U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
CENTER FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
CINCINNATI, OHIO 45226

HEALTH HAZARD EVALUATION DETERMINATION REPORT NO. 74-97-286

Blaw Knox Foundry and Mill Machinery, Inc.
Warwood Plant
Wheeling, West Virginia

MAY 1976

I. TOXICITY DETERMINATION

Based upon the results of environmental and medical investigations by the National Institute for Occupational Safety and Health (NIOSH), it has been determined that a toxic exposure to crystalline free silica exists among foundry workers at this plant. Environmental levels during this investigation exceeded the NIOSH recommended and OSHA standards; review of the results of the company's chest x-ray surveys indicated a number of cases of silicosis or possible silicosis or other pneumoconioses in this plant population. Employees' exposure to phosphine, calcium oxide, and metal fumes were determined not to be toxic at concentrations measured; however, transient levels of each material may have resulted in the complaints noted in the respective areas of usage.

This determination is based on: (1) environmental samples, (2) interviews with exposed employees, (3) observation of work practices, (4) a review of available employee medical information, and (5) a review of available literature concerning the toxicity of the substances under consideration.

II. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are available upon request from NIOSH, Division of Technical Services, Information Resources and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. Copies have been sent to:

A. Blaw-Knox Foundry and Mill Machinery, Inc. Warwood Works, Wheeling, West Virginia
B. Authorized Representative of Employees
C. U.S. Department of Labor - Region III
D. NIOSH - Region III

For the purpose of informing the approximately 75 "affected employees," this report shall be "posted" for a period of at lease 30 calendar days in a prominent place(s) readily available to workers.

III. INTRODUCTION

Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S. Code 669(a)(6) authorizes the Secretary of Health, Education, and Welfare, following a written request by an employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found. The National Institute for Occupational Safety and Health received such a request from the United Steel Workers of America, Local 4218, which alleged irritation from excessive quantities of fumes during desulfurization operations in the foundry area.

IV. HEALTH HAZARD EVALUATION

A. Plant Process

The Warwood Plant of Blaw Knox Foundry and Mill Machinery produces iron castings up to the point of final sizing. Major production trends in recent years have been toward increased production of ductile (also called nodular) iron rolls for the steel industry. The production of ductile iron differentiates this plant from many other medium-sized foundries.

Ductile iron itself is basically of the same composition as the more common gray iron and is melted and handled in a very similar manner. The important difference between the two is that graphite separates during solidification of ductile iron as spheroids (vs. flakes in gray iron) when under the influence and in the presence of magnesium. Sulfur in the iron, however, consumes magnesium uselessly forming magnesium sulfide which interferes with or prevents the nodulizing effect. Therefore, it is important that the iron be low in sulfur content. During the initial visit on September 18, 1974, for this evaluation, iron was being desulfurized (lowering of sulfur content of iron) by placing soda ash in a ladle into which the metal was tapped. The resulting reaction allows the sulfur to be removed as part of the normal slagging operation.

During subsequent visits on April 1-2 and July 22-23, 1975, it was determined that the use of soda ash had been eliminated in favor of a trade name product designed for this purpose.

Nodulization is then obtained by returning metal to the furnace, bringing the melt back to temperature and retapping into the ladle containing master alloys of magnesium just prior to pouring the casting.

To complete operations, castings are cleaned, turned to approximate the required specification, and shipped.

B. Evaluation Design

The areas designated by the request were observed with the employer and employee representatives. Judgements were made regarding operations at risk and a decision was made to conduct environmental sampling in conjunction with medical examinations. Air samples would be collected for free silica calcium oxide metal fumes and phosphine.

C. Evaluation Methods

1. Environmental

On September 18, 1974, an initial survey was made to Blaw Knox's Warwood Plant by Wesley Straub, industrial hygienist for NIOSH. Air samples were taken during the desulfurization operation at this time for sulfur dioxide using Dragerwerk Lubeck detector tubes. The limit of sensitivity of the tubes used was 1.0 part sulfur dioxide per million parts of air (ppm).

Bulk samples of foundry molding sand were collected and analyzed colorimetrically for free silica. The limit of sensitivity of the colorimetric technique used was 100 micrograms for the silico molybdate range per sample. Since the colorimetric technique cannot distinguish between the three types of free silica, bulk samples were also analyzed for quartz cristobalite and tridymite by an x-ray diffraction technique. The decision was then made to use the x-ray diffraction technique throughout the remainder of this evaluation. The limit of sensitivity of the x-ray technique used was 0.5 micrograms per sample.

On April 1-2, 1975, a follow-up evaluation was made and environmental samples for metal fumes, calcium oxide dust, phosphine gas and free silica dust were collected.

Metal fume air samples were collected using MSA Monitaire pumps on mixed cellulose ester filters operating at a flow rate of 1.7 liters per minute.

Samples were subsequently analyzed for manganese nickel, iron oxide and chrome based upon the final alloy composition, selecting those metals with the highest percentage present. Numerous metals present in minimal amounts were not analyzed in view of limited exposure time.

The analyses were performed using an atomic absorption technique which has the following limits of sensitivity.

Manganese	0.2 ug/filter
Nickel	2.0 ug/filter
Iron Oxide	1.0 ug/filter
Chromium	0.7 ug/filter

Exposures to calcium oxide during desulfurization was evaluated using high volume area and low volume personal samplers. Samples were collected on mixed cellulose ester filters and analyzed by atomic absorption. The limit of sensitivity of this method is 5 ug/filter.

Wet grinding operations were evaluated for phosphine using Dragerwerk Lubeck detector tubes, which have a limit of sensitivity of 0.1 ppm phosphine.

Exposures to airborne free silica containing dust were evaluated using personal air sampling equipment. Air samples were collected on pre-weighed polyvinyl chloride (PVC) filters preceeded by a cyclone presampler which removed non-respirable particles. Respirable dust concentrations were calculated from results of filter gravimetric determinations. Dust samples were then analyzed colorimetrically for free silica. However, due to a high background of amorphous silica in the filters used, a range of results were obtained such that the information was considered invalid. As a result of this invalidation, a re-evaluation was conducted on July 23-24, 1975. Free silica samples were collected on an alternate make of PVC filters and analyzed by x-ray diffraction. The results are presented in Tables 5 and 6.

During the July follow-up survey, an attempt was made to obtain additional information regarding phosphine gas levels. Samples were collected using either Dragerwerk Lubeck detector tubes or filters impregnated with silver nitrate and sampled at one liter per minute.

2. Medical

The medical investigation consisted of a thorough inspection of the plant and the various operations involved in the production of nodular iron rolls. Detailed interviews with employees in the foundry and machining areas on the first and second (shake out) shifts were then conducted. These interviews focused on the signs and/or symptoms of silicosis as well as the signs and/or symptoms associated with exposure to phosphine and calcium oxide.

In addition, a review was made of the results of the 1971-72 and 1974-75 chest radiograph programs. In each year, approximately 180 persons participated in this program.

D. Evaluation Criteria

1. Environmental

Two primary sources of environmental evaluation criteria are used in this report: (1) NIOSH criteria documents on recommended occupational health standards and (2) Federal occupational health standards. The occupational health standards promulgated by the U.S. Department of Labor (Federal Register, June 27, 1974, Volume 39, No. 125, Title 29, Chapter XVII, Part 1910, Subpart G, Table G-1) applicable to the individual substances of this evaluation are as follows:

Substance	8-Hour Time Weighted Average Exposure Standard	
	ppm[a]	mg/m^3[b]
Manganese[c]		5.0
Nickel, metal as Ni		1.0
Iron oxide fume		10.0
Chromium, metal as Cr		1.0
Calcium oxide		5.0
Free silica[d]		$\frac{10}{\%\ Quartz + 2}$
Sulfur dioxide[e]	5.0	
Phosphine	0.3	

(a) Parts of vapor or gas per million parts of contaminated air by volume.
(b) Milligrams of particulate per cubic centimeter of air.
(c) U.S. Department of Labor Standards require that employee exposure to manganese never exceed the 5 mg/m level. NIOSH in its Criteria for a Recommended Standard - Occupational Exposure to Crystalline Silica recommends that occupational exposure be controlled so that no worker is exposed to a time-weighted average (TWA) concentration of free silica greater than 50 micrograms per cubic meter of air as determined by a full-shift sample for up to a 10-hour workday, 40-hour workweek.
(d) Respirable fraction as calculated from the formula listed above as established by the U.S. Department of Labor.
(e) NIOSH in its Criteria for a Recommended Standard - Occupational Exposure to Sulfur Dioxide recommends that employee exposure to sulfur dioxide be controlled to 2 ppm on an 8-hour time weighted average basis.

2. Description of Known Pathophysiological Effects of Suspected Agents

a. Silica (SiO_2)

Silicosis is a pneumoconiosis characterized by a nodular pulmonary fibrosis caused by the inhalation and pulmonary desposition of dusts containing silicon dioxide (SiO_2). In addition to mining and quarrying, important exposure to free silica may occur in stonemasonry and sandblasting operations. Perhaps less obviously, certain other occupations entail a risk of significant exposure to free silica. These occupations include: tunneling, foundry work, pottery work, and the manufacture of refractory products. Crystalline silica, defined as silicon dioxide, will be referred to hereafter in this report as free silica. "Crystalline" refers to the orientation of the SiO_2 molecules in a fixed pattern as opposed to amorphous. The three most common crystalline forms of free silica encountered in industry are quartz, tridymite, and crystobalite.

From the experimental animal studies, the following sequence of events is thought to be involved in the pathogenesis of silicosis: first, the deposition of free silica produced changes in pulmonary macrophages leading to cell death and lysis; second, the attraction of more macrophages to ingest the liberated silica particles; third, a fibroblastic reaction leading to the formation and deposition of collagen; and fourth, the hylanization of collagen. This last stage, the hylanization of collagen, seems to be related to the deposition of any amyloid-like material among the collagen fibers. This amyloid-like substance may be derived from immoglobulins produced as part of the general stimulation of the reticuloendothelial system in silicosis. As a result of these changes, the characteristic fibrous silicotic nodule is thought to develop. Fusion of these nodules is frequent and is referred to as progressive massive fibrosis. Extensive and marked fibrosis may be present in the lungs at autopsy with only a relatively small amount of free silica present. Involvement of the hilar and mediastinal and sometimes abdominal lymph nodes is common.

The clinical signs of silicosis are not unique. Symptoms may be progressive with continued exposure to silica-containing dusts, with advancing age, and with continued cigarette smoking. Symptoms may be exacerbated by pulmonary infections and cardiac decompensation. Pulmonary symptomatology usually begins insiduously. Symptoms may include cough, sputum production, progressive dyspnea, wheezes, and repeated nonspecific chest infections. Some of these symptoms may be related to coexisting chronic bronchitis and/or airway obstruction. Impairment of pulmonary function may be progressive. In individual cases there may be little or no decrement in pulmonary function or symptoms when only simple, discrete nodular silicosis (simple silicosis) is present. The two main threats posed by simple silicosis are the development of complicated disease and tuberculosis. The frequency with which these complications occur varies from industry to industry and massive fibrosis develops in about 20-30% of the subjects with simple silicosis. In addition, it has been found that the mortality of foundrymen with simple silicosis is double that of coal workers with similar radiographic category of disease and so simple silicosis should not be considered as entirely benign. When complicated silicosis supervenes, the symptoms of pulmonary restriction occur. These symptoms include dyspnea and paroxysmal cough and are associated with few physical signs. The physical signs associated with generalized pulmonary fibrosis and asbestosis, namely, finger clubbing and basilar rales, are less frequent in silicosis.

As is true of many of the 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 duration of time which the retained dust is permitted to react with the lung tissue. Because there are very few symptoms, very little is known about the early lesions resulting from moderately high exposures to free silica. Occasionally, exposures to very high concentrations occur in short periods of time resulting in acute or rapidly developing silicosis, which is associated with severe respiratory failure and death. Simple silicosis has a definite tendency to progress even in the absence of tuberculosis or further exposure of dusts containing free silica. The same is true once the complicated disease has developed, and, even if the masses do not increase in size, it is common to see increasing disability related to retraction of and bullous formation in the rest of the lung.

The final episode in the life of the patient with complicated silicosis is often due to the development of cardiopulmonary failure associated with recurrent chest infections, cardiac failure (cor pulmonale) and the ever-present danger of developing tuberculosis.

The most common criteria used in the diagnosis of silicosis are the results of pulmonary function tests, chest radiographs and occupational history. A history of exposure to free silica is necessary before the other two criteria can be fully utilized in making the diagnosis of silicosis since several other disease entities can produce similar radiographic patterns and since there is no pulmonary function test specific for silicosis. At the present time, the only method that can unequivocally demonstrate the pulmonary effects of exposure to free silica is lung tissue examination with demonstration of either silica crystals or the finding of the characteristic silicotic nodules.

The study of pulmonary function tests in the diagnosis of a pneumoconiosis is frequently complicated by such factors as the presence of other diseases, principally chronic bronchitis and/or emphysema, the population selected, the retirement of the more disabled persons and the medical-legal implications of assessing disability. Several studies on defined populations have shown that simple silicosis has little effect on ventilatory capacity. Obstructive lung disease was not found in the absence of chronic bronchitis, though there was a greater prevalence of chronic bronchitis among the group studied. When the effects of chronic bronchitis on ventilatory function have been excluded, simple silicosis appears to have little effect on lung function other than causing some reduction in compliance, exercise intolerance and hypoxemia after exercise. Complicated silicosis may result in progressive reduction in lung volumes, gas diffusion and exercise intolerance.

Radiographically, silicosis may be divided into several forms. The classification of these abnormalities is generally done in terms of the "UICC/Cincinnati Classification of the Radiographic Appearance of Pneumoconioses" adopted in 1971. Simple silicosis is graded according to the profusion of and the size of the majority of the opacities. Calcification of the periphery of the hilar lymph nodes may occur in silicosis and is called eggshell calcification. It may occur occasionally in sarcoidosis or less commonly in tuberculosis, but, when seen in a subject exposed to free silica, it is very suggestive of silicosis. Complicated silicosis is present when conglomerate masses greater than 1 cm diameter are present. At advanced stages, these masses are occasionally surrounded by emphysematous bullae. While conglomeration develops, the lungs gradually lose volume and compensatory emphysema occurs in the unaffected regions.

These changes are seen only in advanced disease. It is not uncommon to see a decrease in the size of conglomerate masses associated with a decreasing lung volume, increasing bullous emphysema and increasing disability. When tuberculosis complicates silicosis (called silico-tuberculosis), there may be no radiographic changes. This situation should be suspected when smaller nodular shadows increase in size rapidly or cavitate, if fibrotic apical shadows develop or if any rather rapid change occurs. The basis of the diagnosis of silico-tuberculosis is bacteriology rather than radiology.[1-2]

b. Phosphine (PH_3)[3-5]

When nodular iron is machined, it emits an odor similar to that of acetylene. This odor may become more pronounced when the freshly exposed surfaces are in a moist atmosphere. It has been postulated that the odor may be due to the presence of phosphine since phosphine gas results when a hydrolyzable phosphide is formed in iron by the reaction of magnesium with phosphorous ($3\ Mg + 2P$ -- Mg_3P_2). When the metal is machined, the phosphide is hydrolyzed by moisture in the air or in the coolant to phosphine ($Mg_3P_2 + 6H_2O$ -- $Mg(OH)_2PH_3$).

The health problem attributed to phosphine from nodular iron machining was first noted in Europe in 1955. Workmen reported eye irritation, anorexia and nose bleeding. Subsequent studies revealed that phosphine gas was emitted in concentrations that varied with the depth of cut and machine speed. Dust lying around the machine contributed significantly to the concentrations of phosphine determined in the breathing area of the workers. The use of coolants increased the moisture content at the machining point and increased the amount of phosphine generated. Other studies have also confirmed the production of phosphine during the machining of nodular iron both during "dry" and "wet" machining. During dry machining, the phosphine concentrations have ranged from 0.02 to 0.05 ppm and increased to 0.6-0.74 ppm when the milling and drilling operations were lubricated with a coolant. One study advocates that the hazard can be controlled by efficient collection of the dust which drops into a suitable medium such as a 1% solution of potassium permanganate.

The acute effects of phosphine on man that have been reported include: coldness, chest discomfort, weakness, vertigo, cough, anorexia, nausea and mucous membrane irritation of the eyes and nose.

c. Iron Oxide (Fe_2O_3)

Prolonged, excessive exposure to this agent gives rise to "iron pigmentation" of the lungs, known as siderosis, which is, at the present time, considered a benign pneumoconiosis in that it does not lead to progressive pulmonary fibrosis (scarring) or predispose to lung cancer and tuberculosis. This type of dust or fume is found in a number of occupations such as welding, iron ore mining, foundry work and fettling operations. Regarding the systemic absorption of iron from iron oxide inhalation, no evidence of systemic disease has been noted. With regard to local effects, mucous membrane irritation of the upper respiratory tract and sinuses have been known to occur with excessive exposure to this agent.

d. Calcium Oxide (CaO)

Calcium oxide is a moderately caustic agent producing irritation of the eyes, nose, throat and upper respiratory tract. It is reported to have caused a chemical pneumonia as a result of dust inhalation.

e. Nickel (Ni)

Exposure to nickel has been associated with an increased incidence of lung cancer. Numerous cases of dermatitis have been reported among nickel platers.

f. Manganese (Mn)

Chronic inhalation of manganese containing fumes or dust may produce a pneumonitis associated with pleurisy. Chronic exposure to manganese may result in chronic manganese poisoning (manganism), a disease of the central nervous system in which the characteristic pathological lesion is destruction of the basal ganglia. Manganism may produce a syndrome which is indistinguishable from idiopathic Parkinson's disease.

E. <u>Evaluation Results and Discussion</u>

1. <u>Environmental</u>

Direct reading detector tube samples collected at the time of the initial survey indicated no detectable concentrations of sulfur dioxide during melting desulfurization or alloying operations. It was subsequently learned that most sulfur released from the melt is retained in a bound form in the slag formed. No subsequent work was done in this area regarding sulfur dioxide.

Upon returning to the plant to conduct environmental sampling, it was determined that the practice of using soda ash for desulfurization had been discontinued in favor of a newly developed mixture designed for this purpose. Interviews with employees indicated that this action had improved conditions; however, some irritation was experienced during desulfurization.

The three bulk samples of sand and settled dust that were collected ranged from thirty-nine to sixty-five percent free silica (average fifty-three percent) indicating the presence of free silica in the work environment and a potential health hazard. (See Table 1.) Based on this information, a total of thirty-nine respirable dust samples were collected over two days with sampling being done on three shifts each day. When the samples were evaluated gravimetrically, a wide range of results even within specific job descriptions were found. This may be explained in part by the job duties which vary even though the classification may be the same.

Samples collected during the first visit when analyzed colorimetrically gave inconsistent values for the free silica due to a high background of amorphous silica in the filters and had to be disregarded. Weights obtained from gravimetric determinations performed were valid and appear in Table 6 under the April, 1975, date. Subsequently, samples collected on the second visit were analyzed by x-ray diffraction and were found to have between eight and forty-three percent free silica.

When environmental samples are compared to the OSHA standard, forty-eight percent of the samples (11 out of a possible 23) are in excess of the calculated OSHA standard. It should be noted that all free silica samples were collected over the length of a normal work period during which exposure occurred. When TWA's were calculated for comparison against the OSHA standard, any time in excess of the sample duration up to eight hours was considered as zero exposure. For all job classifications, except the laborer whose TWA's were lower because of limited exposure time, at least one sample was excessive. When the TWA's for which no limit was directly available are compared to the highest limit (i.e., the least restrictive), thirty-three percent (5 out of 15) of the samples were excessive.

NIOSH in its Criteria Document for Silica recommended a more stringent limit, however, of 0.05 mg/m^3 free silica based on a ten-hour time weighted average. When the twenty-three respirable dust samples are evaluated using this criterion (Table 5), ninety-six percent of the samples collected (22 out of 23) were excessive. Although many of the TWA's were between one and two times in excess of the NIOSH criterion, most values were again lower due to the relatively short exposure times used in calculation. When exposures are not time weighted, seventy percent (16 out of 23) were three or more times in excess of the 0.05 mg/m^3 recommended criterion.

Many of these excessive exposures are directly related to material handling problems which are performed without the benefit of local exhaust ventilation, which, in many cases, may not be practical due to the size of castings or operations being performed.

For this reason, it is recommended that serious consideration be given to converting to a sand containing low free silica for operations throughout the foundry.

Samples collected during melting, desulfurization and pouring operations were analyzed for metal fumes (Table 2) and calcium oxide (Table 3) and in all cases were found to be less than present acceptable limits. Although metal fumes evolving from desulfurization and alloying aspects of the metal preparation operations were quite noticeable, the duration of exposure was very limited due to the short duration of the operations and, therefore, do not present a toxic condition.

Eleven direct reading air samples for phosphine were collected on two separate days. During the first day of sampling, a high level was noted during wet grinding of "Magalloy C." In an effort to obtain additional documentation of phosphine concentrations, air samples were collected using silver nitrate impregnated filters for comparison with direct reading detector tube results during the subsequent visit. The reaction desired on the sampling filters involved a conversion of the silver nitrate to silver metal by phosphine. The analysis of the air samples was considered invalid, however, because of high and erratic blank values. This may be explained in part since silver nitrate may also be converted to silver metal by sunlight or organics and since that the analytical test for silver metal may be interfered with by the presence of other metals. Thus, it was determined that this technique could not be used in foundry operations for phosphine determinations.

Phosphine determinations obtained using direct reading detector tubes during the second visit indicated the presence of phosphine (Table 4). However, concentraitons noted were well within the present occupational exposure limit. Based on this information, it is concluded that employees may be transiently exposed to phosphine generated in the machining of nodular iron rolls. This exposure may explain the complaints noted by employees in this area; however, due to the limited exposure time involved with alloys that appeared to generate higher exposure levels, a toxic condition does not appear to exist.

2. Medical

Of the 25 persons working in the foundry area, including several cranemen, 4 persons (2 pitmen and 2 cranemen) reported transient mucous membrane irritation and occasional coughing and occasional skin irritation during the desulfurization process but most especially during the pouring of the molten iron. Eight persons complained that the job was dusty and several persons said that they could not tolerate wearing a respirator. Other than 3 persons - all active cigarette smokers - who gave long histories of chronic bronchitis, no person gave a history consistent with silicosis. No cases of dermatitis were found.

On the day of the NIOSH visit, no complaints of mucous membrane irritation were reported by the employees interviewed in the foundry area. Interviews conducted in the machining area elicited a variety of complaints.

Of the 10 persons interviewd, 5 persons noted that magallory metal emitted a "fishy odor" that transiently irritated the mucous membranes of the eyes and nose. Five persons interviewed gave no complaints.

A review of the combined results of the company's 1971-72 and 1974-75 chest radiograph surveys revealed the following:

Diagnostic Survey	Number of X-rays
Definite Silicosis	2 (same person)
Possible Silicosis or other Pneumoconioses	22
Other Abnormalities	60
Normal	280
Total	363

Included in the "possible silicosis" category are all persons whose chest x-rays are suggestive of silicosis. These chest radiographs showed nonspecific micronodular changes of "p" and "q" categories with a profusion of 0/1 to 1/1. Given that these chest radiographs are of individuals who have worked extensively in foundries, these radiographic changes raise the possibility of simple silicosis. Included in the "other abnormalities" category are radiographic changes not compatible or suggestive of silicosis or other pneumoconioses.

V. CONCLUSION

Based on the environmental data (Tables 1, 5 and 6) which show the workroom air concentrations of crystalline free silica to exceed the current NIOSH recommended standard of 0.05 mg/m^3 and a review of the results of the company's x-ray surveys which indicated a number of cases of silicosis, possible silicosis, or other pneumoconioses, it is concluded that with regard to employee exposure to silica that a toxic exposure exists at this plant.

Based on the environmental data, inspection of the machining area, and interviews, it is concluded that employees may be transiently exposed to phosphine generated in the machining of nodular iron rolls. This exposure would explain the complaints noted by employees in this area. However, it is judged not to represent an excessive exposure due to sporadic nature of the operation.

Although the environmental values for metal fumes and calcium oxide were below the current recommended limits, it is possible that during tapping the concentrations of these fumes could transiently exceed the current limits of occupational exposure accounting for the episodic and transient symptoms of mucous membrane and skin irritation noted by cranemen and pitmen.

VI. RECOMMENDATIONS

In general, when silica is used, environmental and medical recommendations suggested in the NIOSH criteria document are recommended. A copy of this document is enclosed for your information. The following recommendations are more specific for your operations and are made in an effort to improve working conditions.

1. It is advisable that low silica containing sand be substituted wherever and whenever feasible.

2. House cleaning in general needs to be improved in the foundry. Cleaning by dry sweeping should be avoided. In the roll shop, it is advisable to clean up the individual machining area, removing the turnings and swarf on a daily basis. Efficient collection of dust and turnings in a suitable media such as 1% potassium permanganate solution. These measures would minimize the potential development of phosphine gas.

3. Local exhaust ventilation in the area of the sand muller needs to be improved. Employees in the foundry should be provided with an appropriate respirator depending on the air level of respirable silica dust. The cotton dust filters that were observed are not adequate substitutes.

4. It is advisable to suppress and reduce the exposure to airborne free silica dust by wetting foundry sand with water on a regular basis prior to processing sand for reuse. This is of greatest importance during shake-out and sand reclamation aspects.

5. It would be advisable to explore the possibilities of mechanizing the shake-out procedures.

6. The use of self-contained breathing apparatus by the cranemen during the tapping procedures should be encouraged in conjunction with appropriate skin protection such as long sleeve shirts and gloves.

7. It is advisable to repair the seal on the crane cabs so as to maximize the separation between the inside and outside environments.

VII. REFERENCES

1. W. K. C. Morgan and A. Seaton, Occupational Lung Disease, pp. 80-111. Philadelphia, W. B. Saunders Company, 1975.

2. Criteria for a Recommended Standard . . . Occupational Exposure to Crystalline Silica -- 1974. USDHEW Publication No. (NIOSH) 75-120.

3. Phosphine Gas Released in Machining of Nodular Iron, Michigan Occupational Health, 10, 7-8, Winter 1964-65.

4. G. E. Matthew, The Production of Phosphine While Machining Spheroidal Graphite Iron, Ann. Occup. Hyg., 4, 19-35 (1961).

5. J. R. Bowker, The Liberation of Phosphine in the Machining of Spheroidal Graphite Iron, Trans. Assoc. Industrial Medical Officers, 8: 50-53 (1958).

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Table 1
Quartz Percentage
Blaw Knox Foundry & Mill Machinery, Inc.
Warwood Plant
Wheeling, West Virginia
September 18-19, 1974

Location	% Quartz Colorimetric	% Quartz X-Ray Diffraction	Average
Pattern Storage Settled Dust	39	43	41
Sand Mill Operator's Booth Settled Dust	52	58	55
Shake-Out Floor	65	63	64
		Overall Average:	53

Table 2
Metal Fume Concentrations
Blaw Knox Foundry & Mill Machinery, Inc.
Warwood Plant
Wheeling, West Virginia
April 1-2, 1975

Sample Number	Operation	Sampletime Hours	Mn(a) Mg/m^3	Ni(b) Mg/m^3	Fe_2O_3 Mg/m^3	Cr(d) Mg/m^3	Remarks
M-1	Furnace	4.0	.01	.03	.83	.01	Operator's
M-8	Tender	2.9	.01	.04	.74	.01	Exposure
M-12		6.0	.01	.02	1.88	$<$.01*	
M-2	Crane	4.0	.03	.19	6.58	.04	Operator's
M-6	Operator	3.2	.02	.05	1.29	.01	Breathing
M-10		6.1	.01	.03	.73	$<$.01	Zone
M-3	Pitman	3.5	.01	.15	4.38	.01	Operator's
M-5	(Skinner)	3.2	.01	.01	.54	.01	Exposure
M-9		6.1	.01	.01	.59	$<$.01	
M-7	Swing	2.2	.02	.04	1.33	.02	Operator's
M-11	Grinder	2.3	.01	.04	.52	.01	Breathing Zone

Federal Occupational Health Standards based on a time weighted average for an 8-hour working day are (ceiling value never to be exceeded):

(a) Mn - Manganese 5.0 mg/m^3
(b) Ni - Nickel 1.0 mg/m^3
(c) Fe_2O_3 - Iron Oxide 10.0 mg/m^3
(d) Cr - Chromium 1.0 mg/m^3

* $<$ denotes less than

Table 3
Calcium Oxide Concentrations[(a)]
Blaw Knox Foundry & Mill Machinery, Inc.
Warwood Plant
Wheeling, West Virginia
April 1-2, 1975

Sample Number	Location	Sample Time (hours)	Mg/m^3 [(b)]	Remarks
C-1	Foundry	4.0	.02	Operator's breathing zone[(c)] working inside crane cab
C-2		4.0	.06	
C-3		.1	3.21	General air, outside crane cab during desulfurization

(a) Federal Occupational Health Standard based on time weighted average for an 8-hour work day: 5.0 milligrams per cubic meter of air.

(b) Denotes milligrams per cubic meter of air.

(c) Self-contained breating equipment being worn during desulfurization operations.

Table 4
Phosphine Concentrations[a]
Blaw Knox Foundry & Mill Machinery, Inc.
Warwood Plant
Wheeling, West Virginia
April 2, 1975, July 23-24, 1975

Sample Number	Location	PPM[b] 4/75	7/75	Remarks
P-1	Roll Shop	0.5		Operator's exposure 20" Landis grinder light work on Magalloy "C"
P-2		1.0		Operator's exposure 20" Landis grinder main work on Magalloy "C"
P-3		N.D.[c]		Operator's exposure 36" Landis grinder working on Magalloy "B"
P-4	Foundry Bay	N.D.		Operator's exposure Crane Cab during desulfurization
P-5		N.D.		Operator's exposure melting platform during desulfurization
P-6	Roll Shop		0.1	Operator's exposure 36" Landis grinder working on Magalloy "C"
P-7			0.1	Operator's exposure 24" Landis grinder working on Magalloy "B"
P-8			0.1	Operator's exposure dry lathing on Magalloy "C"
P-9			0.1	Operator's exposure 20" Landis grinder working on Magalloy "C"
P-10			0.1	Operator's exposure 24" Landis grinder working on Magalloy "D"
P-11			0.1	General Air behind 24" Landis

(a) Threshold Limit Value based on time weighted average for an 8-hour work day: 0.3 parts per million parts of air.

(b) Denotes parts of phosphine per million parts of air.

(c) Denotes none detected.

Table 5
Respirable Silica Dust Concentrations
Blaw Knox Foundry & Mill Machinery, Inc.
Warwood Plant
Wheeling, West Virginia
July 23-24, 1975

Sample Number	Job Description	Exposure Time (Sample Duration) hours	Silica[a] Mg/M3 [b]	TWA_{10} [c]	Remarks
98	Chipping	6.2	.20	.12	OBZ[d]
159		5.75	.24	.14	OBZ
158	Bench	4.4	.83	.36	OE[e]
190	Molding	4.6	.13	.06	OE
220	Slinger	4.1	.21	.09	OE
167		3.8	.17	.06	OE
160		4.1	.10	.04	OE
212	Crane	3.6	.23	.08	OE
189	Operator (day)	5.75	.17	.10	OE
80	Crane	3.5	.20	.07	OE
168	Operator	6.0	.13	.08	OE
89	(night)	3.5	.16	.06	OE
100	Laborer	3.5	.19	.07	OE
157		5.6	.10	.06	OE
170	Chairman	6.0	.11	.07	OE
169		6.0	.12	.07	OE
178		6.0	.15	.09	OE
207		6.0	.08	.05	OE
216		3.5	.37	.13	OE
88		3.5	.19	.07	OE
79		3.5	.16	.06	OE
90	Muller	5.5	.22	.12	OBZ
97	Operator	5.8	.28	.16	OBZ

(a) NIOSH Recommended Criterion based on a time weighted average for a 10-hour working day: 0.05 milligrams per cubic meter of air.

(b) Denotes milligrams per cubic meter of air.

(c) Denotes time weighted average based on 10-hour working day.

(d) Denotes operator's breathing zone, respirator being worn.

(e) Denotes operator's exposure, respirator not being worn.

Table 6
Respirable Silica Dust Concentrations
Blaw Knox Foundry & Mill Machinery, Inc.
Warwood Plant
Wheeling, West Virginia
April 1-2, 1975, July 23-24, 1975

Sample Number	Job Description	Exposure Time Sample Duration (hours)	Respirable Fraction Total Dust, Mg/m^3 [a] Apr 75	Jul 75	% Free SiO_2	TLV [b]	TWA_8 [c]	Remarks
47	Chipping	4.5	.45				.25	OBZ [d]
98		6.2		1.57	13	.71	1.21	OBZ
159		5.75		1.58	17	.53	1.1	OBZ
36	Bench	4.1	.85				.43	OE [e]
	Molding	4.4		5.56	15	.59	3.06	OBZ
190		4.6		.56	24	.38	.32	OE
41	Slinger	5.0	1.75				1.09	OE
220		4.1		1.49	15	.61	.76	OBZ
167		3.8		.93	18	.5	.44	OE
160		4.1		.42	25	.37	.21	OE
212	Crane	3.6		2.12	11	.77	.95	OE
189	Operator (Day)	5.75		2.24	8	1.05	1.61	OE
34	Crane	5.3	.36				.24	OE
50	Operator	5.1	.45				.28	OE
39	(Night)	4.7	.40				.23	OE
80		3.5		.83	24	.38	.36	OE
168		6.0		.81	16	.55	.61	OE
89		3.5		.69	23	.40	.30	OE
42	Laborer	6.4	1.8				1.44	OBZ
100		3.5		1.57	12	.71	.69	OE
157		5.6		.75	14	.63	.53	OE
44	Chainman	4.6	.75				.45	OE
45		4.5	.28				.16	OE
32		4.5	7.69				4.32	OE
31		4.5	13.15				7.4	OE
35		4.5	.35				.20	OE
38		4.2	.18				.09	OE
170		6.0		.67	16	.55	.50	OE
169		6.0		.54	22	.42	.40	OE
178		6.0		1.04	15	.59	.78	OE
207		6.0		.42	19	.49	.31	OE
216		3.5		2.19	17	.53	.96	OE
88		3.5		.64	29	.32	.28	OE
79		3.5		.38	43	.22	.16	OE
33	Muller	6.0	3.0				2.25	OBZ
90	Operator	5.5		1.77	12	.71	1.2	OBZ
97		5.8		1.91	14	.63	1.3	OBZ
40	Chill	2.5	.39				.12	OBZ
46	Cleaner	2.0	N.D. [f]					OBZ

(a) Denotes milligrams per cubic meter of air.
(b) Federal Occupational Health Standard for respirable free silica as calculated from formula: $\frac{10}{\%\ Quartz + 2}\ Mg/m^3$
(c) Time weighted average based on an 8-hour working day.
(d) Denotes operator's breathing zone, respirator worn.
(e) Denotes operator's exposure, no respirator worn.
(f) Denotes none detected.