worker are of the same magnitude (1,431 pounds) as the Maximum Permissible Limit (MPL) of 1,430 pounds. Workplace modifications to reduce manual material handling and improve human/fixtures coupling design are needed. These may include material handling system alternatives (lifting aids) such as hooks, bars, rollers, jacks, platforms, trestles, conveyors, cranes, and hoists, which may be found in the Thomas Register Catalog.[24]

b. In the Glaze Spray area, the calculated compressive force of 1,029 pounds, was in excess of the recommended Action Level (AL) of 770 pounds. Initially, it is recommended that administrative controls be applied to this job. These include worker education and training in safe material handling procedures.

c. It is also recommended that the evaluations such as those presented in the NIOSH Technical Report "Work Practices Guide for Manual Lifting," (Appendix E-13), be conducted by the engineering staff or that the advice of an ergonometric specialist be sought to evaluate more completely the tasks and associated stresses in the casting, glaze spray, and glaze preparation areas; and to offer recommendations for the effective reduction of these stresses.

5. An Environmental Monitoring Program, including periodic air monitoring and dust control systems monitoring, would validate the effectiveness of the dust control program.

C. Recommendations Involving Larger Expense

1. The work areas in the Casting Shop need to be redesigned, both from the viewpoints of ergonomics and of dust control. The prototype line with a roller conveyor is an appreciable improvement over the present arrangement. Additional improvements would be to avoid the use of three-tiered storage shelves for the greenware, provision for easier cleanup of dust and scrap, and the use of a clean, conditioned air shower over the principal work area in each station. Competent industrial engineering and ventilation expertise should be consulted in this design.

2. As an alternative to #1 above, a complete redesign of the production process, with a centralized casting area and optimal material flow, may be warranted. This would involve even more opportunity for improved ergonomics and dust control.

3. Spray exposures to workers at the semiautomatic Glaze Spray booth station could be further reduced by the installation of an automated spray robot.

The preceding recommendations are all intended for use by the Woodbridge Sanitary Pottery Corporation to improve the working environment at that facility. With the exception of the items in Section VI C, (larger expense, for which there are a number of alternatives) these recommendations are felt to be both specific and feasible. These recommendations should also be implemented, as appropriate, at the two other plants producing GERBER Brand fixtures. and by any other sanitary ware plant, which may have problems similar to those observed in this study.

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Environmental Data - SKC Air Check Sampler

Woodbridge Pottery, Woodbridge, NJ

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Resp. Dust

LOCATION	JOB TITLE	DATE	FLOW (l/m)	RUN TIME (min)	MASS (mg)	CORR. MASS (mg)	CONC (ug/m3)	QUARTZ MASS (mg)	QUARTZ CORR (mg)	QUARTZ CONC (ug/m3)	PIECES PRODUCED
AREA	SLIP HOUSE MIX 3-4	06/07/88	1.7	490	0.86	0.85	1020	0.28	0.28	336	
AREA	SLIP HOUSE TANK 3	06/07/88	1.7	490	0.20	0.19	227	0.05	0.05	60	
C1	GLAZE PREPARATION	06/07/88	1.7	364	0.13	0.12	193	0.09	0.09	145	
C2	GLAZE PREPARATION	06/07/88	1.69	405	0.64	0.63	919	0.2	0.2	292	
AREA	GLAZE PREPARATION	06/07/88	1.7	482	0.18	0.17	207	0.05	0.05	61	
BLANK		06/07/88			0.02	0.01		ND	0	ERR	
B4	SEMI-AUTO	06/07/88	1.69	411	2.76	2.75	3958	0.18	0.18	259	
B5	SEMI-AUTO	06/07/88	1.71	396	1.70	1.69	2495	0.13	0.13	192	
B6	SEMI-AUTO	06/07/88	1.71	413	0.93	0.92	1302	0.08	0.08	113	
B1	INSPECTOR	06/07/88	1.7	337	0.81	0.80	1395	0.18	0.18	314	
B2	AUTO TANK SPRAY	06/07/88	1.7	181	0.26	0.25	810	0.08	0.08	260	
B8	MANUAL SPRAY	06/07/88	1.7	417	1.85	1.84	2595	0.14	0.14	197	
AREA	WEST	06/07/88	1.7	480	0.10	0.09	109	0.04	0.04	49	
AREA	EAST	06/07/88	1.7	478	0.73	0.72	885	0.08	0.08	98	
BLANK		06/07/88			-0.02	-0.03		ND	0	ERR	
A2	TANK CAST 51	06/07/88	1.7	342	0.19	0.18	308	0.08	0.08	138	80
A4	BOWLS 19	06/07/88	1.7	478	0.59	0.58	713	0.16	0.16	197	30
A5	BOWLS 17	06/07/88	1.7	380	0.17	0.16	247	0.08	0.08	124	30
A10	LAVS 38	06/07/88	1.7	260	0.11	0.10	225	0.08	0.08	181	52
AREA	CAST 35 60	06/07/88	1.7	461	0.13	0.12	152	0.08	0.08	102	
AREA	CAST 32 41	06/07/88	1.7	457	0.14	0.13	166	0.03	0.03	39	
AREA	SLIP HOUSE BINS	06/07/88	1.7	305	0.67	0.66	1272	0.2	0.2	386	
AREA	SLIP HOUSE MIX 4	06/07/88	1.7	303	0.15	0.14	270	0.06	0.06	116	
BLANK		06/07/88			-0.01	-0.02		ND	0	ERR	
BLANK		06/07/88			-0.02	-0.03		ND	0	ERR	
AREA	SLIP HOUSE TANK 3	06/08/88	1.7	503	0.94	0.93	1087	0.19	0.19	222	
AREA	SLIP HOUSE MIX 3-4	06/08/88	1.7	503	2.56	2.55	2981	0.99	0.99	1158	
C1	GLAZE PREPARATION	06/08/88	1.7	380	0.31	0.30	463	0.08	0.08	124	
C2	GLAZE PREPARATION	06/08/88	1.7	422	0.80	0.79	1100	0.2	0.2	279	
AREA	GLAZE PREPARATION	06/08/88	1.71	509	0.21	0.20	229	0.13	0.13	149	
BLANK		06/08/88			0.01	-0.00		ND	0	ERR	
AREA	TANK CAST N BAY 1	06/08/88	1.7	372	0.27	0.26	410	0.08	0.08	127	
AREA	CAST 35 60	06/08/88	1.7	376	1.18	1.17	1829	0.09	0.09	141	****
A1	TANK CAST N BAY 1	06/08/88	1.7	332	0.80	0.79	1319	0.09	0.09	150	80
A3	TANK CAST N BAY 1S	06/08/88	1.7	352	0.33	0.32	534	0.08	0.08	134	80
A9	BOWLS N END E BAY	06/08/88	1.7	389	0.38	0.37	558	0.08	0.08	121	32
A5	BOWLS 17	06/08/88	1.7	385	0.70	0.69	1053	0.08	0.08	122	30
A6	BOWLS ROW 3 MIDDLE	06/08/88	1.7	393	0.87	0.86	1286	0.08	0.08	120	24
A4	BOWLS 19	06/08/88	1.7	491	0.87	0.86	1030	0.1	0.1	120	30
A7	BOWLS ROW 4 MIDDLE	06/08/88	1.7	395	0.44	0.43	639	0.08	0.08	119	30
AREA	CAST 32 41	06/08/88	1.7	435	0.47	0.46	621	0.08	0.08	108	
AREA	BOWL CAST N ROW 4	06/08/88	1.7	430	0.31	0.30	409	0.08	0.08	109	
A8	BOWLS 21	06/08/88	1.7	431	0.64	0.63	859	0.11	0.11	150	30
BLANK		06/08/88			0.02	0.01		ND	0	ERR	
BLANK		06/08/88			0.02	0.01		ND	0	ERR	
B4	SEMI-AUTO	06/08/88	1.69	423	3.83	3.82	5343	0.31	0.31	434	
B5	SEMI-AUTO	06/08/88	1.71	440	2.95	2.94	3904	0.24	0.24	319	
B6	SEMI-AUTO	06/08/88	1.71	421	0.87	0.86	1194	0.09	0.09	125	

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Woodbridge Pottery, Woodbridge, NJ

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LOCATION	JOB TITLE	DATE	FLOW (L/m)	RUN TIME (min)	Resp. Dust MASS (mg)	CORR. MASS (mg)	CONC (ug/m3)	QUARTZ MASS (mg)	QUARTZ CORR (mg)	QUARTZ CONC (ug/m3)	PIECES PRODUCED
B3	AUTO TANK SPRAY	06/08/88	1.7	200	0.44	0.43	1263	0.08	0.08	235	
B1	INSPECTOR	06/08/88	1.7	340	0.73	0.72	1175	0.08	0.08	131	
B8	MANUAL SPRAY	06/08/88	1.7	408	3.03	3.02	4353	0.34	0.34	490	
AREA	WEST	06/08/88	1.7	516	0.04	0.03	33	0.08	0.08	91	
AREA	EAST	06/08/88	1.7	510	0.81	0.80	922	0.12	0.12	138	
BLANK		06/08/88			0.06	0.05		ND	0	ERR	
B4	SEMI-AUTO	06/09/88	1.69	421	1.61	1.60	2248	0.18	0.18	253	
B5	SEMI-AUTO	06/09/88	1.71	425	0.88	0.87	1201	0.11	0.11	152	
B7	SEMI-AUTO	06/09/88	1.71	420	0.81	0.80	1113	0.14	0.14	195	
B3	AUTO TANK SPRAY	06/09/88	1.7	288	0.59	0.58	1183	0.08	0.08	163	
B1	INSPECTOR	06/09/88	1.7	392	0.70	0.69	1034	0.08	0.08	120	
B8	MANUAL SPRAY	06/09/88	1.7	440	4.87	4.86	6496	0.5	0.5	668	
AREA	WEST	06/09/88	1.7	493	0.14	0.13	154	0.02	0.02	24	
AREA	EAST	06/09/88	1.7	490	0.45	0.44	527	0.08	0.08	96	
BLANK		06/09/88			0.02	0.01		ND	0	ERR	
C1	GLAZE PREPARATION	06/09/88	1.7	385	0.26	0.25	381	0.05	0.05	76	
C2	GLAZE PREPARATION	06/09/88	1.7	406	0.53	0.52	752	0.08	0.08	116	
AREA	GLAZE PREPARATION	06/09/88	1.7	493	1.82	1.81	2159	0.4	0.4	477	
BLANK		06/09/88			0.03	0.02		ND	0	ERR	
A8	BOWLS 21	06/09/88	1.7	333	0.31	0.30	529	0.08	0.08	141	30
A6	BOWLS ROW 3 MIDDLE	06/09/88	1.7	398	0.67	0.66	974	0.1	0.1	148	24
A7	BOWLS ROW 4 MIDDLE	06/09/88	1.7	459	0.22	0.21	268	0.08	0.08	103	30
A9	BOWLS N END E BAY	06/09/88	1.7	439	0.60	0.59	790	0.08	0.08	107	32
A5	BOWLS 17	06/09/88	1.7	286	0.14	0.13	266	0.03	0.03	62	30
A3	TANK CAST N BAY 16	06/09/88	1.7	370	1.18	1.17	1859	0.09	0.09	163	80 ****
A1	TANK CAST N BAY 1	06/09/88	1.7	368	0.40	0.39	622	0.08	0.08	128	80
AREA	TANK CAST N BAY 1	06/09/88	1.7	376	0.17	0.16	249	0.08	0.08	125	
AREA	CAST 35 40	06/09/88	1.7	397	0.25	0.24	355	0.08	0.08	119	
BLANK		06/09/88			0.00	-0.01		ND	0	ERR	
BLANK		06/09/88			0.02	0.01		ND	0	ERR	
BLANK		06/09/88			0.01	-0.00		ND	0	ERR	
BLANK		06/09/88			0.00	-0.01		ND	0	ERR	
BLANK		06/09/88			0.02	0.01		ND	0	ERR	

**** - FILTER WAS USED TWICE

ND - NOT DETECTED

Summary of Dust Exposures for Samples Containing Measurable Silica

Location	Type Sample	Resp. Dust mg/m³	Silica Dust mg/m³	% Silica %	PEL Resp. Dust mg/m³	Fraction of PEL
A. Slip House[a]						
1. a. Mix 3-4	Area	1.02	0.34	33	0.29	3.55
b. Mix 3-4	Area	2.98	1.16	39	0.24	12.21
2. a. Tank 3	Area	0.23	0.06	26	0.35	0.64
b. Tank 3	Area	1.09	0.22	20	0.45	2.44
3. Bins	Area	1.27	0.39	30	0.31	4.10
4. Mix 4	Area	0.27	0.12	43	0.22	1.21
Average		1.14	0.38	32	0.31	4.02
B. Casting Department[b]						
1. Bowl Cast 35/60	Area	1.84	0.14	8	1.03	1.77
2. Bowl Cast 32/41	Area	0.17	0.04	23	0.39	0.42
3. a. Tank Cast (A-4)	Personal	1.32	0.15	11	0.75	1.77
b. Tank Cast (A-3)	Personal	1.86	0.14	8	1.03	1.80
4. a. Bowl Cast (A-4)	Personal	0.71	0.20	28	0.34	2.11
b. Bowl Cast (A-4)	Personal	1.03	0.12	12	0.73	1.41
c. Bowl Cast (A-5)	Personal	0.27	0.06	23	0.41	0.65
d. Bowl Cast (A-6)	Personal	0.97	0.15	15	0.58	1.68
e. Bowl Cast (A-8)	Personal	0.86	0.15	17	0.51	1.67
Average		1.00	0.13	16	0.64	1.48
C. Glaze Spray Department[c]						
1. a. West Side	Area	0.11	0.05	45	0.21	0.51
b. West Side	Area	0.15	0.02	16	0.57	0.27
2. East Side	Area	0.92	0.14	15	0.59	1.56
3. Inspector (B-1)	Personal	1.40	0.31	23	0.41	3.42
4. a. Semiauto Bowls (B-4)	Personal	3.96	0.26	7	1.18	3.36
b. Semiauto Bowls (B-4)	Personal	5.34	0.43	8	0.99	5.40

(continued)

A-2 (continued)

Location	Type Sample	Resp. Dust mg/m^3	Silica Dust mg/m^3	% Silica %	PEL Resp. Dust mg/m^3	Fraction of PEL
c. Semiauto Bowls (B-4)	Personal	2.25	0.25	11	0.75	2.99
d. Semiauto Bowls (B-5)	Personal	2.50	0.19	8	1.03	2.42
e. Semiauto Bowls (B-5)	Personal	3.90	0.32	8	0.98	3.98
f. Semiauto Bowls (B-5)	Personal	1.20	0.15	13	0.68	1.77
g. Semiauto Bowls (B-6)	Personal	1.19	0.13	10	0.80	1.49
h. Semiauto Bowls (B-7)	Personal	1.11	0.20	18	0.51	2.17
5. a. Manual Lav. (B-8)	Personal	2.60	0.20	8	1.04	2.49
b. Manual Lav. (B-8)	Personal	4.35	0.49	11	0.75	5.79
c. Manual Lav. (B-8)	Personal	6.50	0.67	10	0.81	7.99
Average		2.50	0.25	14	0.75	3.04
D. Glaze Preparation Area[(d)]						
1. a. Near Office	Area	0.21	0.06	29	0.32	0.65
b. Near Office	Area	0.23	0.15	65	0.15	1.54
c. Near Office	Area	2.16	0.48	22	0.41	5.20
2. a. Formulator (C-1)	Personal	0.19	0.15	75	0.13	1.48
b. Formulator (C-1)	Personal	0.38	0.08	20	0.45	0.84
3. a. Mix Operator (C-2)	Personal	0.92	0.29	32	0.30	3.10
b. Mix Operator (C-2)	Personal	1.10	0.28	25	0.36	3.01
Average		0.74	0.21	38	0.30	2.26

(a) All samples (6 of 6) in this area had measurable quantities of silica.

(b) Forty-seven percent (9 of 19) samples in this area had measurable quantities of silica. Samples that did not contain measurable silica were not necessarily below the OSHA PEL, due to less than LOD quantities of silica.

(c) Sixty-two percent (15 of 24) samples in this area had measurable quantities of silica. Samples that did not contain measurable silica were not necessarily below the OSHA PEL, due to less than LOD quantities of silica.

(d) Seventy-eight percent (7 of 9) samples in this area had measurable quantities of silica. Samples that did not contain measurable silica were not necessarily below the OSHA PEL, due to less than LOD quantities of silica.

DYNAMIC AIR
Conveying Systems

June 2, 1988

WOODBRIDGE SANITARY POTTERY CORPORATION
500 Green Street
Woodbridge, New Jersey 07095

Attention: Mr. Thomas S. Tutwiler

Subject: Dense Phase Pneumatic Transfer System
Dynamic Air Proposal #1-A-188096-A

Gentlemen:

We offer our revised proposal 1-A-188096-A outlining the proposed equipment which is based on the routing and system design as requested by our representative in your area, Mr. Ed Zondag of KV2 Corporation.

Continued . . . .

DYNAMIC AIR, INC. • 1125 WOLTERS BLVD. • ST. PAUL MN 55110 • 612-484-2900 • DNMA UR TELEX NO 28-4141

June 2, 1988

WOODBRIDGE SANITARY POTTERY CORPORATION
Dynamic Air Proposal #1-A-188096-A

Page -2-

SECTION A: To convey

Material Characteristics:

Material	Flint & Feldspar
Bulk Density (Lbs/Cu.Ft. . .	70
Temperature	100°F
Particle Size	200 MESH
Moisture	0 - 3%
Abrasiveness	High
Gravity Flow	Good

Components to allow pneumatic truck to fill two (2) one hundred ton (100) storage silo's at an unloading rate equal only to the truck's capability.

A.1 Two (2) - 4" Truck/Hose adapters with dust cap and chain.

A.2 Twelve (12) - 4" Compression couplings with gaskets, bolts, and axial retainer bar.

A.3 Two (2) - 4" End receivers fabricated of mild steel, dust tight with wear shield.

A.4 One hundred - lineal feet (100') - 4" Schedule 40 tubing, shipped unpainted in 20-foot random lengths.

A.5 Two (2) - 4" Schedule 40 ceramic backed tubing bends at 90°.

A.6 One (1) - Electrical control enclosure to contain level control lights and On-Off control for bin vent filter.

A.7 Two (2) - Dynamic Air Model #400 dust filters, Series 343 with 400 square feet of filter media of reverse air, continuous cleaning design. Housing complete with filter access door. Included is a control board mounted in NEMA 12 enclosure with adjustable cleaning cycle designed for 120 volt, 60 hertz power. 15 CFM at 90 to 100 PSIG clean, dry, compressed air is required for cleaning.

PRICE: (EQUIPMENT ONLY) Items A.1 - A.7 . . . . $ 9,228.00

A.8 Two (2) - Storage silo's 12' 0" diameter 48' 4" overall height with 2858 cubic foot working capacity based on a 45° angle of repose, silos are of a welded carbon steel construction complete with four (4) support legs, maintaining a discharge clearance of 13' 0".

DESIGN SPECIFICATIONS

Design bulk density.................................70 lbs./cu.ft.
Seismic Zone..1
Wind Velocity.......................................100 MPH
Internal Pressure Rating............................14" H20
Internal Vacuum Rating..............................2" H20
Roof Load...30 PSF
Welding-Per AWS Using AWS Certified Welders

ACCESSORIES

- 20" Diameter manway.
-8" Diameter PRV flange.
-Bin vent filter matching flange.
-Two (2) 3/4" NPT couplings for level controls.
-60° Cone with a 10" diameter flange outlet.
-Fill line - stand off brackets.
-Deck guard railing.
-Ladder with safety cage assembly complete with rest platform every 30'0" intervals. (mounted on one (1) silo).
-Crosswalk assembly with hand railing, 4 foot span.

INTERIOR FINISH:

Unfinished and unpainted.

EXTERIOR FINISH:

Solvent wash and prime painted 2 mils DFT.

Foundation and anchor bolts to be designed and furnished by purchaser.

PRICE (EQUIPMENT ONLY): Item A.8.........................$ 28,400.00

ADDITIONAL EQUIPMENT:

(2) Pressure relief valves for silos.
(2) Vibra-Jet aeration system with controls NEMA (12) electricals.
(2) Air cannons complete with quick exhaust solenoid valve NEMA 12 electricals.
(4) Level control NEMA 4.
(2) 10" Manually operated maintenance gates.

PRICE: (ADDITIONAL EQUIPMENT ONLY).....................$ 8,070.00

SYSTEM 100:

To weigh and convey flint or feldspar from one (1) of two (2) storage silos to one (1) of four (4) receiving bins based upon the following material characteristics and design parameters.

Material Characteristics:

Material	Flint	Feldspar
Bulk Density (Lbs./Cu.Ft.)	70	70
Temperature	100°F	100°F
Particle Size	200 MESH	200 MESH
Moisture	3%	3%
Abrasiveness	High	High
Gravity Flow	Good	Good

General Design Parameters:

Type of System	Dense Phase, Convention Concept
Nominal Batch Weight	1400 Lbs.
Transporter Capacity	20 Cu.Ft.
Cycles Per Hour	14
Conveying Distance	100 Ft.
Conveying Line Size	3 In.
Conveying Rate	20,000 Lbs./Hr.

Calculated Air Requirements: (Based on above parameters.)

Average Air Consumption	50 SCFM
Total Air Consumption Per Cycle . . .	182 Std.Cu.Ft.
Fill Time	1 Minutes
Conveying Time	2.0 Minutes
Surge Air Usage During Blow Cycle .	91 SCFM

1.1 One (1) - Butterfly Valve 10" diameter constructed of cast iron Nodular Iron disc and stem with Black EPDM seats. Three-position valve with air actuator, solenoid, limit switches, 120 VAC, Nema 12 electrical enclosure.

1.2 One (1) - Dyna-Slide air-activated gravity conveyor, 8" wide by 12' long centerline inlet to centerline discharge at a 10° slope. Controls included are four 3/4" air metering valves, two 3/4" solenoid valves and one 3/4" air filter. Also included is one inlet section and a flanged discharge section. Unit is designed to discharge 30 cu.ft. of product per minute at a max. temp. of 140°F. Air source is understood to be from an air compressor and 3/4" air manifold piping is to be field furnished by others. This unit designed for fast and dribble feed.

1.3 One (1) - Inlet chute with the following features:

- Mild steel welded construction
- Three (3) support lugs for mounting
- 60° Cone with a 10" diameter outlet
- 8" Diameter inspection opening
- 10" Butterfly Valve (2-position)

1.4 One (1) - Dynamic Air Model #10C-200 weigh transporter, 20 cubic foot capacity. Vessels are designed to ASME code and National Board certified for 90 PSIG rating.

- Complete with the following:
- 10" Diameter inlet valve
- Vent valve
- Aeration Jets
- Rotatable Outlet
- Vessel constructed of carbon steel
- Valves constructed of cast iron with Nodular iron disc and stem with back EPDM
- Valves complete with actuator, solenoid and limit switches, 120 VAC, NEMA 12 electrical enclosure

1.5 One (1) - Weigh-transporter support stand, fabricated of mild steel complete with load cell mounting brackets, anti-sway rods with mounting brackets and fasteners, and three threaded leveling pad on each support leg.

1.6 Thirteen (13) - 3" Compression couplings with gaskets, bolts and axial retainer bar.

1.7 Five (5) - Dyna-Chek[3] booster fittings of molded nylon construction to control material velocity through the conveying line and to reduce wear. An exclusive design feature allows both the pressure and volume to be adjusted to determine exact material-to-air ratios.

1.8 One-hundred lineal feet (100') - 3" Schedule 40 tubing, shipped unpainted in 20-foot random lengths.

1.9 Three (3) - 3" Schedule 40 ceramic backed conveying line tubing bends at 90°.

1.10 Three (3) - 3" Butterfly 90° diverter valves including air inflatable valves with controls, flanged valve housing, and limit switches.

1.12 One (1) 3" End receiver, fabricated of mild steel, dust tight with wear shield.

1.12 One (1) - 4-Station delivery air control module. Unit complete with all the necessary air controls as required for system operation, prepiped and prewired with enclosure. This unit will use 2 regulators.

1.13 One (1) Dynamic Air Model #400, Series 343 Modu-Kleen® reverse jet cartridge dust collector; complete with the following features:

- 400 Square feet filter media
- Reverse jet continuous cleaning
- Carbon steel welded construction
- Quick release cartridges
- Access door
- Solid state sequence timer
- Safety grid under filter media
- Nema (12) electrical controls 120 bolt, 60 hertz
- 15 CFM require at 80 to 100 PSIG for reverse air cleaning
- Differential pressure gauge
- Design pressure of ± 17" W.G.
- Hopper bottom with 10" automatic valve and 10" dust pipe

Note: All mixers will be intervented by others.

1.14 One (1) - Programmable logic controller (PLC) to automatically weigh and convey both materials to mix tanks. Multiple batches of each material will be weighed out. When the first material is weighed out to the desired amount, the system will stop and wait for further operator instructions. Each batch will be printed. The operator will then select the desired amount of the next material and the system will stop when the total batch weight is achieved. The batches again will be printed. The following equipment will be included:

- NEMA 12 electrical control panel with graphics
- Allen-Bradley PLC 2/30 processor
- Report generation module
- Input/Output modules
- Model 200 scale with keypad
- One set of load cells with junction box
- Printer
- Complete software and documentation including wiring and piping drawings, input/output list, and written sequence of operation

PRICE: (EQUIPMENT ONLY) Items 1.1 thru 1.14 . . . . $ 80,222.00

Please note it is required that the customer provide clean, dry compressed air at 90 to 100 PSIG minimum for the above Dynamic Air system to insure optimum operation.

All prices are f.o.b. St. Paul, Minnesota and shipping points, freight collect.

Prices and terms are firm for thirty (30) days and are in accordance with the enclosed Dynamic Air Terms and Conditions.

Delivery: 8-10 weeks after receipt of approved drawings.

Terms: 25% upon receipt of order; 75% upon shipment of equipment net thirty (30) days with a 2% monthly finance charge on overdue balances.

Start-up service is at an extra cost as stated in the enclosed Terms and Conditions.

Unless stated above, we do not include state and local taxes, freight, installation labor and materials, motor starters, foundations and footings, pits, pit steel, any and all expansion joints, tubing supports, structural steel work, fasteners, compressed air, compressed air piping or anything not specified.

Dynamic Air will provide, at our expense, a preliminary checkout of the software program and/or electrical control at our facility; however, due to the custom nature of the equipment provided, final software changes may have to be provided in the field after final installation of all field connected devices is complete. These final modifications and/or changes, if required, will be at the customer's expense, chargeable at Dynamic Air's normal field service rates.

The above proposed Dynamic Air equipment, with the exception of the conveyor tubing, will be painted with one finishing coat of Dynamic Air standard green enamel. The conveying line is furnished unpainted. Such items as hoppers, steel silos, etc., are prime painted only. Purchased components from Dynamic Air suppliers to be painted manufacturer's standard color. If other than the standard paint is required, it can be furnished at an extra cost.

We wish to thank you for your interest in Dynamic Air's product and should you have any questions on our proposal, please feel free to contact us at your convenience.

Respectfully,

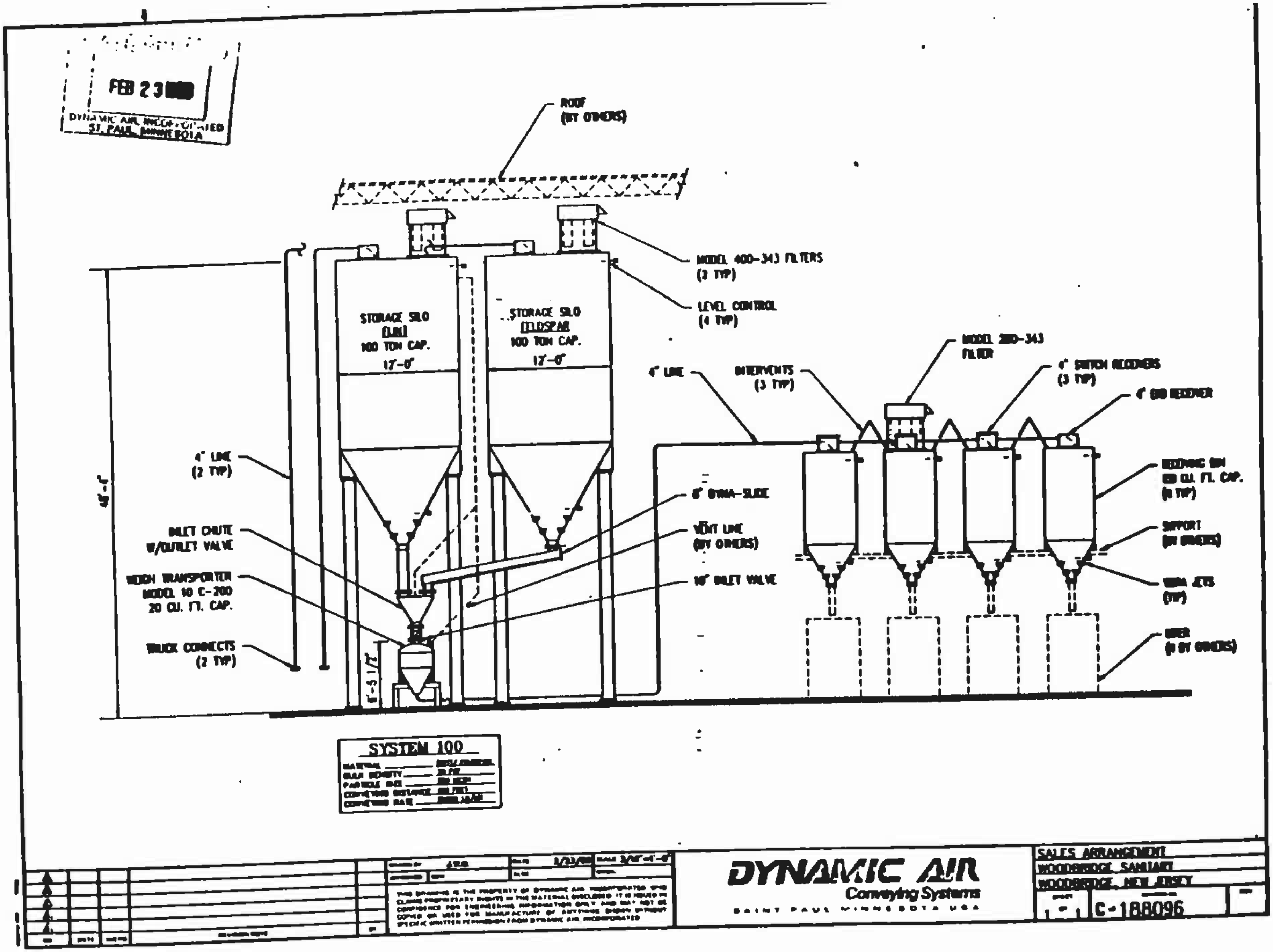
DYNAMIC AIR, INCORPORATED

Steven L. Coon
Regional Sales Manager

SLC/smk

Enclosures: Terms and Conditions 093083
General Literature

cc: Ed Zondag - KV2 Corporation


FEB 23
DYNAMIC AIR, INCORPORATED
ST. PAUL, MINNESOTA
ROOF
(BY OTHERS)
MODEL 400-343 FILTERS
(2 TYP)
LEVEL CONTROL
(4 TYP)
STORAGE SILO
100 TON CAP.
17'-0"
STORAGE SILO
FELDSPAR
100 TON CAP.
17'-0"
4" LINE
(2 TYP)
INLET CHUTE
W/OUTLET VALVE
WEIGH TRANSPORTER
MODEL 10 C-200
20 CU. FT. CAP.
TRUCK CONNECTS
(2 TYP)
4" LINE
INTERVENTS
(3 TYP)
MODEL 280-343
FILTER
4" SWITCH RECEIVERS
(3 TYP)
4" END RECEIVER
8" DYNA-SLIDE
VENT LINE
(BY OTHERS)
10" INLET VALVE
SUPPORT
(BY OTHERS)
SYSTEM 100
DYNAMIC AIR
Conveying Systems
SAINT PAUL MINNESOTA USA
SALES ARRANGEMENT
WOODBRIDGE SANITARY
WOODBRIDGE, NEW JERSEY
C-188096

Criteria for Guidelines for Lifting Tasks
Maximum Permissible Limit (MPL) and Action Level (AL)

(excerpt from NIOSH Pub. No. 81-122)

CRITERIA FOR GUIDELINE

It is concluded, regardless of the approach taken to evaluate the physical stresses of lifting, that a large individual variability in risk of injury and lifting performance capability exists in the population today. This realization requires that the resulting controls be of both an engineering and administrative nature. In other words, there are some lifting situations which are so hazardous that only a few people could be expected to be capable of safely performing them. These conditions need to be modified to reduce stresses through job redesign. On the other hand, some lifting conditions may be safely tolerated by some people, but others, particularly weaker individuals, must be protected by an aggressive selection and training program. To specifically define these conditions two limits are provided based on epidemiological, biomechanical, physiological, and psychophysical criteria.

1. Maximum Permissible Limit (MPL)

   This limit is defined to best meet the four criteria:

   a. Musculoskeletal injury rates and severity rates have been shown to increase significantly in populations when work is performed above the MPL.

   b. Biomechanical compression forces on the L_5/S_1 disc are not tolerable over 650 kg (1430 lb) in most workers This would result from conditions above the MPL.

   c. Metabolic rates would exceed 5.0 Kcal/minute for most individuals working above the MPL.

   d. Only about 25% of men and less than 1% of women workers have the muscle strengths to be capable of performing work above the MPL.

2. Action Limit (AL)

   The large variability in capacities between individuals in the population indicates the need for administrative controls when conditions exceed this limit based on:

   a. Musculoskeletal injury incidence and severity rates increase moderately in populations exposed to lifting conditions described by the AL.

b. A 350 kg (770 lb) compression force on the L_5/S_1 disc can be tolerated by most young, healthy workers. Such forces would be created by conditions described by the AL.

c. Metabolic rates would exceed 3.5 for most individuals working above the AL.

d. Over 75% of women and over 99% of men could lift loads described by the AL.

Thus, properly analyzed lifting tasks may be of 3 types:

1. those above the MPL should be viewed as unacceptable and require engineering controls

2. those between the AL and MPL are unacceptable without administrative or engineering controls

3. those below the AL are believed to represent nominal risk to most industrial workforces.

To illustrate this point, Figure 8.1 shows the three regions and boundaries defined for infrequent lifting (F < .2) from the floor (V = 15 cm [6 in]) to knuckle height (D = 60 cm [24 in]). Depending on the size of the object, in terms of horizontal hand location, the maximum weight which can be lifted can be determined

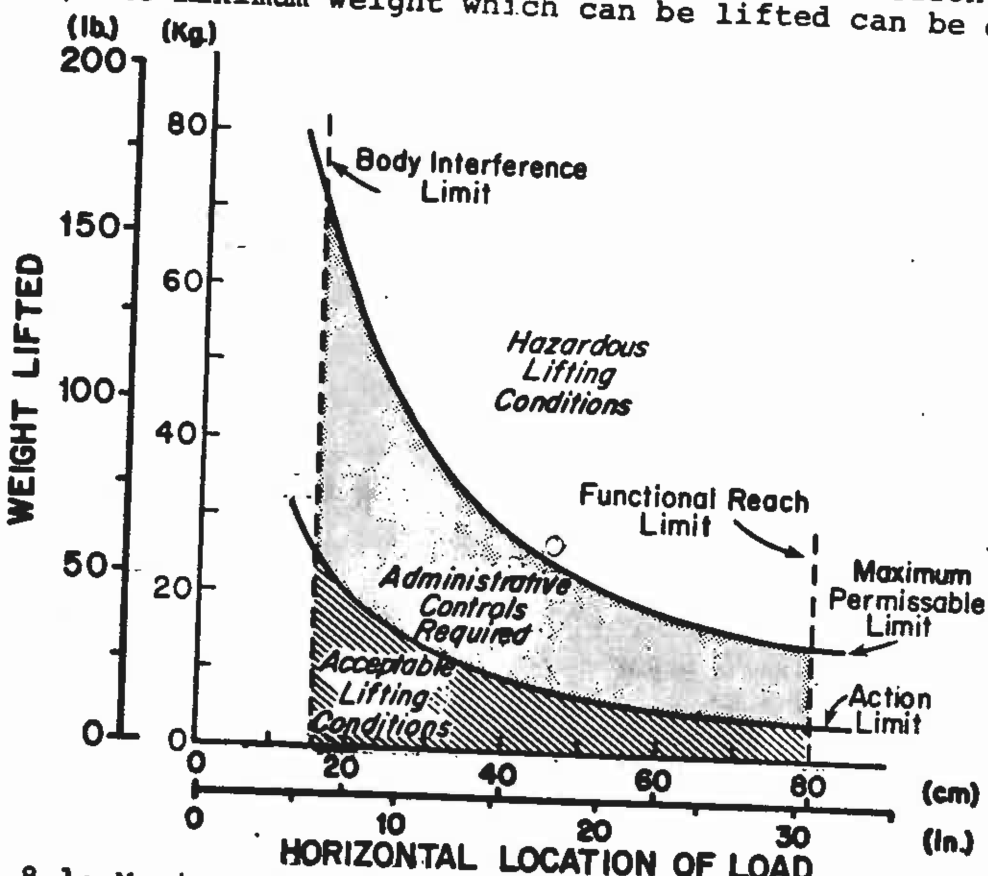
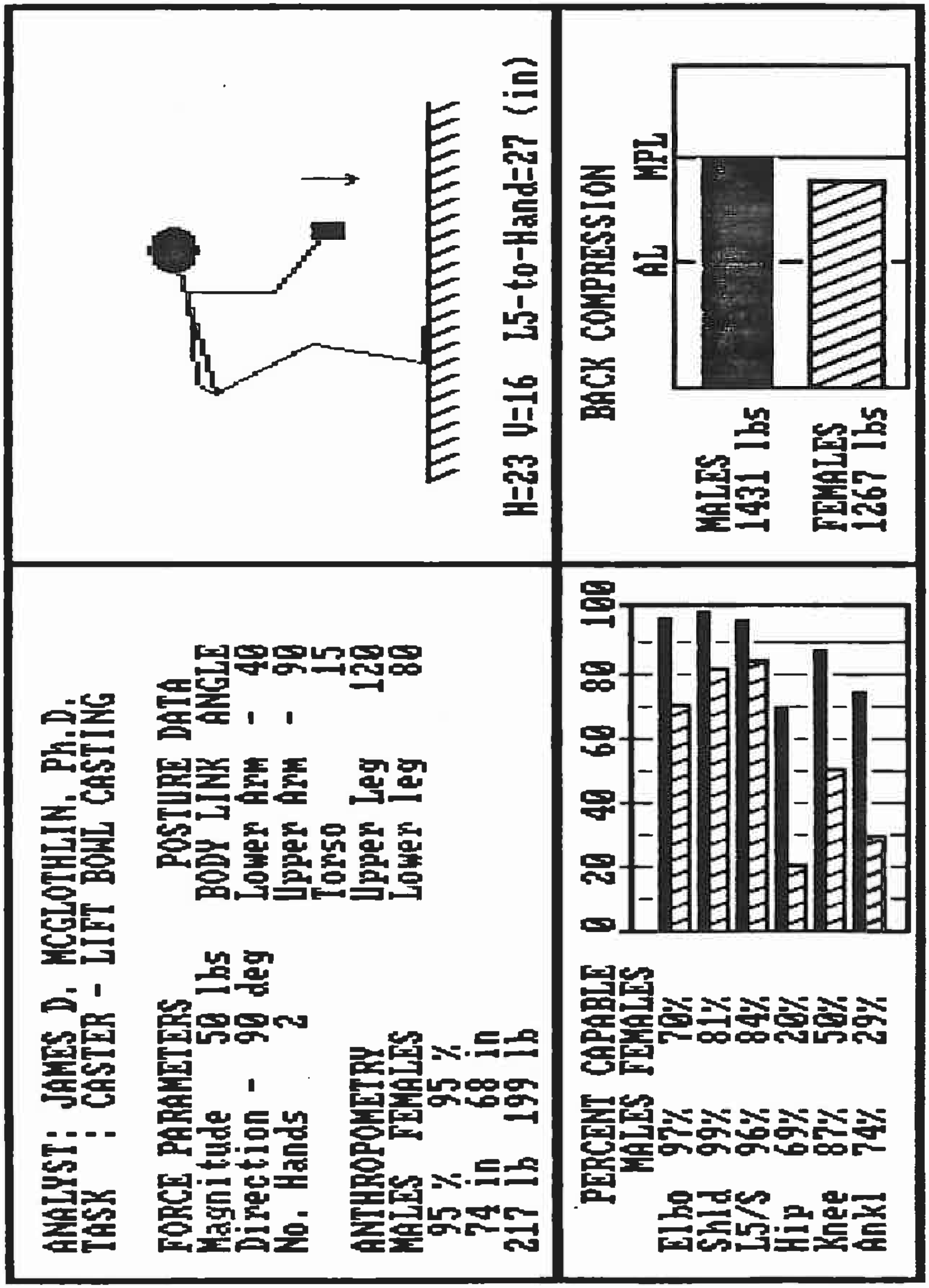


Figure 8.1: Maximum Weight versus Horizontal Location for Infrequent Lifts from Floor to Knuckle Height

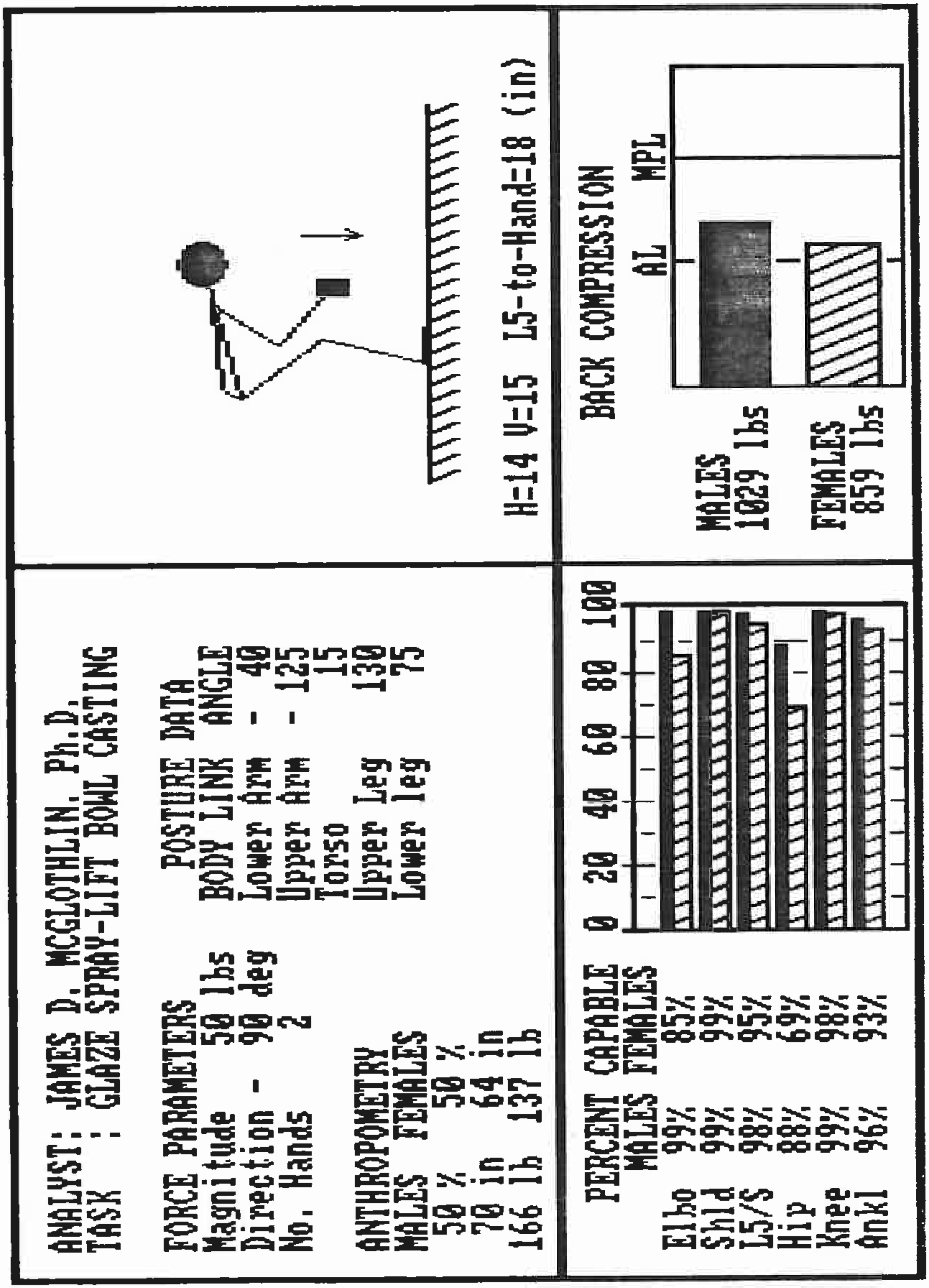
Appendix C-2

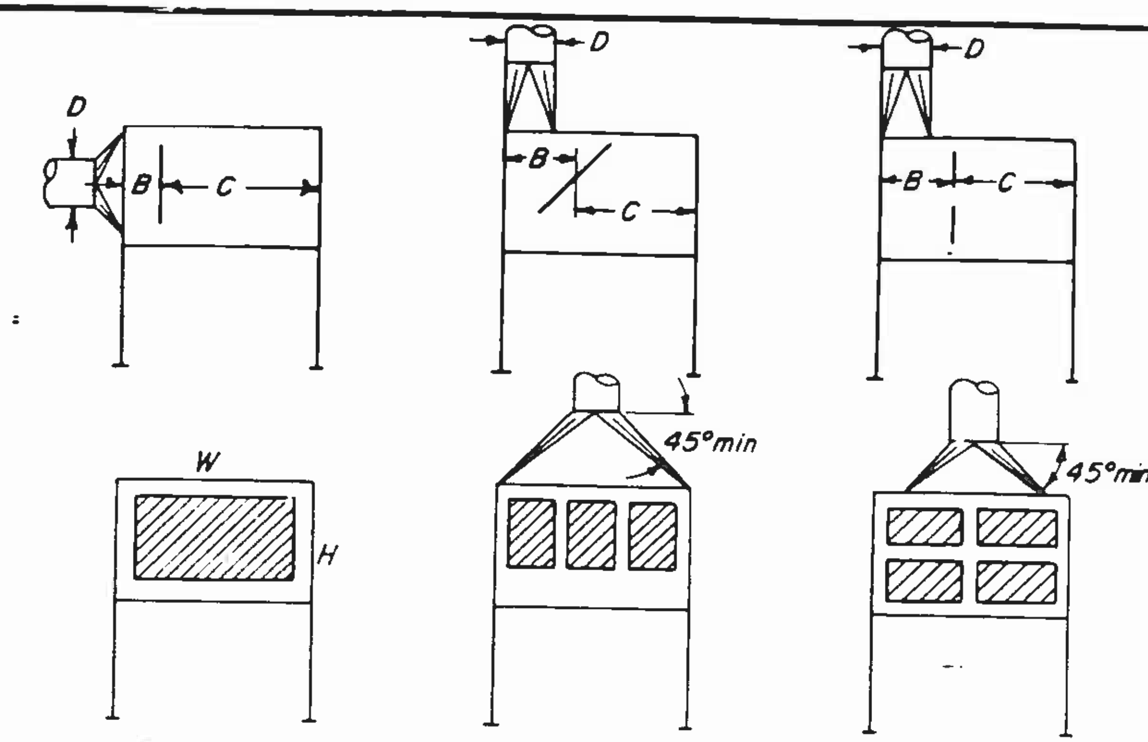
Static Strength Program - Caster



Appendix C-3

Static Strength Program - Glaze Spray Inspector





1. Solid Baffle
B = 0.75D
Baffle area = 0.60WH

2. Angular Baffle
B = D + 6"
Baffle area = 0.60WH

3 Split Baffle or Filters
B = D + 6"
Baffle area = 0.75 WH

For filter area See Note 2

Air spray paint design data
Any combination of branch ducts and baffles may be used
W = work size + 12"
H = work size + 12"
C = 0.75 W or H, whichever is larger.
Q = 200 cfm/sq ft (200WH) – for face area up to 4 sq ft
= 150 cfm/sq ft – for face area over 4 sq ft
Entry loss = Baffles: 1.78 slot VP + 0.25 duct VP
= Filters: Dirty filter resistance + 0.25 duct VP
Duct velocity = 1000 – 3000 fpm

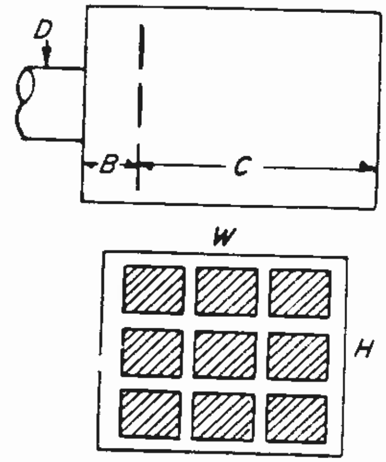
Airless spray paint design data
Q = 125 cfm/sq ft (125WH) – for face area up to 4 sq ft
= 100 cfm/sq ft – for face area over 4 sq ft

Notes:
1. Baffle arrangements shown are for air distribution only.
2. Paint arresting filters usually selected for 100-500 fpm, consult manufacturer for specific details.
3. For construction and safety, consult NFPA [113]

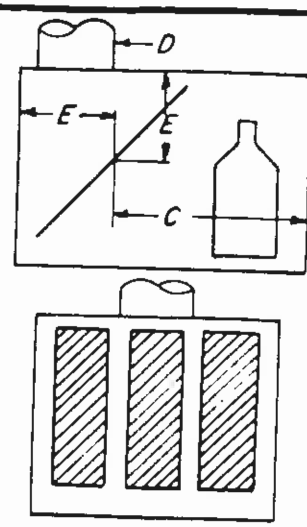
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

SMALL PAINT BOOTH

DATE 1-86 | VS-604



1 Split Baffle or Filters
B = 0.75 D
Baffle area = 0.75 WH
For filter area, See Note 2



2. Angular Baffle
E = D + 6"
Baffle area = 0.40WH
For filter area, See Note 2

Air spray paint design data

Any combination of duct connections and baffles may be used. Large, deep booths do not require baffles. Consult manufactures for water-curtain designs. Use explosion proof fixtures and non-sparking fan. Electrostatic spray booth requires automatic high-voltage disconnects for conveyor failure, fan failure or grounding.

Walk-in booth

W = work size + 6'
H = work size + 3' (minimum = 7')
C = work size + 6'
Q = 100 cfm/sq ft booth cross section
May be 75 cfm/sq ft for very large, deep, booth. Operator may require a NIOSH certified respirator.

Operator outside booth

W = work size + 2'
H = work size + 2'
C = 0.75 x larger front dimension
Q = 100-150 cfm/sq ft of open area, including conveyor openings.

Entry loss = Baffles: 1.78 slot VP + 0.50 duct VP
= Filters: Dirty filter resistance + 0.50 duct VP
Duct velocity = 1000-2000 fpm

Airless spray paint design

Q = 60 cfm/sq ft booth cross section, walk-in booth
= 60-100 cfm/sq ft of total open area, operator outside of booth

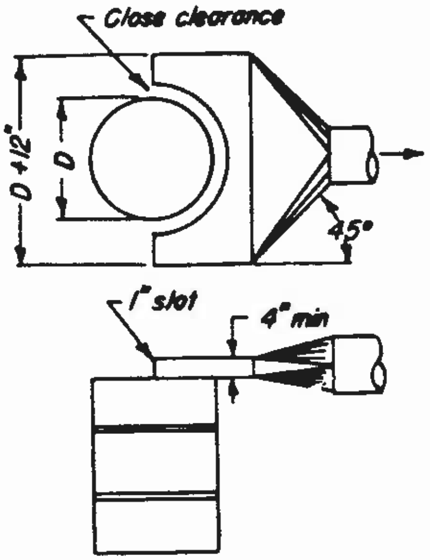
Notes:

1. Baffle arrangements shown are for air distribution only.
2. Paint arresting filters usually selected for 100-500 fpm, consult manufacturer for specific details.
3. For construction and safety, consult NFPA[113]

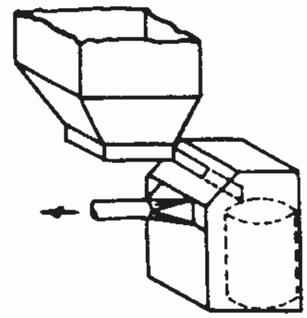
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

LARGE PAINT BOOTH

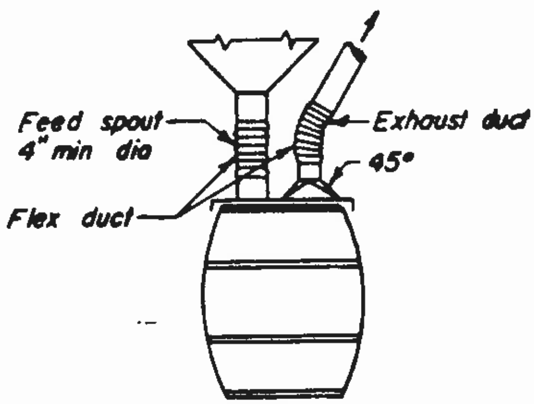
DATE 1-86	VS-603



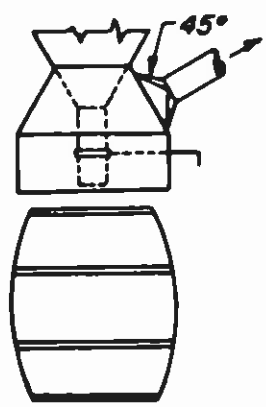
Q = 100 cfm/sq ft barrel top min
Duct velocity = 3500 minimum
Entry loss = 0.25 VP + 1.78 slot VP
Manual loading.



Q = 150 cfm/sq ft open face area
Duct velocity = 3500 fpm minimum
Entry loss = 0.25 VP for 45° taper



Q = 50 cfm × drum dia (ft) for weighted lid
150 cfm × drum dia (ft) for loose lid
Duct velocity = 3500 fpm minimum
Entry loss = 0.25 VP



Q = 300-400 cfm
Duct velocity = 3500 fpm min
Entry loss = 0.25 VP

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BARREL FILLING

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Appendix E

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. (513) 841-4221.

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

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

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