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SUMMARY

In April 1990, the Division of Respiratory Disease Studies, National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE) from the United Steelworkers of America (USA), Local 3096. The USA asked NIOSH to evaluate workplace exposures at Blaw Knox Rolls Inc. which is a foundry located in Wheeling, West Virginia.

Environmental samples were collected during typical working shifts (day, evening, night) in the foundry in an attempt to evaluate the workers' exposures to total particulate, respirable silica, metals, isopropyl alcohol, and sulfur dioxide. Personal breathing zone samples were obtained on a number of foundry occupations, including molding, furnace tending, and maintenance. Area samples were also placed throughout the foundry near jobs thought to have excessive exposures.

The environmental results indicate that one of the major health hazards at the Blaw Knox Rolls foundry is exposure to free crystalline silica. To summarize, 22 (42%) of ***all*** (personal and area) samples collected exceeded the NIOSH Recommended Exposure Level (REL) of 50 $\mu g/m^3$ for respirable quartz and 13 (23%) exceeded the OSHA Permissible Exposure Limit (PEL) of 100 $\mu g/m^3$. It was also determined that a health hazard exists from employee overexposure to nickel, lead, chromium, sulfur dioxide and isopropyl alcohol. The metals chromium and nickel were found in excess of the NIOSH RELs of 0.001 mg/m^3 and 0.015 mg/m^3, respectively. Lead exceeded the OSHA PELs of 0.05 mg/m^3. Concentrations of sulfur dioxide ranged from 0.40 to slightly above 7 ppm, with the highest concentrations measured near the furnaces in Bay M and the horizontal spin spray coater in Bay J. Three sulfur dioxide samples exceeded both the NIOSH REL and the OSHA PEL of 2 ppm time-weighted average (TWA) exposure, with many more at or above the 1 ppm action level. A personal breathing zone sample for isopropyl alcohol showed an exposure of 708.2 ppm. This concentration exceeded both the NIOSH REL and the OSHA PEL of 500 ppm for a short term exposure limit (STEL) to isopropyl alcohol.

A medical survey was conducted which focused on the respiratory health of the exposed workers. The survey included a chest x-ray, a lung function test, and a self-administered respiratory questionnaires.

Of the 183 current workers, 129 (70%) participated in the medical survey. The mean age of those who participated was 43 years and the average tenure was 17 years. Pneumoconiotic changes with a median profusion reading of 1/0 or greater on the 12 point International Labor Organization (ILO) scale were considered to be present on the chest x-rays of two (1.6%) of the workers. Such x-ray markings can result from the inhalation of silica dust and other dusts. Obstructive lung function abnormalities were observed in 23% of the participants. Seventy-five percent of participants were current or former smokers and more than 10% had worked in other dusty trades prior to their Blaw Knox employment. No workers were determined to have restrictive lung function abnormalities.

As a result of environmental sampling, NIOSH investigators determined that, at the time of this survey, a health hazard existed due to elevated levels of nickel, lead, chromium, sulfur dioxide, isopropyl alcohol, and respirable free silica dust. Hazardous levels of these substances were measured at several locations in the Blaw Knox foundry. Recommendations for reducing these hazardous exposures and for providing medical surveillance are included in this report.

Because of the potential respiratory problems associated with the inhalation of silica dust, a medical evaluation including chest x-ray, lung function, and respiratory questionnaire was administered to workers. Two of the 129 participants were notified that their chest x-rays appeared to have rounded fibrotic nodular lung changes (with median x-ray profusion readings of 1/0 or greater on the 12 point ILO scale). These lung markings are consistent with silicosis which is a potentially debilitating pneumoconiotic (dust-induced) lung disease caused by the inhalation of silica dust. Of the 129 participating workers, 23% (30 workers) were found to have an obstructive lung function abnormality (an FEV_1/FVC ratio less than 86.9% of that predicted). Seventy-five percent of participants were current or former smokers and more than 10% had worked in other dusty trades prior to their Blaw Knox employment.

Keywords: SIC 3321. Gray and ductile iron foundries, silica, nickel, chromium, lead, pneumoconiosis, silicosis, cough, phlegm, spirometry.

INTRODUCTION

In April 1990, the Division of Respiratory Disease Studies, National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE) from the United Steelworkers of America (USA), Local 3096. The USA asked NIOSH to evaluate worker exposures to dusts created during cutting and grinding of metal rolls at Blaw Knox Rolls Inc., Wheeling, West Virginia.

On June 7, 1990, a NIOSH industrial hygienist made an initial site visit to the Blaw Knox facility. He discussed the HHE request and the evaluation with the company and union officials and conducted a walk-through survey of the foundry operations. As a result of that walk-through survey, NIOSH investigators determined that the health complaints outlined in the HHE request could have been caused by multiple sources and decided that the HHE evaluation should encompass most of the foundry operations.

On January 14-18, 1991, medical and environmental surveys were conducted. All Blaw Knox foundry employees were invited to complete a medical questionnaire and were offered lung function testing and chest x-ray examination. For the environmental survey personal breathing zone and work area samples were collected to quantify actual and potential worker exposures to metals, carbon monoxide, isopropyl alcohol, sulfur dioxide, and respirable silica. Prior to this field survey some of the workforce at Blaw Knox had been laid-off, curtailing a number of key operations which, therefore, could not be monitored. The impact of the lay-off on the results of this study will be discussed later in this report.

BACKGROUND

Blaw Knox produces rolls for both ferrous and non-ferrous rolling mills. The foundry, located in Wheeling, West Virginia, produces both conventional cast carbon and alloy steel rolls using static pouring processes, and rolls containing a matrix of various alloys from centrifugal casting processes. Rolls are custom made to meet the client's specifications in sizes from a few tons to sixty tons and varying diameters. Alloys used at Blaw Knox include iron, chromium, nickel, vanadium, manganese, molybdenum, magnesium, copper and carbon. The process of adding the various alloys depends on the type of roll being cast. The raw materials come mostly from waste or scrap (recycled) metal. Analysis of the scrap is performed to determine its composition. The scrap metal is stored in bins, according to the composition, until needed. Procedures observed at Blaw Knox are typical for a foundry, except that the scale is large, due to the size of the finished products. After a roll has been cast and cleaned by removing the molding sand, it is transported to the mill for finish work. The mill was not included in this health hazard evaluation.

During the late 1960's, over 1,000 workers were employed by Blaw Knox. Currently, there are approximately 180 workers at this foundry (not including the mill). This decline in employment is reportedly the result of market conditions and economic factors.

METHODS

Industrial Hygiene

During the period of January 14-18, 1991, environmental samples were collected during typical work shifts (day, evening, night) in the foundry in an attempt to evaluate the workers' exposures to total particulate, respirable silica, metals, isopropyl alcohol, carbon monoxide and sulfur dioxide. Personal breathing zone samples were obtained for a number of foundry job titles, including molders, furnace tenders, and maintenance. Area samples were also placed throughout the foundry near jobs thought to have potential for excessive exposures. The methods used to sample and analyze substances during this survey are as follows:

Respirable Dust and Silica

Samples for the estimation of respirable dusts and respirable quartz dust exposure, were collected on a pre-weighed, 37-mm (diameter), 5-µm (pore size) polyvinyl chloride (PVC) membrane filter, mounted in series with 10 mm nylon cyclone. Air was drawn through the filter at a flow rate of 1.7 liters per minute (lpm) using a battery powered sampling pump. Time-integrated samples were collected in the breathing zone of some workers for a full shift, generally 7 hours (depending on individual work schedules). In addition to the personal breathing zone samples, area air samples were collected in close proximity to various job categories. Job categories sampled included chippers, molders, crane operators, furnace tenders, and maintenance employees.

All air samples were analyzed for respirable dusts and total respirable crystalline free silica (alpha quartz, tridymite and cristobalite). Respirable dust content was analyzed gravimetrically according to NIOSH Method 0600[1] with the following modifications: (1) The filters were stored in an environmentally controlled room (21 ± 3°C and 40 ± 3% RH) and were subjected to the room conditions for a long duration for stabilization. Therefore, the method's 8- to 16-hour time for stabilization between tare weights was reduced to 5 to 10 minutes. (2) The filter and back-up pads were not vacuum desiccated. The total weight of each sample was determined by weighing the sample on an electrobalance and subtracting the previously determined tare weight of the filter.[1] The limit of detection (LOD) for this method was determined to be 0.01 mg per sample. (The LOD is defined as the smallest amount of analyte which can be distinguished from background.)

Respirable crystalline silica dust content was analyzed by NIOSH Method 7500,[1] using X-ray diffraction with the following modifications: (1) Filters were dissolved in tetrahydrofuran rather than being ashed in a furnace; and (2) Standards and samples were run concurrently and an external calibration curve was prepared from the integrated intensities rather than using the suggested normalization procedure. The analysis of some of the samples for quartz and cristobalite required additional modifications due to interference problems in the primary quartz region. These samples were analyzed on a Siemems D-5000 that used a profile-fitting program to remove the interference. The LOD and Limit of Quantification (LOQ) for quartz, cristobalite and tridymite were determined to be 0.015 milligrams (mg) for quartz and 0.03 mg for cristobalite and tridymite. (The 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 0.01).[1]

Metals

Samples for the estimation of exposure to elemental metals were collected on 37-mm (diameter), 0.8-µm (pore size) cellulose ester membrane filters, mounted in open-face cassettes. Air was drawn through the filters at a flow rate of 1.7 liters per minute (lpm) using a battery powered sampling pump. Time-integrated samples were collected in the breathing zone of some workers for a full shift, generally 7 hours (depending on individual work schedules). In addition to the personal samples, area samples were also collected in close proximity to various job categories, such as chippers, molders, crane operators, furnace tenders, welders, and maintenance employees. All air samples collected for elemental analysis were digested according to NIOSH Method 7300[1] and analyzed using a scanning inductively coupled plasma emission spectrometer. The LOD's for the analysis were:

ANALYTE:	LOD:
Chromium	1 µg/sample
Iron	1 µg/sample
Lead	2 µg/sample
Nickel	1 µg/sample

Gases

Sulfur Dioxide

Samples for the estimation of sulfur dioxide were collected using Dräger long term diffusion indicator tubes. These tubes operate on the basis of the diffusion processes in gases. For example, sulfur dioxide molecules to be measured flow into the tube and chemically react with a reagent layer in the tube. This chemical reaction results in a color change of the reagent layer. The mean concentration of sulfur dioxide is then calculated from the length of discoloration of the reagent layer, divided by the exposure time.

Isopropyl Alcohol

Samples for the estimation of isopropyl alcohol exposures were collected on standard size charcoal tubes at a flowrate of 10 cubic centimeters per minute (cc/min) using a battery powered sampling pump. Time-integrated samples were collected in the breathing zone of one worker for a 30 minute period. In addition to the personal samples, 30 minute and 2.5 hour area samples were collected in close proximity to the work areas. Only the job where a worker coats the inside of Chills (Bay J, near the sand plant) with a releasing agent as sampled. This sampling was done at the request of the company because of their concerns of a possible overexposure. Samples were analyzed according to NIOSH Method 1400, using a gas chromatograph equipped with a flame ionization detector.(1)

Medical

The medical survey was designed to evaluate the respiratory health of the Blaw Knox workers. The medical survey included a chest x-ray, a lung function test, and a self-administered, respiratory-oriented questionnaire.

Chest x-rays were taken on a full-size (14 × 17 inch) film and read independently by two B-readers for any presence of reticulo-nodular changes using the 1980 International Labour Organization (ILO) classification system.(2) B-readers are physicians specially trained and certified by NIOSH in the use of the ILO classification system. If the first two B-readers disagreed about the appearance of pneumoconiotic markings, the chest x-ray was re-read by a third B-reader.

According to the 1980 ILO classification system, the profusion of pneumoconiotic small opacities is graded on a 12 point scale, from 0/- to 3/+. Pneumoconiosis (fibrotic lung disease) was considered to be present on chest x-ray if two or more readers reported the presence of small opacities with profusion 1/0 or greater.

Lung function testing was conducted according to 1987 American Thoracic Society Guidelines.(3) Workers were asked to blow at least five times into an Ohio Medical Model 827 dry rolling seal spirometer attached to an HF4 dedicated computer. The flow-volume curve data were stored on magnetic tape and later retrieved to calculate forced vital capacity (FVC), forced expiratory volume in 1 sec (FEV_1), and the ratio of FEV_1 over FVC (FEV1/FVC).

Predicted lung function values based on sex, age and height for a nonsmoking asymptomatic population were calculated.[4] The predicted values for blacks were determined by reducing these values by 15% (with the exception of the predicted ratio of FEV_1/FVC). For each lung function test, the 95th percentile lower limit of normal is the value below which fewer than 5% of the reference population's results occur. The lower limits of normal from Knudson et al[4] (applicable for the age range of the Blaw Knox workers) were used to determine whether a worker's lung function was considered abnormal. Using the criteria of Knudson, a designation of "obstruction" was made when the ratio of FEV_1/FVC was below the 95th percentile lower limit of normal (less than 86.9% of that predicted for persons aged 25-99 which encompasses all of the ages of the Blaw Knox workers) and the FVC was above the lower limit of normal. A designation of restriction was made when FVC was below the 95th percentile lower limit of normal and the ration of FEV_1/FVC was above it.

At the time of the survey some of the foundry work processes had been shut down and some of the production crews had been laid-off. The questionnaire was, however, mailed to all the eligible wage workers and those who had been laid-off were contacted by telephone to encourage participation.

The questionnaire distributed was similar to the questionnaires developed by the British Medical Research Council (MRC) and International Union Against Tuberculosis (IUAT) for the investigation of occupational lung disease. Respiratory symptoms such as cough, phlegm production, and wheezing were assessed. The questionnaire included questions about previous medical and family histories as well as previous work exposures. A worker's smoking history was quantified in terms of "pack-years." This was calculated for each worker by multiplying the average packs of cigarettes smoked per day by the number of years that the worker smoked. For example, workers who had never smoked would be designated as having 0 pack-years and workers who had smoked 2 packs per day for 15 years would be described as having a 30 pack-year history.

EVALUATION CRITERIA

General Guidelines

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

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

The primary source of environmental evaluation criteria for the workplace are: (1) NIOSH Criteria Documents and recommendations, (2) the American Conference of Governmental Industrial Hygienist' (ACGIH) Threshold Limit Values (TLVs), and (3) the U.S. Department of

Labor (OSHA) occupational health standards. Both NIOSH recommendations and current ACGIH TLVs usually are lower than OSHA permissible exposure limits (PELs) because the OSHA standards may be required to take into account the feasibility of controlling exposures in various industries where the agents are used. The NIOSH recommended exposure limits (RELs), by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling (C) values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures. The environmental exposure standards, are summarized in Table 1.

Respirable Silica[5,6]

Crystalline silica dusts present one of the greatest and most widespread health hazards to foundry workers, sandblasters, tunnel workers, and miners. Crystalline silica, referred to as free silica, is defined as silicon dioxide (SiO_2) in the form of quartz, tridymite, and cristobalite. Crystalline silica is contained in molding and core-making sands, in clays used as bonding agents, in parting compounds, in some refractory materials, and as surface contamination on castings. Exposure can occur almost anywhere within the foundry. In most operations workers may have exposure to other contaminants as well. The chief concern of excessive free silica exposure is the development of silicosis. This form of pneumoconiosis is characterized by a nodular pulmonary fibrosis caused by the deposition of fine particles of crystalline silica in the lungs. In silicosis, as in many other pneumoconioses, the various stages of progression of silicotic lesions are related to the degree of exposure to free silica, the duration of exposure and the length of time the dust is permitted to react with the lung tissue. Symptoms usually develop insidiously, with cough, shortness of breath, chest pain, weakness, wheezing, and nonspecific chest illnesses. Silicosis usually appears after years of exposure, but may appear in a shorter time if exposure concentrations are very high. This latter form is referred to as rapidly-developing or acute silicosis, and its etiology and pathology are not as well understood. Silicosis is usually diagnosed through chest x-rays, occupational histories, and pulmonary function tests. Among the different crystalline structures and surface properties of quartz particles, some forms may have a greater capacity to produce silicosis. Crystalline silica may also cause lung cancer.[7]

Epidemiological studies have shown an association between silicosis and lung cancer.[8-10] The International Agency for Research on Cancer (IARC) reviewed the data regarding crystalline silica and determined that there is sufficient evidence for the carcinogenicity in laboratory animals and limited evidence for human carcinogenicity.[11] Because these data meet the OSHA definition of a potential occupational carcinogen as defined in 29 CFR 1990, NIOSH revised its policy on crystalline silica exposure criteria and recommended that OSHA consider crystalline silica as a potential occupational carcinogen.[7]

The ACGIH TLV for crystalline silica (cristobalite and tridymite) as quartz (respirable dust) is 50 micrograms per cubic meter ($\mu g/m^3$) of air. The ACGIH TLV for crystalline silica (crystalline quartz) as quartz (respirable dust) is 100 $\mu g/m^3$ as an 8-hour TWA. The OSHA PELs for crystalline silica, as revised in 1989, under the Air Contaminants Standard, were identical to the ACGIH TLVs. However, in 1992, the 11th Circuit Court of Appeals vacated the 1989 Air Contaminants Standard, and Federal OSHA is currently enforcing the previous transitional limits for crystalline silica. The OSHA transitional limit for crystalline silica is calculated based on the respirable dust exposure to dust containing $\geq$ 1% quartz. Some states operating their own OSHA-approved job safety and health compliance programs may continue to enforce the 1989 limits. The NIOSH REL for respirable crystalline silica is 50 $\mu g/m^3$ as a TWA for up to 10 hours per day during a 40-hour week. This REL is intended to prevent silicosis.

Chromium

The dust from chromium metal is relatively nontoxic. However, chromium alloys can be oxidized to trioxide (chromic acid anhydride), a soluble chromium (VI) compound. (Samples collected during this survey were assumed to be chromium trioxide fume.) There is strong evidence that hexavalent chromium compounds may cause irritation and allergic contact dermatitis, skin ulcers, and nasal irritation varying from rhinitis (inflammation of the nasal passages) to perforation of the nasal septum.(5) NIOSH considers chromium (VI) to be an occupational carcinogen.(7)

The ACGIH TLV for chromium VI (including water soluble and certain water insolubles) is 50 $\mu g/m^3$ for a TWA exposure. The current OSHA PEL for occupational exposure to chromium is being enforced at the transitional level of 1000 $\mu g/m^3$ (which is identical to the 1989 Air Contaminants Standard). The NIOSH REL for chromium VI is 1.0 $\mu g/m^3$ as a TWA for up to 10 hours per day during a 40-hour week.

Lead

Inhalation of lead dust and fumes is the major route of lead exposure. A second source of exposure may be from ingestion of lead dust deposited on food, cigarettes, or other objects. Once absorbed, lead is excreted from the body very slowly. Absorbed lead can damage the kidneys, peripheral and central nervous systems, and the blood-forming organs (bone marrow). These effects may be manifested as weakness, tiredness, irritability, digestive disturbances, high blood pressure, kidney damage, and neurological impairment such as slow reaction times. Chronic lead exposure is associated with infertility and with fetal damage in pregnant women.(12)

The ACGIH TLV for lead is 150 $\mu g/m^3$ for a TWA exposure. The current OSHA PEL for occupational exposure to lead is being enforced at the transitional level of 50 $\mu g/m^3$ (which is identical to the 1989 Air Contaminants Standard). The NIOSH REL for lead is 100 $\mu g/m^3$ as a TWA for up to 10 hours per day during a 40-hour week.

Nickel

Inorganic nickel compounds are suspected of causing lung and nasal cancers, based on the mortality experience of nickel refinery workers. Occupational exposure to nickel is defined as working with compounds, solutions, or metals containing nickel that can become airborne or can be splashed on the skin or in the eyes. Nickel fumes are respiratory irritants and may cause pneumonitis. Skin contact may cause an allergic skin rash known as "nickel itch". NIOSH considers nickel as an occupational carcinogen.(7)

The ACGIH TLV for nickel is 100 $\mu g/m^3$ for a TWA exposure. The current OSHA PEL for occupational exposure to nickel is being enforced at the transitional level of 100 $\mu g/m^3$ (which is identical to the 1989 Air Contaminants Standard). The NIOSH REL for nickel is 15 $\mu g/m^3$ as a TWA for up to 10 hours per day during a 40-hour week.

Sulfur Dioxide

Sulfur dioxide gas is a severe irritant of the eyes, mucous membranes, and skin. Its irritant properties are due to the rapidity with which it forms sulfurous acid on contact with moist membranes. In combination with certain particulate matter and/or oxidants, the effects may be markedly increased. Approximately 90% of all sulfur dioxide inhaled is absorbed in the upper respiratory passages, where most effects occur. High concentrations of sulfur dioxide may produce respiratory paralysis and pulmonary edema. Exposure to concentrations of 10 to 50 ppm can cause irritation to the eyes and nose, rhinorrhea ("runny nose"), choking, cough, nosebleeds, and in some instances, reflex bronchoconstriction ("wheezing") with increased pulmonary resistances.[5,13]

The ACGIH TLV for sulfur dioxide is 2 parts per million (ppm) for an 8-hour TWA exposure and 5 ppm for a short term exposure limit (STEL) of 15 minutes. The current OSHA PEL for occupational exposure to sulfur dioxide is being enforced at the transitional level of 5 ppm. However, OSHA recommends that exposures to sulfur dioxide be controlled at 2 ppm for a TWA exposure and 5 ppm for a STEL exposure, as outlined in the 1989 Air Contaminants Standard. The NIOSH REL for sulfur dioxide is identical to the ACGIH criteria of 2 ppm TWA and 5 ppm STEL exposures.

Isopropyl Alcohol

Isopropyl alcohol can affect the body if it is swallowed, is inhaled, or comes in contact with the skin or eyes. Exposure to high air concentrations of isopropyl alcohol may cause mild irritation of the eyes, nose, and throat. Drowsiness, headache, and incoordination may also occur. Isopropyl alcohol can produce mild central nervous system depression and it can alter consciousness in high concentrations.[5,13]

The ACGIH TLV for isopropyl alcohol is 400 parts per million (ppm) for an 8-hour TWA exposure and 500 ppm for a short term exposure limit (STEL) of 15 minutes. The current OSHA PEL for occupational exposure to sulfur dioxide is being enforced at the transitional level of 400 ppm for a TWA exposure. However, OSHA recommends that STEL exposures to isopropyl alcohol not exceed 2 ppm for a TWA exposure and 5 ppm for a STEL exposure, as outlined in the 1989 Air Contaminants Standard. The NIOSH REL for sulfur dioxide is identical to the ACGIH criteria of 2 ppm TWA and 5 ppm STEL exposures.

RESULTS

Industrial Hygiene

For simplicity, sampling results have been grouped into seven job activities as follows: furnace, cleaning/chipping, pouring, molding, maintenance, cranes and other.

Respirable Silica

The results of the silica analysis are shown in Table 2. A total of 53 samples were collected and subsequently analyzed using NIOSH Method 7500 for total silica content, to include quartz, cristobalite and tridymite. Of those 53 samples, 18 (34%) were personal breathing zone samples and 35 (66%) were area samples. To summarize, 22 (42%) of ***all*** (personal and area) samples collected exceeded the NIOSH Recommended Exposure Level (REL) of 50 $\mu g/m^3$ for respirable quartz. Eighteen samples (34%) exceeded the calculated OSHA Permissible Exposure Limit (PEL) for respirable dust containing $\geq$ 1% quartz (the crystalline silica content was determined to be 28.3%). Of the 18 personal breathing zone samples, 13 (72%) exceeded the NIOSH REL for quartz. Nine personal samples (50%) exceeding the calculated OSHA Permissible Exposure Limit (PEL) for respirable dust containing $\geq$ 1% quartz. Overall, the personal breathing zone samples, which represent as closely as possible the actual workers inhalation exposure, ranged from none detected (ND) to 280 $\mu g/m^3$ respirable silica.

Of the 35 area silica samples, 9 (26%) exceeded the NIOSH REL and 9 (26%) exceeded the calculated OSHA Permissible Exposure Limit (PEL) for respirable dust containing ≥ 1% quartz. Area sample concentrations ranged from ND to 199 $\mu g/m^3$ with the greatest majority of those exceeding exposure criteria being collected near molding operations.

One location not sampled during this survey was the "shakeout" area for cast steel. No shakeouts were performed during the NIOSH survey; however, based on general observations of the shakeout area, its engineering controls, discussions with employees and the results of our foundry wide silica sampling, it is anticipated that dust levels in this area would also likely exceed silica exposure criteria.

Furnace

Two personal breathing zone and 4 area samples were collected on job occupations or in areas of close proximity to the induction furnaces located in Bay M. Both personal samples, collected on different days, were in excess of both the NIOSH REL and the calculated OSHA Permissible Exposure Limit (PEL) for respirable dust containing ≥ 1% quartz. Silica concentrations for these personal samples were
198 $\mu g/m^3$ and 280 $\mu g/m^3$. Three area samples exceeded the calculated OSHA Permissible Exposure Limit (PEL) for respirable dust containing ≥ 1% quartz.

Chipping/Cutting

Ten samples, 3 personal breathing zone and 7 area, were collected during chipping and cutting operations. Sample concentrations for this job category ranged from None Detected (ND) to 263 $\mu g/m^3$ of respirable quartz. All personal samples collected on chippers working in Bay E exceeded the NIOSH REL for occupational exposure to respirable quartz and the calculated OSHA Permissible Exposure Limit (PEL) for respirable dust containing ≥ 1% quartz. In addition, respirable cristobalite was identified in one sample collected in Bay E; which exceeded the NIOSH and OSHA exposure criterion. All chippers working in Bay E were observed wearing 3M powered air purifying respirators (PAPRs) during chipping operations. The workers' actual exposures to the levels of respirable silica were probably less due to the use of respiratory protection. Two area sampling results exceeded the calculated OSHA Permissible Exposure Limit (PEL) for respirable dust containing ≥ 1% quartz.

Two samples collected in Bay L near the Fox saw and the Mid-West grinder had concentrations that were less than the NIOSH and the OSHA exposure criteria for respirable quartz. However, the Fox saw or the Mid-West grinder did not operate for most of the NIOSH survey. Samples collected at those locations during non-running shifts showed measurable quantities of respirable quartz above the NIOSH Action Level and one sample exceeded the calculated OSHA Permissible Exposure Limit (PEL) for respirable dust containing ≥ 1% quartz.

Pouring

Three personal breathing zone samples and 3 area samples were collected on or near employees involved in pouring operations. During this survey, most of the pouring that was done or observed on the shifts which were monitored was accomplished in Bay L at the Vertical Spin Caster. Only one static pour was accomplished in Bay C during the sampling shift while NIOSH personnel were present. In addition, the electric arc furnace for melting steel was not operated during this survey.

Samples collected had silica concentrations from ND to 98 $\mu g/m^3$ for the pouring operations. One personal breathing zone sample, collected on a worker in a pit (C-1 pit) while shoveling sand, had a concentration that exceeded the NIOSH REL for occupational exposure to quartz.

Molding

Seven personal breathing zone and 14 area samples were collected on employees or in close proximity to activities involving molding operations. Of the samples collected, 71% had concentrations that exceeded either the NIOSH REL exposure to respirable quartz or the calculated OSHA Permissible Exposure Limit (PEL) for respirable dust containing $\geq$ 1% quartz. Concentrations of respirable quartz ranged from ND to 199 $\mu g/m^3$. The most consistent and highest concentrations were measured at the sand plant, located in Bay J.

Both personal and area samples collected at the sand blasters station in Bay J also showed respirable quartz exposures that exceeded either the NIOSH REL exposure to respirable quartz or the calculated OSHA Permissible Exposure Limit (PEL) for respirable dust containing $\geq$ 1% quartz.

An area of major concern, where respirable quartz exceed exposure criteria, was the horizontal spray spin coater, located in Bay J. To compound the exposure from this silica spraying operation, is the sandblasting operation located some 10-15 yards away. Disposable respirators were available for use by the operators of both stations, but the operators seldom used them.

Maintenance

Three personal breathing zone samples were collected on maintenance employees. Of those three samples, one showed an exposure that exceeded either the NIOSH REL exposure to respirable quartz and the calculated OSHA Permissible Exposure Limit (PEL) for respirable dust containing $\geq$ 1% quartz. That sample was collected on a maintenance employee working in a furnace in Bay E. This maintenance employee used compressed air to blow dust (silica sand) from an area where he was working. No respiratory protection was utilized by that employee.

Cranes

Seven samples were collected inside the crane cabs operating over the furnace areas. None of the samples had concentrations that exceeded the criteria for occupational exposure to respirable silica. The crane operator in the shakeout bay has the potential for high silica exposure, however; this area was not sampled because no shakeouts were performed during the NIOSH survey.

Other

One respirable silica sample (not shown on Table 2) was collected on one of the NIOSH investigators. This sample was worn the entire shift by the investigator while he observed different operations within the foundry. The measured concentration of that sample was at the NIOSH REL of 50 $\mu g/m^3$ for occupational exposure to respirable silica. The results of this sample tend to indicate how widespread the exposures to respirable silica are within the foundry.

Metals Analysis

The results of the elemental analysis are shown in Table 3. A total of 35 samples were collected and analyzed for elemental analysis using NIOSH Method 7300. To summarize, 25 samples were collected at areas adjacent to foundry activities and 10 were collected within the breathing zone of foundry workers, primarily furnace, chipping and maintenance employees. The metals chromium (in 18 samples), nickel (in 6 samples) and lead (in 1 sample) were found in excess of the NIOSH RELs of 1 $\mu g/m^3$ for chromium (VI), 15 $\mu g/m^3$ for nickel and the OSHA PEL for lead of 50 $\mu g/m^3$.

Inside a crane cab in Bay B, the lead concentration measured was 211 $\mu g/m^3$ TWA. Nickel and chromium in this sample were also in excess of the NIOSH REL. This sample was collected during a pouring operation in Bay B. This was the only pouring operation conducted in Bay B during the NIOSH survey.

Gases

Sulfur Dioxide

The results of the sulfur dioxide sampling are shown in Table 4. Sulfur dioxide was detected at every sampling station, primarily from Bay J to Bay M within the foundry. The primary generation source of sulfur dioxide appears to be from the induction furnaces in Bay M. Workers had informed us that each day the furnaces are de-sulfurized using calcium carbide. Three samples, two personal breathing zone and one area sample, had sulfur dioxide concentrations that exceeded both the NIOSH REL (and the OSHA PEL) of 2 ppm TWA exposure, with many more at or above the 1 ppm action level. Concentrations of sulfur dioxide ranged from 0.40 to slightly above 7 ppm, with the highest concentrations measured near the furnaces in Bay M and the horizontal spin spray coater in Bay J.

Isopropyl Alcohol

The results of the isopropyl alcohol sampling are shown in Table 5. These samples were collected at the request of Blaw Knox Rolls Inc. on a job where hot Chills are coated with a material containing 95% isopropyl alcohol. A total of seven, (six area and one personal breathing zone), short term samples were collected on two separate occasions at the sand plant located in Bay J. The personal breathing zone sample collected on the employee performing the job showed an exposure to isopropyl alcohol of 708 ppm. This concentration exceeded both the NIOSH REL and the recommended transitional OSHA PEL of 500 ppm STEL for exposures to isopropyl alcohol. All other area samples had concentrations below both exposure criteria.

Medical

Of the 183 current workers, 129 participated (70%). All of the participants were male with a mean age of 43 and 92% of the participants were white. In regard to cigarette smoking, 43% of the participants were current smokers, 32% were former smokers and 25% never smoked. The current smokers had an average of 31 pack-years of smoking. More than 10% of participants had worked in other dusty trades prior to their Blaw Knox employment.

Tables 6, 7, and 8 summarize the medical results. Table 6 describes some of the characteristics of the participants and non-participants and indicates that the average tenure of both groups was 17 years. Table 7 is a list of workers whose chest x-rays were read as being at least 1/0 by two radiologists who looked at their x-rays. Differences in x-ray interpretation are indicated. Table 7 shows that two of these chest x-rays (1.6% of the participants) had median profusion readings of 1/0 or greater. Both of these workers were smokers and one also had previously worked in a job associated with exposure to dust. They each had a tenure of approximately 18 years at Blaw Knox. Table 8 lists the prevalence of chest x-ray findings, lung function results, sick day patterns, and "chronic" cough and phlegm according to smoking categories and indicates that both subjective and objective findings were more prevalent among the workers who had smoked. Of the 129 participating workers, 23% 30 workers) were found to have an obstructive lung function abnormality (an FEV_1/FVC ratio less than 86.9% of that predicted). No workers were determined to have restrictive lung function abnormalities.

CONCLUSIONS

Industrial Hygiene

During the NIOSH survey period, a number of employees were laid off. Some workers questioned what effect the lay-off, with its cutback on production, would have on the sampling results. Despite the limited work activities and curtailed production during this survey, exposures were measured that exceeded either the NIOSH REL, the OSHA PEL, or both for time weighted average exposures. For example, in some instances respirable silica levels measured were close to 6 times higher than the NIOSH REL and nearly 3 times the OSHA PEL. The fact that the measured exposure levels were as high as observed during this period of limited production, clearly supports the need for intervention and control of employee exposures.

Many industrial products which contain hazardous ingredients are used at the Blaw Knox foundry; a large majority of those products containing free crystalline silica. The hazard warnings on those products are clearly labeled; however, little is done in the way of preventing exposures. In a few locations of the foundry, signs were posted requiring respiratory protection, but we saw no attempt at enforcement.

Some workers wore respiratory protection, but the majority did not. Engineering controls, when present, were in very poor condition and in most instances ineffective. One new local exhaust ventilation system in Bay L had recently been installed to control emissions from the Fox saw and the Mid-west grinder. During this survey we were unable to adequately evaluate this system because the Fox saw only operated for 4 hours during one shift in which environmental samples were collected. The Mid-west grinder did not operate during any of the shifts monitored. The reasons given for this down time were many, ranging from mechanical to low production.

Another area not operating during this survey was the electric arc furnace located in Bay B. This furnace is used to melt steel for static casts. We were told that because there were no orders for steel during the NIOSH survey, the furnace would not operate. After the NIOSH survey, the furnace was placed on line for steel production. Many workers interviewed expressed concern regarding the emissions from the arc furnace. This area has since been monitored by OSHA.

Many workers said that they either were unsure or did not know the ingredients or the hazards of the materials or chemicals they used on the job. This raises questions as to the adequacy of training these employees receive under the Hazard Communication Standard (29 CFR 1910.1200). Material Safety Data Sheets are maintained at the nurse's office for all products used on-site. However, some of the employees stated that they did not know where the MSDS were located or could not understand them.

Over the one week survey, many situations were observed which could cause a potential health hazard to the worker. Some examples are:

- An employee shoveling silica sand in the bottom of a 40 foot pit. This resulted in large amount of dust being generated. The shoveling was being done in order to level out a spot to place a static cast. No respiratory protection was used by the employee.

- The indiscriminate use of compressed air to blow silica sand from parts or work areas. This contributes to employees exposure to silica. Employees not using respiratory protection were observed using compressed air as a means of cleaning.

- The spraying of a substance called Spincoat, which contains free crystalline silica. This Spincoat material is sprayed inside a rotating Vertical Spin Cast (VSC) chill. There is no local exhaust ventilation to prevent the overspray from being released into the work area.

Also, once the chill is coated, a high-speed wire brush and air hose are used to remove the over-sprayed silica from the chill. To compound this exposure problem, the spray coating operation is located adjacent to a sandblasting operation. The sandblasting operation appears to be controlled to some extent; however, poor maintenance in replacing the seals around the top of the chills causes silica sand to be released into the work area.

- In Bay L near the Vertical Spin Caster, after the outer shell of metal was poured, a flux material (approximately 5 pounds of powder) was dumped into the rotating mold prior to the pouring of the inner core. This flux material was calcium fluoride. After being dumped into the mold, large quantities of the flux blew out the ventilation system exhaust near the back of the control room. This exhaust was not controlled, and the calcium fluoride was discharged into the work areas. Fluoride samples were not collected during this survey, but any future evaluations should include fluoride sampling.

In addition to health hazards, we observed a number of safety hazards, although not the primary focus of this survey:

- Many of the deep pits were unguarded; this could result in a falling hazard. Where guard devices were present, the guards were in poor order and were very unstable. Guards around all pits need to be installed or repaired in order to prevent a falling hazard.

- The releasing compound used at the Sand Plant in Bay J consists of 95% isopropyl alcohol. This is a Class 1B flammable liquid and should not be stored near open sparks or ignition sources. We saw open containers of this solution, along with 55 gallon drums, stored adjacent to an open welding shop. Proper control and storage of flammable liquids was pointed out to management during this survey.

Medical

At the time of this survey, a health hazard existed for workers as a result of exposure to elevated levels of nickel, lead, chromium, sulfur dioxide, isopropyl alcohol, and respirable free silica dust.

Chest x-ray findings consistent with pneumoconiosis (silicosis) were found in two (1.6%) of workers examined. This figure is low compared to other studies of foundry workers: 7.6% annual prevalence from 1950 to 1960 at an English steel foundry[(14)], 5.4% for those with more than 10 years of tenure among Finnish foundry workers[(15)], 9.6% in a U.S. foundry[(16)], and 10.3% in a South African foundry[(17)]. Less than half of those employees who were away from work because of lay-offs, injuries or other reasons were evaluated. The 129 workers who agreed to participate included persons currently at work and persons away from work because of injuries, illness, or lay-offs. Unfortunately, whereas 79% (106/134) of those at work participated, only 47% (23/49) of those away from work participated. This difference in the rates of participation means that the results may not accurately reflect the extent of disease or symptoms in Blaw Knox workers as a whole (selection bias). In other words, although there were no significant differences between the group that participated and the group that did not in terms of age, tenure, or race (Table 6), there may have been important health-status differences between those two groups. Another possible source of bias in this study was survivor bias. This refers to the situation in which those workers who develop medical problems as a result of toxic job-related exposures decide to leave the offending job and are, therefore, not included in the epidemiological analyses. Additionally, chest x-ray screening was performed by the company in 1986. Workers identified with chest x-ray abnormalities may have left work at that time, contributing to the relatively low prevalence found in this study. If selection bias and survivor bias were present in this study, they would tend to reduce the amount of disease detected. In other words, the two workers having opacities with median profusion of 1/0 or greater may be an underestimate of the actual number of workers with important x-ray abnormalities who have worked at this foundry in recent years. Lastly, pneumoconiosis typically has a long latency period with radiographic manifestations occurring after 20 years or more of exposure to dust.

RECOMMENDATIONS

Industrial Hygiene

Based on the results of the environmental sampling, engineering controls should be designed and installed to maintain free silica dust, metal fume and sulfur dioxide levels below prescribed limits. A list of resource materials, and where they may be obtained, is presented at the end of this report. While the availability of a corporate industrial hygienist is a valuable resource, it is important that responsibility for health and safety be assigned to one individual within the foundry management.

Personal Protection

The primary means of respiratory protection at the Blaw Knox foundry is through the use of NIOSH/MSHA approved (TC 21 series) single use disposable respirators. In addition, chippers are issued 3M Model W-2940 air helmet PAPR respirators. The worker applying the isopropyl alcohol to the chills has access to single use 3M Model 9913 Dust and Mist Respirator impregnated with charcoal for organic vapors.

Based on the discussions with the workers, problems in the respiratory protection program were noted. First, the workers are not adequately informed on the proper use of the respirators provided or properly informed of the health hazards associated with their jobs. In reviewing the job descriptions for all foundry occupations, all outlined the safety hazards associated with the job, but none listed the health hazards of the job. For example, some job descriptions listed dust as a safety hazard, but did not note silicosis as a health hazard.

Secondly, workers complained that there was no established program to evaluate the effectiveness of the issued respirators, no fit testing program, or instruction in the proper use of respirators.

Until such time that effective engineering controls are installed, a mandatory personal protective equipment policy should be established to require the use of certified respirators in all areas of the foundry. A respiratory protection program should be in place which meets the requirements of 29 CFR 1910.134 of the OSHA standard. In addition, the disposable respirators currently used are not approved for protection against compounds (such as nickel, chromium, lead, and silica) having a TWA exposure level below 0.05 mg/m^3 . Even though these compounds have different exposure criteria under both NIOSH and OSHA, NIOSH generally recommends that the most conservative estimate be used as a guide for respirator selection.

Respirators suitable for protection against silica dusts should be used in all operations, including mold making, sand blasting, spray coating, shakeout, knockout and chipping areas. In addition to silica, employees working in Bays L through M should wear respiratory protection against metal fumes and sulfur dioxide. It would also be prudent for crane operators in all bays to wear respiratory protection for silica, metal fumes and sulfur dioxide.

Respirators with particulate filters and organic vapor cartridges should also be worn by core making operators at the sand plant for respiratory protection against silica and isopropyl alcohol. The currently used respirator, 3M, Model 9913 is not approved for protection against gases or vapors at levels greater than the OSHA PEL.

Each employee exposed to hazardous substances, such as free silica, should receive training, at the beginning of his employment or assignment, regarding the hazards, relevant symptoms, appropriate emergency procedures, and proper conditions and precautions for safe use or exposure. Health hazard information regarding silica, metal fume and sulfur dioxide should be included in employee job descriptions in order to draw appropriate attention to these potential workplace exposures. Such information should be kept on file and should be accessible to the worker at each place of employment where hazardous materials are involved in unit processes and operations. Workers should also be advised of the increased risk of impaired health due to the combination of exposures, including smoking.

Work Practices and Control Procedures

Wherever a hazard can be eliminated by a reasonable substitution of other less toxic materials, the substitution should be made.

Uncontrolled abrasive blasting and hand or machine spraying 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. Also, the operation of spraying chills in Bay J needs to be one of the primary focuses for an engineering control.

Water can substantially reduce the exposure to airborne respirable free silica dust, and should be added whenever applicable.

Where local exhaust ventilation and collection systems are used, they should be maintained to prevent the accumulation or recirculation of particulate matter into the workplace. The small baghouse attached to the Fox saw in Bay L is a good example of a poorly maintained system. The direction of the saw cut is away from the exhaust hood which shrouds the abrasive blade. The hood, when checked, was nearly clogged, also limiting the effectiveness of the control device. The dust particles collected were channeled into a small cyclone for separation and into a bag house for collection. The small particles collected by the bag house, however, were released into the general work area at the top of the bag house, defeating the purpose of the dust collection system. Typically those particles are of a size which can easily be inhaled and are most hazardous to the workers' health.

As for the new control ventilation system, we were unable to adequately assess the effectiveness for the reasons previously described. However, the distance from the generation source to the centerline of the control device appears too great for the device to be effective as currently designed. The total system should be inspected periodically for efficiency of operation. In addition, necessary measures should be taken to ensure that discharges to the outdoors meet EPA and any state or local requirements.

The flexible tubing from the blade hood on the Swing Gate grinder located in Bay E to the overhead duct was so clogged that the tube created a sink for dust particles, greatly reducing the effectiveness of the system. This system should be redesigned to eliminate the sink in the flexible tubing.

A thorough evaluation of all the existing ventilation systems should be conducted to assure that the capture velocities are adequate and there are no leaks in the systems.

The electric arc welding conducted in open areas needs local exhaust ventilation and personal respiratory protection to protect the health of the welder and other workers in the immediate area.

General Housekeeping

Cleaning by blowing with compressed air or dry sweeping should be prohibited and dustless methods of cleaning such as vacuuming or washing down with water should be substituted.

Emphasis should be placed upon cleanup of spills, preventive maintenance and repair of equipment, proper storage of materials, and collection of dusts containing free silica.

Posting

The following warning should be posted to be readily visible at or near entrances or access ways to work areas where there is potential exposure to free silica.[6]

WARNING!
FREE SILICA WORK AREA
Unauthorized Persons Keep Out

The following warning should be posted in readily visible locations in any work area where there is potential exposure to free silica.

WARNING!
FREE SILICA WORK AREA

Avoid Breathing Dust
Use Appropriate Respiratory Protection
May Cause Delayed Lung Injury (Silicosis)

The posting should be printed both in English and in the predominant language of non-English-speaking workers, unless they are otherwise trained and informed of the hazardous areas. Illiterate workers shall receive such training. Enforcement of respiratory protection need to be stressed to all workers.

Recommended Publications

American Conference of Governmental Industrial Hygienists:

Industrial Ventilation, A Manual of Recommended Practice, (current edition).

Industrial Ventilation Workbook (1989)

"Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1990-1991" (or most current edition)

National Institute for Occupational Safety and Health
(1-800 356-4674)

An Evaluation of Occupational Health Hazard Control Technology for the Foundry Industry, 1978. DHEW Publication no. (NIOSH) 79-114.

Recommendations for Control of Occupational Safety and Health Hazards ... Foundries DHHS (NIOSH) Publication No. 85-116.

NIOSH Respirator Decision Logic, 1987. DHHS Publication No. 87-108.

Medical

The company should establish a medical surveillance program including pre-placement chest radiographs, spirometry testing, and tuberculosis skin testing for all employees potentially exposed to crystalline silica dust. This will provide a baseline for future evaluation.

Additionally, the company should provide periodic medical examinations at least once every 3 years for all employees with exposure to crystalline silica dust. These examinations should include as a minimum:

- A medical and occupational history to collect data on worker exposure to crystalline silica dust, and signs and symptoms of respiratory disease.

- A chest radiograph (posterior-anterior 14" x 17") classified according to the ILO International Classification of Radiographs of Pneumoconioses.

- Pulmonary function testing (spirometry) including Forced Vital Capacity (FVC) and Forced Expiratory Volume at one second (FEV_1) using equipment and methods consistent with ATS recommendations.(3)

- An annual evaluation for tuberculosis.

If positive findings are found on the chest radiograph or spirometry or both, the employee should be notified and referred for further clinical evaluation. All cases of silicosis should be reported to State health departments and recorded by OSHA as required. To enhance the uniformity of reporting, NIOSH has developed reporting guidelines and a surveillance case definition for silicosis (Appendix I). The definition and guidelines are recommended for surveillance of work-related silicosis by State health department and regulatory agencies receiving reports of cases from physicians and other health care providers.

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Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Publications Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. Blaw Knox Rolls Inc.
2. United Steelworkers of America, Local 3096
3. United Steelworkers of America, Health, Safety, Environment Department, Pittsburgh, PA.
4. OSHA, Region III

Appendix I

SURVEILLANCE GUIDELINES: SILICOSIS

Reporting Guidelines

State health departments and regulatory agencies should encourage physicians (including radiologists, pathologists, and other healthcare providers) to report all diagnosed or suspected cases of silicosis. These reports should include persons with

-- a physician's provisional or working diagnosis of silicosis, OR

-- a chest radiograph interpreted as consistent with silicosis, OR

-- pathologic findings consistent with silicosis

To set priorities for workplace investigations, State health departments and regulatory agencies should collect appropriate clinical, epidemiologic, and workplace information about persons reported to have silicosis.

Surveillance Case Definition

A. 1. History of occupational exposure to airborne silica dust

AND

2. Chest radiograph or other imaging technique interpreted as consistent with silicosis

OR

B. Pathologic findings characteristic of silicosis.

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Table 1

Blaw Knox Rolls, Inc.
Wheeling, West Virginia
HETA 90-249

Environmental Exposure Criteria

Substance	NIOSH REL[18]	OSHA PEL[19]	ACGIH TLV [20]
Respirable Silica			
Quartz	50 µg/m^3	$\frac{10}{\%Quartz+2}$	100 µg/m^3
Cristobalite	50 µg/m^3	½ Quartz Value	50 µg/m^3
Tridymite	50 µg/m^3	½ Quartz Value	50 µg/m^3
Metals			
Chromium (as $Cr0_3$)	1 µg/m^3	1,000 µg/m^3	50 µg/m^3
Iron	5,000 µg/m^3	10,000 µg/m^3	5,000 µg/m^3
Nickel	15 µg/m^3	100 µg/m^3	100 µg/m^3
Lead	100 µg/m^3	50 µg/m^3	150 µg/m^3
Gases			
Sulfur Dioxide	2 ppm 5 ppm STEL	5 ppm	2 ppm 5 ppm STEL
Isopropyl Alcohol	400 ppm 500 ppm STEL	400 ppm	400 ppm 500 ppm STEL

All exposure criteria expressed as Time Weight Average (TWA) concentrations unless otherwise indicated.

STEL = Short Term Exposure Limit of 15 minutes.

Table 2

Blaw Knox Rolls, Inc.
Wheeling, West Virginia
HETA 90-249

Respirable Dust and Crystalline Silica Exposures

DATE	WORK ACTIVITY	LOCATION	SAMPLE TYPE	SAMPLE NUMBER	VOLUME (liters)	RESPIRABLE DUST (mg/m^3)	QUARTZ ($\mu g/m^3$)	CRISTOBALITE ($\mu g/m^3$)
Jan 15	Furnace	Furnace Operator - Bay B	Personal	FW2968	756	0.55	198	ND
Jan 18	Furnace	Furnace Operator - Bay M	Personal	FW2941	758	1.32	280	ND
Jan 14	Furnace	Near Furnace - Bay M	Area	FW2940	721	0.44	ND	ND
Jan 15	Furnace	Near Furnace - Bay M	Area	FW2933	765	0.60	26.1	ND
Jan 17	Furnace	Furnace Platform - Bay M	Area	FW4590	805	0.50	24.8	ND
Jan 18	Furnace	Furnace Platform - Bay M	Area	FW4438	756	0.74	ND	ND
Jan 17	Chipping	Chipper - Bay E	Personal	FW2914	607	1.30	263.6	ND
Jan 17	Chipping	Chipper - Bay E	Personal	FW4630	604	0.45	149.1	66.3
Jan 15	Chipping	Chipper - Bay E	Personal	FW4441	751	0.46	103.9	38.9
Jan 15	Chipping	Near Fox Saw - Bay L	Area	FW2955	583	0.81	34.3	ND
Jan 17	Chipping	Near VSC - Bay L	Area	FW526	544	0.20	36.8	ND
Jan 17	Chipping	Near VSC - Bay L	Area	FW4472	544	0.15	ND	ND
Jan 17	Chipping	Near Fox Saw - Bay L	Area	FW4596	734	0.19	40.8	27.2
Jan 17	Chipping	Near Mid-West Grinder	Area	FW4598	672	0.24	29.8	ND
Jan 18	Chipping	Near Chipper - Bay E	Area	FW4460	765	0.10	ND	ND
Jan 18	Chipping	Near Chipper - Bay E	Area	FW4453	714	0.60	70.0	42.0

Table 2. (continued)

Blaw Knox Rolls, Inc.
Wheeling, West Virginia
HETA 90-249

Respirable Dust and Crystalline Silica Exposures

DATE	WORK ACTIVITY	LOCATION	SAMPLE TYPE	SAMPLE NUMBER	VOLUME (liters)607	RESPIRABLE DUST (mg/m^3)	QUARTZ (µg/m^3)	CRISTOBALITE (µg/m^3)
Jan 14	Pouring	Working near C-1 Pit - Bay C	Personal	FW4624	678	0.10	ND	ND
Jan 14	Pouring	Ladelman - Bay L	Personal	FW527	607	0.25	49.4	ND
Jan 15	Pouring	Iron - Bay C	Personal	FW2966	697	0.25	97.8	ND
Jan 14	Pouring	C-1 Pit -Bay C	Area	FW531	663	0.03	ND	ND
Jan 15	Pouring	Between Furnace & Ladle - Bay C	Area	FW2907	757	0.09	ND	ND
Jan 15	Pouring	Iron - Bay C	Area	FW2954	757	0.01	ND	ND
Jan 14	Molding	Roll Pitman - Handspraying	Personal	FW2964	687	0.42	58.2	ND
Jan 15	Molding	Making Heads - Bay B	Personal	FW2948	695	0.15	28.9	ND
Jan 15	Molding	Making Heads - Bay B	Personal	FW2966	697	0.26	101.1	ND
Jan 17	Molding	Roll Molder - Sand Slinger	Personal	FW2908	634	0.35	126.2	ND
Jan 17	Molding	Sand Plant Operator	Personal	FW2650	705	0.38	170.1	ND

Jan 17	Molding	Spin Coat Operator - Bay J	Personal	FW4447	774	0.32	64.6	ND
Jan 18	Molding	Sand Blaster - Bay J	Personal	FW4458	681	0.32	73.3	ND

Table 2. (continued)
Blaw Knox Rolls, Inc.
Wheeling, WV
HETA 90-249

Respirable Dust and Crystalline Silica Exposures

DATE	WORK ACTIVITY	LOCATION	SAMPLE TYPE	SAMPLE NUMBER	VOLUME (liters)	RESPIRABLE DUST (mg/m^3)	QUARTZ ($\mu g/m^3$)	CRISTOBALITE ($\mu g/m^3$)
Jan 14	Molding	Near Vertical Spin Coater - Bay J	Area	FW4625	737	0.08	ND	ND
Jan 14	Molding	Sand Plant	Area	FW4626	766	0.40	91.3	26.1
Jan 14	Molding	Sand Plant	Area	FW530	4059	0.36	123.1	ND
Jan 14	Molding	Sand Plant	Area	FW535	757	0.16	26.4	ND
Jan 15	Molding	Near Vertical Spin Coater - Bay J	Area	FW2942	757	0.17	ND	ND
Jan 15	Molding	Making a Head - Bay B	Area	FW2952	734	0.68	ND	ND
Jan 15	Molding	Making a Head - Bay B	Area	FW2931	734	0.55	163.4	ND
Jan 17	Molding	Near Vertical Spin Coater - Bay J	Area	FW4576	697	0.10	57.3	ND
Jan 17	Molding	Near Vertical Spin Coater - Bay J	Area	FW4578	3771	0.19	63.64	8.0
Jan 17	Molding	Sand Plant	Area	FW4588	703	0.24	113.8	28.4

Jan 17	Molding	Sand Blaster - Bay J	Area	FW2953	627	0.26	111.9	ND
Jan 18	Molding	Sand Blaster - Bay J	Area	FW4442	800	0.39	24.9	ND

Table 2. (continued)

Blaw Knox Rolls, Inc.
Wheeling, WV
HETA 90-249

Respirable Dust and Crystalline Silica Exposures

DATE	WORK ACTIVITY	LOCATION	SAMPLE TYPE	SAMPLE NUMBER	VOLUME (liters)	RESPIRABLE DUST (mg/m^3)	QUARTZ ($\mu g/m^3$)	CRISTOBALITE ($\mu g/m^3$)
Jan 18	Molding	Near Vertical Spin Coater - Bay J	Area	FW4459	787	0.18	25.4	ND
Jan 18	Molding	Near Vertical Spin Coater - Bay J	Area	FW4446	4167	0.27	64.8	7.2
Jan 15	Cranes	Inside Cab - Bay M	Area	FW2969	765	0.09	ND	ND
Jan 15	Cranes	Inside Cab - Bay B	Area	FW4627	665	2.80	ND	30.1
Jan 15	Cranes	Inside Cab - Bay M	Area	FW2936	791	0.10	ND	ND
Jan 17	Cranes	Inside Cab - Bay M	Area	FW2938	731	0.15	ND	ND
Jan 17	Cranes	Inside Cab - Bay M	Area	FW4595	794	0.43	25.2	ND
Jan 17	Cranes	Inside Cab - Bay M	Area	FW4450	748	0.20	26.7	ND
Jan 17	Cranes	Inside Cab - Bay M	Area	FW4439	806	0.42	ND	ND
Jan 18	Maint	Pipefitter	Personal	FW4461	755	0.25	26.5	ND
Jan 18	Maint	Pipefitter	Personal	FW4444	757	0.15	ND	ND
Jan 18	Maint	Worked on Ovens	Personal	FW4454	670	0.73	74.7	29.9

Table 3.

Blaw Knox Rolls, Inc.
Wheeling, WV
HETA 90-249

Elemental Metal Exposure

DATE	WORK ACTIVITY	SAMPLE TYPE	SAMPLE NUMBER	VOLUME (liters)	CHROMIUM (µg/m^3)	IRON (µg/m^3)	NICKEL (µg/m^3)	LEAD (µg/m^3)
Jan 14	Furnace	Personal	19461	714	43	574	17	15
Jan 15	Furnace	Personal	19497	757	4	344	9	5
Jan 17	Furance	Personal	19479	765	29	366	16	5
Jan 14	Furance	Area	19441	805	0	36	1	4
Jan 14	Furnace	Area	19519	721	3	194	4	12
Jan 17	Furnace	Area	19492	805	2	347	14	11
Jan 18	Furnace	Area	19445	757	4	357	17	16
Jan 15	Chipping	Personal	19433	558	11	2152	52	0
Jan 17	Chipping	Personal	19489	734	1	368	14	7
Jan 15	Chipping	Area	19501	583	7	1561	38	3
Jan 17	Chipping	Area	19502	672	1	223	9	6
Jan 18	Chipping	Area	19482	714	3	252	1	13
Jan 18	Chipping	Area	19433	801	21	225	5	6
Jan 18	Chipping	Area	19481	765	1	183	4	10
Jan 14	Pouring	Personal	19466	607	3	125	3	3
Jan 14	Pouring	Area	19463	678	0	60	0	12
Jan 15	Pouring	Area	19485	757	0	25	0	3
Jan 15	Pouring	Area	19506	716	0	8	0	0
Jan 17	Pouring	Area	19471	757	0	69	1	4

Table 3. (continued)

Blaw Knox Rolls, Inc.
Wheeling, WV
HETA 90-249

Elemental Metal Exposure

DATE	WORK ACTIVITY	SAMPLE TYPE	SAMPLE NUMBER	VOLUME (liters)	CHROMIUM (µg/m³)	IRON (µg/m³)	NICKEL (µg/m³)	LEAD (µg/m³)
Jan 14	Molding	Area	19440	767	0	74	3	0
Jan 14	Molding	Area	19520	738	0	136	4	3
Jan 15	Molding	Area	19491	750	0	124	4	3
Jan 17	Molding	Area	19453	697	0	69	1	0
Jan 17	Molding	Area	19515	704	0	70	0	0
Jan 18	Molding	Area	19508	787	0	88	1	6
Jan 15	Maint.	Personal	19446	646	5	1424	3	3
Jan 17	Maint.	Personal	19435	588	0	408	2	3
Jan 17	Maint.	Personal	19469	653	17	1011	9	17
Jan 17	Cranes	Personal	19474	794	0	151	8	9
Jan 14	Cranes	Area	19439	665	5	1173	32	211
Jan 14	Cranes	Area	19468	765	0	78	4	4
Jan 15	Cranes	Area	19509	719	0	11	0	0
Jan 15	Cranes	Area	19422	765	4	327	8	7
Jan 15	Cranes	Area	19437	790	0	215	8	4
Jan 18	Cranes	Area	19448	748	0	0	0	0

Table 4.

Blaw Knox Rolls, Inc.
Wheeling, WV
HETA 90-249

Sulfur Dioxide Exposure

DATE	WORK ACTIVITY	SAMPLE TYPE	LOCATION	EXPOSURE (ppm)
Jan 14	Furnace	Personal	Furnace Operator - Bay M	3.6
Jan 15	Furnace	Personal	Furnace Operator - Bay M	1.1
Jan 17	Furnace	Personal	Furnace Operator - Bay M	1.1
Jan 18	Furnace	Personal	Furnace Operator - Bay M	1.1
Jan 14	Furnace	Area	Near Control Booth. - Bay M	7.1
Jan 15	Furnace	Area	Furnace Platform - Bay M	1.6
Jan 17	Furnace	Area	Furnace Platform - Bay M	0.6
Jan 18	Furnace	Area	Furnace Platform - Bay M	1.1
Jan 14	Chipping	Area	Near Vertical Spin Coater - Bay L	0.7
Jan 15	Chipping	Area	Near Vertical Spin Coater - Bay L	0.8
Jan 15	Chipping	Area	Near Fox Saw - Bay L	0.9
Jan 17	Chipping	Area	Near Fox Saw - Bay L	0.7
Jan 17	Chipping	Area	Near Mid-West Grinder - Bay L	0.7
Jan 18	Chipping	Area	Near Sandblasting - Bay J	1.3
Jan 18	Chipping	Area	Center of Bay E	0.7
Jan 18	Chipping	Area	Near Chipping - Bay E	0.7
Jan 14	Molding	Area	Sand Plant - Bay J	0.7
Jan 15	Molding	Area	Iron - Bay C	0.3
Jan 17	Molding	Area	Sand Plant - Bay J	1.0
Jan 17	Molding	Area	Sand Slinger - Bay C	0.4
Jan 17	Molding	Area	Near Vertical Spin Coater - Bay L	1.4
Jan 18	Molding	Area	Near Vertical Spin Coater - Bay L	2.6

Table 4. (continued)

Blaw Knox Rolls, Inc.
Wheeling, WV
HETA 90-249

Sulfur Dioxide Exposure

DATE	WORK ACTIVITY	SAMPLE TYPE	LOCATION	EXPOSURE (ppm)
Jan 14	Cranes	Area	Inside Cab of Crane - Bay M	1.9
Jan 14	Cranes	Area	Inside Cab of Crane - Bay B	0.8
Jan 15	Cranes	Area	Inside Cab of Crane - Bay M	1.0
Jan 17	Cranes	Area	Inside Cab of Crane - Bay M	1.3
Jan 18	Cranes	Area	Inside Cab of Crane - Bay J	1.4
Jan 18	Cranes	Area	Inside Cab of Crane - Bay M	1.2

Table 5.

Blaw Knox Rolls, Inc.
Wheeling, WV
HETA 90-249

Isopropyl Alcohol Exposures
(Sand Plant - Bay J.)

DATE	SAMPLE NUMBER	VOLUME (liters)	SAMPLE TYPE	EXPOSURE (ppm)
Jan 17	7803-A1	26.1	Area	68.3
Jan 17	7803-A2	25.7	Area	56.3
Jan 18	7803-A3	2.7	Area	18.1
Jan 18	7803-A4	2.7	Personal	708.2
Jan 18	7803-A5	3.0	Area	39.3
Jan 18	7803-A6	2.9	Area	49.1
Jan 18	7803-A7	2.9	Area	136.1

Table 6.

Blaw Knox Rolls, Inc.
Wheeling, WV
HETA 90-249

Selected Characteristics of Participants and Non-Participants

	PARTICIPANTS	NON-PARTICIPANTS
NUMBER	129 (70.5%)	54 (29.5%) (6: injured, 5: vacation, 15: laid-off)
AGE	42.5±8.0	42.7±8.4
TENURE	16.6±5.8	16.7±6.9
RACE		
WHITE	119 (92%)	51 (94%)
BLACK	10 (8%)	3 (6%)

Table 7.

Blaw Knox Rolls, Inc.
Wheeling, WV
HETA 90-249

Chest X-ray Classifications for Blaw Knox Workers Having a Profusion of 1/0 or Greater by 2 or More Readers

Worker:	[1]Reader #1	[1]Reader #2	[1]Reader #3	[2]Prior Dust
1	1/0, R	1/0, R	0/1, R	Yes (1.5 yr)
2	1/1, IR	2/1, R/IR	1/0, R/IR	No

[1] Profusion: 12 point scale from 0/- to 3/3
"R" refers to rounded opacities
"IR" refers to irregular opacities
[2] Past history of work experience in a dusty prior to employment at Blaw Knox.

Table 8.

Blaw Knox Rolls, Inc.
Wheeling, WV
HETA 90-249

Proportion Of Workers With Major Respiratory Findings Or Reported Symptoms By Smoking Category At Blaw Knox Rolls, Inc.

SIGN or SYMPTOM:	Current Smokers	Ex-Smokers	Never Smokers	ALL
Obstructive Lung function[1]	32% (18 of 56)	20% (8 of 41)	13% (4 of 31)	23% (30 of 129)
Chronic Phlegm[2]	52% (29 of 56)	20% (8 of 41)	12% (4 of 32)	32% (41 of 129)
Chronic Cough[3]	46% (26 of 56)	20% (8 of 41)	12% (4 of 32)	29% (38 of 129)
Sick Days with Wheezing[4]	18% (10 of 56)	5% (2 of 41)	0% (0 of 32)	9% (12 of 129)
Sick Days with Chest Tightness[5]	11% (6 of 56)	10% (4 of 41)	0% (0 of 32)	9% (12 of 129)
Sick Days with Cough[6]	23% (13 of 56)	17% (7 of 41)	3% (1 of 32)	16% (21 of 129)
Sick Days with Difficult Breathing[7]	11% (6 of 56)	10% (4 of 41)	3% (1 of 32)	9% (11 of 129)
Pneumoconiotic Changes[8]	2% (1 of 56)	2% (1 of 41)	0% (0 of 32)	2% (2 of 129)

1 FEV_1/FVC less than 86.9% of the predicted ratio.
2 Phlegm on most days for 3 months or more in a year.
3 Cough on most days for 3 months or more in a year.
4 Wheexing present during most episodes of sick leave.
5 Sensation of chest tighness npresent in most episodes of sick leave.
6 Cough present in most episodes of sick leave.
7 Difficulty with breathing present in most episodes of sick leave.
8 Markings on chest x-ray of "profusion greater than or equal to 1/0."