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COMMERCIAL STEEL TREATING COMPANY
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NIOSH INVESTIGATOR:
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I. SUMMARY

On January 9, 1992, the National Institute for Occupational Safety and Health (NIOSH) received a request through the Sentinel Event Notification System for Occupational Risk (SENSOR) Program, from the Ohio Department of Health (ODH) to assist them in investigating a death of a worker who died from silico-tuberculosis that was acquired from a sandblasting operation at the Commercial Steel Treating Company in Cleveland, Ohio. This sentinel occupational event of silicosis, was recognized by an infectious disease physician while treating the patient for Mycobacterium kansassii. The physician reported the case of end stage silicosis to the ODH who identified the case as a "sentinel" event and requested a more thorough evaluation of the worksite for other possible silicosis cases.

On January 22, 1992, a team of investigators from ODH and NIOSH went to the facility and obtained information regarding the operation of the plant. The Ohio Department of Health obtained a total of four air samples of the sandblasting operation. One personal sample was collected outside of the blaster's helmet. Three area samples were collected inside the sandblasting room, immediately outside on the back of the sandblasting room, and in the center of the facility. All of the samples were evaluated for airborne respirable silica. The time-weighted average (TWA) respirable quartz concentration of the personal sample was 11.5 mg/m^3. The area sample TWA concentrations of respirable quartz were 24.4 mg/m^3, 0.39 mg/m^3, and undetected, respectively. All except the last are above the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) of 0.1 mg/m^3, and the NIOSH Recommended Exposure Limit of 0.05 mg/m^3.

Aware of the risk to current employees of excess exposure to the silica levels detected, on March 4, 1992, the ODH requested that NIOSH evaluate the respiratory health of the workers at the facility.

NIOSH investigators reviewed the pathology specimens and chest radiographs of the initial case, to confirm the presence of silicosis, and on March 31 and April 1, 1992, conducted a medical evaluation of the workers at Commercial Steel Treating Company. The evaluation included a medical and occupational history questionnaire, pulmonary function tests, and a chest x-ray. There were 16 males who participated in this survey. Thirteen of the participants currently worked at the facility, while 3 were former employees. The workers ranged in age from 20-78; the average age was 42. Tenure at the facility ranged from 2 months to 51 years. The average tenure was 15 years. Eleven of the workers were current or former sandblasters in the facility.

Five individuals (31%) had abnormal pulmonary function results (three with mild obstruction, one with mild restriction, and one with severe restriction and moderate obstruction). Chest x-rays were obtained on all individuals and were read by three B readers. Four of the employees had opacities in the lung suggestive of tissue reaction to silica dust (profusion of 1/0 or greater), one with advanced silicosis (International Labour Organization category C). This last worker was also the worker who had severe restrictive disease on spirometry. All of the workers with pneumoconiosis were presently or had been a sandblaster at the facility for at least 1 year. Four out of sixteen (25%), of the workers had x-ray changes suggestive of tuberculosis scarring in the lung.

No large differences in the descriptions of breathing and the prevalence of symptoms/symptom groups were apparent when the workers with and without sandblasting experience were compared. Overall,

the participants reported a high level of respiratory problems (exertional dyspnea, chronic bronchitis, and wheezing). Due to the small number of men involved in this survey, it was not possible to compare their symptom prevalences with those found in other populations.

Based on the sentinel case and the environmental and medical results of this evaluation a serious and extensive problem with respect to respirable silica dust from a sandblasting operation is documented. One documented death from silico-tuberculosis led to an investigation of a sandblasting operation, where another worker was found to have advanced silicosis, (severe restriction and moderate obstruction on pulmonary function, and progressive massive fibrosis on chest x-ray). Pulmonary function and chest x-ray abnormalities consistent with silica-induced lung damage were identified in other workers with sandblasting exposure. Recommendations regarding medical screening and engineering controls are presented.

KEYWORDS: SIC, 3471 (Electroplating, Plating, Polishing, and Coloring), Silica, Pneumoconiosis, Obstructive Lung Function, Restrictive Lung Function, Silicosis, Silico-Tuberculosis, Respirable Quartz, Medical Screening, Mycobacteria, Chest X-ray, Sandblasting

II. INTRODUCTION

In January 1992, the Ohio Department of Health (ODH) requested technical assistance from NIOSH to investigate the death in March 1991, from silicosis, of a worker who had been employed as a sandblaster for a period of 10 years at Commercial Steel Treating Co., Cleveland, Ohio.

This worker presented to a Cleveland area hospital with severe respiratory compromise. He was followed and treated for a period of 9 months for accelerated respiratory decline due to advanced silicosis and associated Mycobacteria kansassii infection. His treating physician notified the state health department of his death and mentioned its possible relationship to the sandblasting exposure.

On January 22, 1992, a joint walk-through survey was conducted by representatives from the ODH and NIOSH. A meeting was arranged with the reporting physician to review the radiographs and pathology specimens from the sentinel case. The medical data confirmed a case of advanced silicosis.

An industrial hygiene interim report prepared by the ODH, was sent to the facility addressing the levels of respirable quartz dust measured.[1] This letter recommended immediate changes in the current practice of sandblasting, and highlighted concerns for the health of current workers at the facility.

The NIOSH medical evaluation included chest x-rays, spirometry, and questionnaires. All participants had their individual results mailed to their home address or to personal physicians at the participants request.

III. BACKGROUND

FACILITY OPERATION

Typical services provided at the facility include heat-treating a customer's product (usually a weldment) in one of ten furnaces. Nine furnaces are gas fired and one is electric. Heating is followed by cooling the product in either air, oil, or water, depending on the customer's requirements. The product is then straightened with a press as needed, and finally sandblasted in a blast booth.

The facility has a total of 17 employees: 3 office personnel, 12 production workers, and 2 maintenance workers. The plant operates on three shifts: midnight to 8:00 a.m., 8:00 a.m. to 4:00 p.m., and 4:00 pm. to midnight. All three shifts have a full-time sandblaster.

SANDBLASTING OPERATION

The sandblasting is done to provide a "white to near white" finish to the weldment after it has been heat-stressed by one of the ovens at the facility. The process of "heat stressing" leaves an onionskin layer on the metal surface. The sandblaster removes this onionskin layer by "blasting" silica sand onto the metal surface. The process of blasting fractures the sand and creates a mixture of fine quartz dust and sand. The heavier sand is reclaimed through a low pit, while the lighter dust is diverted to a baghouse behind the sandblasting booth.

The sandblasting operation is performed in an enclosed sandblasting booth connected to a dust collector. The sandblaster wears a blasting helmet with an external air source and typically performs the blasting operation for 6 hours a shift. During the remaining 2 hours, sand that has settled on the floor is shoveled into a hopper to be recycled. The process consumes about 5 tons of sand per week. The sandblasting booth is 20 feet long, 16 feet wide, and 8 feet high and is located in the southwest corner of the building. Ventilation for the booth includes: 1) two exhaust take-offs 2 feet from the floor and 8 feet long on the rear sides of the room, and 2) two 18-inch-square openings of unbaffled metal mesh in the ceiling to allow make-up air to enter the room.[1]

The sand reclamation system operates as follows: 1) Sand that has settled to the floor passes through a grate located below the rear half of the room into a hopper; 2) A screw feeder empties the hopper into a bucket elevator; 3) Sand falls by gravity through a chute onto a screen, where sand is separated from dust; 4) Sand goes into a storage vessel to be used again in blasting, and the dust is routed to a small baghouse for disposal. Sand can be reused three or four times. About four or five times each shift the sandblaster shovels sand from the floor onto the grate to be recycled. The sandblaster will wear a particulate mask to perform the shoveling.

During the walk-through survey, the top portion of the bucket elevator enclosure was missing, and a door and access port to the sand separating screen were both open. There was a pile of dust estimated to be 15 feet by 50 feet in size and ranging in depth from 1 foot to over 6 feet. This pile contained an estimated 50 to 100 tons of material, or about 10 to 20 weeks accumulation. The company reported the dust was usually removed bi-weekly. The facility did not have a written policy describing the process of removal, nor did they provide the employees any formal training in the technique or risks involved in the removal of the materials.

INDUSTRIAL HYGIENE EVALUATION

An ODH industrial hygienist conducted environmental sampling at the Commercial Steel Treating Company on January 22, 1992. The results were reported to the company in March 1992.[1] Personal and area samples were collected during typical sandblasting operations in an attempt to evaluate the workers' actual and potential exposures to respirable crystalline silica. Samples were collected over the entire workshift. Filters were analyzed according to NIOSH Analytical Method 7500.[2]

Quartz was the only form of crystalline silica reported from laboratory analysis of the filters. A personal sample collected outside of the sandblaster's helmet had a TWA respirable quartz concentration of 11.5 mg/m^3. The sample collected inside the helmet was not useable due to pump flow control problems. Of the three area samples collected, the one inside the sandblasting booth had 24.4 mg/m^3 of respirable quartz, the one outside the back of the sandblasting booth had 0.39 mg/m^3, and the one located at the center of the factory had no detectable silica. All of these samples were collected for a full shift.

To prevent silicosis, NIOSH recommends that exposure to respirable quartz dust be controlled so that no worker is exposed to a TWA concentration greater than 0.05 mg/m^3 (REL).[3] The OSHA PEL and the American Conference of Governmental Industrial Hygienist (ACGIH) Threshold Limit Value (TLV) for respirable quartz dust are both 0.1 mg/m^3.[4,5]

The personal sample collected on the outside of the sandblaster's helmet (11.5 mg/m^3) is an exposure 230 times larger than the NIOSH REL. The respirator worn by the sandblaster had a label on the inside of the helmet that stated it would provide a protective factor of 25 (dust concentrations outside the respirator would be reduced by 25 times due to its use).[6] Wearing a respirator with a protection factor of 25 would theoretically provide adequate protection for respirable quartz concentrations of up to 25 times the NIOSH REL, far less than the measured level of 230 times the REL. The area samples collected inside the sandblasting booth (24.4 mg/m^3) and outside the back of the booth (0.39 mg/m^3) additionally indicate the potential for overexposures to respirable quartz dust both for the sandblaster and workers in the vicinity outside the sandblasting booth.

IV. EVALUATION OF INITIAL WALK-THROUGH SURVEY

Areas of concern identified during the walk-through included inadequate booth ventilation, inadequate personal respiratory protection for sandblasters and helpers, faulty operation of the dust collecting devices, and lack of hazard communication training for employees working in and around the sandblast booth. Specifically, a 3M 8500 mask was worn while the sandblaster shoveled used sand from the floor into the grate to be recycled. The sandblaster working at the time of the walk-through survey had facial hair which interfered with the mask seal. (This sandblaster was later identified to have severe restrictive and moderate obstructive lung function loss, with category C PMF.) There was no respiratory protection program, and no formal training of employees of risks involved in being exposed to silica containing dust. There also existed significant "leaks" in the recycling system, which had resulted in the significant accumulation of dust around the baghouse due to doors not being adequately closed and discharge valves being open.

Initial employment physical examination records were reviewed for the current and previous employees. Each employee had an initial medical evaluation which consisted of a brief review of systems and a basic medical exam. There were no chest x-rays obtained on any employee at the time

of the initial evaluation.

After the initial walk-through survey, and review of the initial exposure assessments made by the industrial hygiene team, from the ODH, the company was notified by ODH that the medical risks of the current employees were a significant concern. Recommendations were made by ODH to immediately alter current sandblasting practices and to adhere to a more stringent respiratory protective practice.

Aware of the risk of the current employees who have been exposed to the silica-containing dust, the ODH requested additional technical assistance from NIOSH to conduct a medical evaluation of all current and past employees with greater than 1 year of employment.

V. METHODS

The medical investigation was conducted on March 31 and April 1, 1992. Components of the survey included a standardized respiratory questionnaire, a chest radiograph, and spirometry.

QUESTIONNAIRE

The questionnaire (Appendix I) which was administered by a NIOSH employee, addressed symptoms of cough, phlegm, wheezing, breathlessness, and past respiratory and heart disease. Additional questions related to cigarette smoking, and occupational history.
The following definitions were established for the purpose of analysis.

"Chronic cough" -cough on most days for 3 months a year.
"Chronic phlegm" -the production of phlegm on most days for at least 3 months during the year.
"Chronic bronchitis" -chronic phlegm production for at least 3 months a year for 2 years.
"Exertional dyspnea" -shortness of breath brought on by walking with people of the same age on level ground.
"Wheezing or whistling sounds in chest" -those noises in chest not associated with a cold.
"Seasonal Rhinitis" - nasal drainage on most days for as much as 3 months each year.
"Non-diagnosed Asthma" -attacks of shortness of breath with wheeze, with normal breathing in between attack, with no history of a medical diagnosis of asthma

CHEST X-RAY

A standard posterior-anterior (PA) chest radiograph was obtained for each participating employee. Chest x-rays were read using the International Labour Organization (ILO) 1980 classification system for pneumoconiosis (dust related lung disease).[7] Each x-ray was read independently by three B readers, who had no prior knowledge of the participants age, occupation, or smoking history (a B reader is a physician trained and certified in the use of the ILO system). The ILO classification system is used extensively internationally for epidemiological research, for the surveillance of those in dusty occupations, and for clinical purposes. Parenchymal and pleural abnormalities in the lung are recorded with a positive (pneumoconiosis) being defined as a small opacity perfusion of 1/0 or greater, in at least two of three readings.

SPIROMETRY

One-second forced expiratory volume (FEV_1) and forced vital capacity (FVC) were measured with an Ohio Medical Model 822 dry rolling seal spirometer attached to a Spirotech 200B dedicated computer. Equipment and test procedures conformed to the American Thoracic Society standards for screening spirometry.[8] Predicted values for FEV_1 and FVC were calculated using the equations of Knudson;[9] these values were multiplied by 0.85 to obtain the predicted values for blacks.[10]
Test results were compared to the 95th percentile lower limit of normal (LLN) values obtained from Knudson's reference equations to identify participants with abnormal spirometry pattern of obstruction and restriction.[9] (For each spirometric parameter, 5 percent of the population will have a value that falls below the LLN, while 95% will have results above the lower limit.)

Using this comparison, obstructive and restrictive pattern were defined as:

Obstruction: Observed ratio of FEV_1/FVC% below the LLN
Restriction: Observed FVC below the LLN, with FEV_1/FVC% above the LLN

The criteria for interpretation of the level of severity for obstruction and restriction, as assessed by spirometry, is based on the following classification scheme.

	Obstruction ($FEV_1/FVC * 100$)	Restriction (% Predicted FVC)
Mild	>60	
		>65
Moderate	≥45 to ≤60	
	≥51 to ≤65	
Severe	<45	
	<51	

VI. TOXICOLOGY

The use of sand for abrasive blasting typically results in the fracturing of the sand into fine particles which become airborne. Inhalation of this freshly fractured crystalline silica appears to be more fibrogenic than aged silica.[11]

A worker can develop three types of silicosis, depending on the airborne concentration of crystalline silica: simple silicosis which occurs after many (usually 15 or more) years of relatively low exposure to free silica; accelerated silicosis which results from exposure to higher concentrations of free silica and developing 5 to 15 years after the initial exposure; and acute silicosis, in which exposure to high concentrations results in symptoms developing from as soon as a few weeks to 4 or 5 years after the initial exposure.[12] Simple silicosis and accelerated silicosis manifest as scarring of the lung parenchyma, as a result of the fibrogenic reaction to the silica dust, accelerated silicosis becomes manifest earlier due to the higher concentrations over a shorter period of time. The scarring that is created results in less of an ability for oxygen transfer in the lung, and a decrease in the lungs volume of air. Acute silicosis occurs in situations where the lung has an overwhelming degree of exposure to silica and is associated with a proteinaceous fluid accumulating in the lungs as a result of the lungs reaction to the silica dust. Acute silicosis can cause death from the flooding the lungs with the proteinaceous fluid and has very little scarring that is typical of the other two forms.

Sandblasters are at risk of developing acute or accelerated silicosis because they are potentially exposed to high concentrations of free and freshly fractured silica.[13] Mycobacterial or fungal infections often complicate silicosis cases and in many cases can be fatal.[14] These infections are believed to be due to the reduced ability of silica-filled macrophages to kill the mycobacteria and other organisms.[15]

Because of the risk of silicosis associated with sandblasting, and the difficulty in controlling the exposure, the use of crystalline silica for blast cleaning operations was prohibited in Great Britain in 1950 [21], and in other European countries in 1966. In 1974, NIOSH recommended that silica sand (or other substances containing >1% free silica) be prohibited as an abrasive blasting material.[3] Evidence now indicates that crystalline silica is a potential occupational carcinogen, and NIOSH is reviewing the data on carcinogenicity.[16,17,18]

VII. STUDY RESULTS

QUESTIONNAIRE RESULTS

A letter was sent by the ODH to 29 current and former employees notifying them that they would be eligible for medical testing. Sixteen males participated in this survey: 13 of the participants were

currently employed, and 3 were former employees. The workers ranged in age from 20 to 78; the average age was 42. Ten of the participants were black (62%) and the remaining 6 were white. Tenure at Commercial Steel ranged from 2 months to 51 years. The average tenure at this work-site was 15 years.

Eight of the 16 men, 4 of whom had sandblasting experience, reported that they had been skin tested in the past for tuberculosis. All test results were reported to be negative. One employee with 10 years of sandblasting experience reported current treatment for Mycobacterial kansassii infection of the lung. Two employees (one with sandblasting experience) reported that a blood relative(s) (children and siblings) had a history of tuberculosis.

Eight of the participants were current smokers, with an average age of 41 years and an average smoking history of 22 pack years. Three participants were former smokers with an average age of 48 and average smoking history of 10-pack years. There were five participants who had never smoked.

Seven (44%) of the 16 participants reported that they knew of no health problems associated with sandblasting. Six of the twelve employees who had done sandblasting, were never told and were unaware of health problems associated with sandblasting.

CHEST X-RAY RESULTS

Radiographs from four participants had a median reading consistent with pneumoconiosis (dust related lung disease). Three of the participants had findings of simple silicosis, and one participant had extensive scarring and lung volume loss consistent with advanced silicosis (ILO category C). Four employees had radiographic findings of tuberculosis read by the ILO readers. One of these employees had active Mycobacterium kansasii infection. Two employees had granuloma formation, signifying past disease, one employee had advanced silicosis. All of the participants with radiographic findings had been sandblasters at the facility for at least 1 year.

Of the participants with dust related chest x-ray changes, none had seen a physician or had a chest x-ray taken for pulmonary complaints, including the worker with advanced category C findings.

PULMONARY FUNCTION TEST RESULTS

All 16 participants completed pulmonary function testing. Five participants (31%) had pulmonary function tests that did not fall within the normal range. All five participants were current cigarette smokers, and three had sandblasting experience and chest x-ray signs of pneumoconiosis. Of the participants with abnormal pulmonary function, three had mild obstructive patterns, one had a mild restrictive pattern, and one was both moderately obstructed and severely restricted.

VIII. DISCUSSION

Both the environmental and medical evaluations at Commercial Steel indicate that current sandblasters and other employees who work in the area around the sandblasting chamber are at a high risk of significant silica exposure and silicosis.

In addition to the fatal case of silicosis in a sandblaster from this facility, the medical evaluation detected another worker with advanced silicosis on chest x-ray and severe impairment of pulmonary

function. Four other workers were found to have radiographic changes consistent with silicosis. Two of them had obstructive changes in pulmonary function. The worker with a pure restrictive lung impairment had no x-ray signs of silicosis. The individual with the severe restriction and obstruction, had category C pneumoconiosis and was notified at the time of the study of the results, due to the severity of his lung findings. He commented that he knew his health was bad, but couldn't afford to see a physician, and couldn't afford to quit working because he had a family to support. This same worker commented that when he was hired 10 years ago he was not given formal instruction and warning about the sandblasting operation. The day he was hired he observed, through a window, a sandblaster doing sandblasting. He was asked if he could do this job. The following day he began working as a sandblaster.

One worker, who has been a sandblaster for 10 years, did not have detectable radiographic changes consistent with pneumoconiosis, but did have radiographic changes consistent with tuberculosis, and is being treated for Mycobacterium kansassii infection. This may represent an infectious disease related to suppression of the lung immune response known to be caused by silica particles.[15] Of the three other x-rays with changes consistent with tuberculosis, two have had skin testing for tuberculosis (one more than 10 years ago, and the other at a unspecified time) both workers state that their skin testing was negative, the other worker has never been skin tested for tuberculosis. All individuals were notified of the concern for active tuberculosis infection.

IX. RECOMMENDATIONS

NIOSH has recently published an ALERT requesting assistance in the prevention of death in sandblasters.[19] In the ALERT are recommendations, many of which have been included in this report. These recommendations are made to provide the workers the opportunity to have a working environment that maintains as little exposure to crystalline silica as possible. The risk of silica under the conditions that existed at Commercial Steel at the time of our survey, highlight the need for the facility to make changes to ensure a safe working environment.

First and foremost a recommendation to immediately discontinue the practice of using silica sand for the purpose of abrasive blasting was made at the time of the initial survey. This emphasizes the NIOSH recommendation made in 1974 that "Uncontrolled abrasive blasting with silica sand is such a severe silicosis hazard that special attention must be given to this problem. Silica sand, or other materials containing more than 1% free silica, should be
prohibited as an abrasive substance in abrasive blasting cleaning operations."[3]

If the use of silica sand is continued then:

1. Appropriate respirators should be provided and used. Respirators should also be provided and used for non-routine operations (occasional brief exposures above the environmental standard and for emergencies). For the purpose of determining the type of respirator to be used, the employer should measure the atmospheric concentration offree silica in the work-place. The employer should ensure that no worker is exposed to free silica in excess of the standard because of improper respirator selection, fit, use, or maintenance.

2. Informing employees of the hazards of free silica exposure and other occupational risks is imperative. A consistently documented and effective worker awareness program should be developed for education and protection. NIOSH recommended in 1974 that "each employee

exposed to free silica shall be apprised at the beginning of his employment or assignment to a free silica exposure area of the hazards, relevant symptoms, appropriate emergency procedures, and proper conditions and precautions for safe use or exposure.[3] OSHA requires this same standard as part of the HAZCOM regulations.[20]

3. Warning signs should be posted to mark the boundaries of crystalline silica contaminated work areas. These signs should warn workers about the hazard of free crystalline silica and specify any protective equipment required.

4. Work clothing worn during the process of abrasive blasting should be vacuumed before removal. Clothes should not be cleaned by blowing or shaking. Personal hygiene is an important element of any program for protecting workers from exposure to silica and other contaminants during the abrasive blasting operation. All sandblasting workers should wash their hands and faces before eating, drinking, or smoking, and they should not eat, drink, or use tobacco products in the work area.

5. Workers should change into work clothes at the work site. To minimize the amount of silica dust that may collect in workers' cars, homes, and in other work areas from a blasters' dusty clothing, washable coveralls or disposable clothing should be used whenever possible and should be removed before exiting a blasting area. Workers should change back into street clothes after working or showering and before leaving the work site.

6. Medical examinations should be available to all workers who may have "exposure to free silica" prior to employee placement and at least once every 3 years thereafter.[3]

Examinations should include as a minimum:

A. A medical and occupational history to elicit data on worker exposure to free silica and signs and symptoms of respiratory disease.

B. A chest radiograph classified according to the 1980 ILO International Classification of Radiographs of Pneumoconioses.

C. Spirometry.

D. Annual evaluation for tuberculosis, including skin testing with intradermal PPD. Anyone with a positive skin test should have appropriate medical evaluation for tuberculosis.

E. Employees should be informed of any abnormal findings resulting from these medical examinations. Medical results and records should be kept in a confidential manner.

The following recommendations are made to adequately monitor silica exposure and to provide medical screening and respiratory protection to workers exposed to the risks of silica containing dust:

1. Personal breathing samples of respirable quartz, representative of the workers' exposure, should be obtained on a regular basis. An adequate number of samples should be collected to permit determination of full-shift exposure.

2. When monitoring of the workers' exposures indicates a free silica concentration in excess of the NIOSH REL, suitable controls should be initiated to reduce the exposure

level below the recommended limit. In such cases monitoring should continue at 30 day intervals until 2 consecutive surveys indicate the recommended limit is no longer exceeded. Periodic review and evaluation of environmental and medical data should be performed to determine the effectiveness of control measures.

3. Records should be maintained of medical examinations and all environmental sampling, sampling and analytical methods, type of personal protection devices, if any, in use at the time of sampling, and the results. Records should be maintained for at least 30 years following termination of workers' employment. Each current and former employee should be able to obtain information on his work exposure.

X. REFERENCES

1. Liston R, [1992] Silica Survey Report, Company Number 12292, Ohio Department of Health. March 1992.

2. NIOSH [1984]. NIOSH Manual of Analytical Methods. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 84-100.

3. NIOSH [1974]. NIOSH criteria for a recommended standard: occupational exposure to crystalline silica. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 75-120.

4. ACGIH [1991]. Threshold limit values for chemical substances and physical agents and biological exposure indices for 1991-1992. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

5. CFR. Code of Federal regulations. U.S. Department of Labor, Occupational Safety and Health Administration. [29 CFR 1910.1000]. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

6. NIOSH [1987]. NIOSH Respirator Decision Logic. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH). Publication No. 87-108.

7. International Labour Office [1980]: Guidelines for the Use of ILO International Classification of radiographs of pneumoconiosis. Revised Ed. 1980. Geneva, Switzerland: International Labour Office, 1980 (International Office Occupational Safety and Health Series No. 22, Rev 80).

8. American Thoracic Society [1987]. Standardization of Spirometry 1987 update. Am Rev Respir Dis 136:1285-1298.

9. Knudson RJ, Slatin RC, Lebowitz MD, Burrows B. The maximal expiratory flow-volume curve. Normal standards, variability and effects of age Am Rev Respir Dis 1976;113:587-600.

10. Lanese RR, Keller MD, Foley MF, Underwood EH. Differences in pulmonary function tests among whites, blacks, and american indians in a textile company. J Occup Med 1978;20:39-44.

11. Vallyathan V, Shi X, Dalal NS, Irr W, Castronova V [1988]. Generation of free radicals from freshly fractured silica dust: potential role in acute silica induced lung injury. Am Rev Respir Dis 138:1213-1219.

12. Parkes WR [1982] Diseases due to Free Silica. Occupational Lung Disorders. Second Ed. Pgs. 134-175.

13. Merewether, ERA [1936]. The risk of silicosis in sandblasters. Tubercle 17:385-391.

14. Bailey WC, Brown M, Buechner HA, Weill H, Ichinose H, Ziskind M [1974]. Silico-Mycobacterial Disease in Sandblasters. Am Rev Res Dis 110:115-125.

15. Allison AC, Hart PD [1968]. Potentiation by silica of the growth of Mycobacterium tuberculosis in macrophage cultures. Br. J Exp Pathol 49:465-476.

16. NIOSH [1988a]. NIOSH testimony to the U.S. Department of Labor: statement of the National Institute for Occupational Safety and Health. Presented at the public hearing on OSHA PELS/Crystalline Silica, July 1988. NIOSH policy statements. Cincinnati, OH: U.S. Department of Health and Human Service, Centers for Disease Control, National Institute for Occupational Safety and Health.

17. IARC [1987]. IARC monographs on the evaluation of the carcinogenic risk of chemicals to humans: silica and some silicates. Vol. 42. Lyon, France: World Health Organization, International Agency for Research on Cancer, pp.49, 51, 73-111.

18. DHHS [1991]. Sixth annual report on carcinogens: summary 1991. Research triangle Park, NC: U.S. Department of Health and Human Services, Public Health Service, National Institute of Environmental Health Sciences, pp. 357-364.

19. NIOSH [1992]. NIOSH Alert - request for assistance in preventing silicosis and deaths from sandblasting. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-102.

20. CFR. Code of Federal regulations. U.S. Department of Labor, Occupational Safety and Health Administration. [29 CFR 1910.1200]. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

21. Factories Act, 1937 and 1948--blasting (casting and other articles) special regulations, [1949]. London, England: Ministry of Labour and National Service, Factory Department, SI 1949, No. 2225, pp. 4331-4335.

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2. OSHA
3. Commercial Steel

For the purpose of informing affected employees, copies of this report should be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.