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ASBURY GRAPHITE MILLS, INC.
ASBURY, NEW JERSEY

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I. SUMMARY

In December 1992, the Division of Respiratory Disease Studies, National Institute for Occupational Safety and Health (NIOSH) received a request for technical assistance from the Occupational Health Service, New Jersey Department of Health (NJDOH) to evaluate exposures to pneumoconiotic dusts at the Asbury Graphite Mill in Asbury, New Jersey. The request was made after a case of pneumoconiosis in a former plant employee was reported to NJDOH.

During July 19-23, 1993, environmental and medical surveys were conducted at the facility. The environmental portion of the survey consisted of collecting personal breathing zone and area environmental air samples. The medical portion of the survey consisted of an occupational and medical history questionnaire, spirometry, and a single view (posterior-anterior) chest x-ray.

Both personal breathing zone and area air sampling were conducted during the first shift for 3 consecutive days to measure respirable graphite, respirable dust, respirable crystalline silica, and total dust. Of 35 personal samples and 19 area samples collected for respirable graphite, one personal sample had a concentration that exceeded the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) of 2 mg/m^3. Sixty-seven personal breathing zone samples and 16 area samples for respirable dust and respirable crystalline silica were collected. There are no applicable evaluation criteria for "respirable dust" for this facility; the samples were collected for use in evaluating exposures to respirable crystalline silica. Because of interferences in the analytical method, silica content of the respirable dust samples could not be determined. However, using silica percentages found in samples collected by the Mine Safety and Health Administration (MSHA), the potential for overexposure to respirable crystalline silica was demonstrated for several of the samples collected by NIOSH. Of 34 personal breathing zone and 20 area samples collected for total dust, one personal and two area concentrations exceeded the ACGIH TLV and the MSHA Permissible Exposure Limit (PEL) of 10 mg/m^3 for total particulate, not otherwise classified. Local exhaust ventilation systems for some of the operations were not adequate to prevent dust emissions. Some of the operations did not have local exhaust ventilation and some existing systems were disabled.

Forty-seven of the 54 current mill employees participated in the medical study. Three current employees had x-rays that were classified as being consistent with pneumoconiosis. Individuals performing jobs with higher potential for exposure

reported symptoms of chronic cough and chronic phlegm more frequently than workers with lower potential for exposure. Pulmonary function was inversely related to exposure; the mean percent predicted forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) were lower for individuals with higher exposure potential and higher for those with lower exposure potential.

Based on the index case and results of this investigation, the NIOSH investigators have concluded that, during the time of this evaluation, a potential health hazard from exposure to silica-containing dusts existed at the Asbury Graphite Mill. Air sampling revealed a few overexposures to dusts, and the potential for overexposure to silica was demonstrated. Deficiencies were noted in the engineering controls for some of the feeding and bagging operations. The medical findings suggest that there may be long-term adverse health effects associated with exposure to silica-containing graphite, including decreased pulmonary function and the development of pneumoconiosis.

The recommendations made include improving local exhaust ventilation systems, developing a formal respiratory protection program, and instituting a medical surveillance program.

Keywords: SIC 1499 (Miscellaneous Nonmetallic Minerals), Natural Graphite, Synthetic Graphite, Silica, Pneumoconiosis.

II. INTRODUCTION

In October 1992, the National Institute for Occupational Safety and Health (NIOSH) received a request from the New Jersey Department of Health to review the medical records of an individual whose death certificate listed "pneumoconiosis" as the underlying cause of death. The available medical records and chest x-rays were reviewed and the case was discussed with a physician who cared for the patient prior to his death.

The index case had worked at the Asbury Graphite Mill in Asbury, New Jersey, for 24 years until he was unable to continue working because of his health. The death certificate listed his usual occupation as "miller." His only previous work was as a farmer. The decedent's 1990 and 1992 chest radiographs were classified for pneumoconiosis by a NIOSH certified B Reader using the International Labour Office (ILO) system.(1) The radiographs from his terminal hospitalization in 1992 were difficult to interpret due to the presence of pleural effusions and pulmonary edema. The 1990 radiograph was classified as q/p 3/3 involving all zones of both lungs indicating the highest major profusion category for small, rounded opacities.

In December 1992, the New Jersey Department of Health (NJDOH) was notified that this case met the NIOSH surveillance case definition for silicosis.(2) Specifically, the case satisfied both criteria A.1. (a history of occupational exposure to airborne silica dust) since graphite has been shown to contain silica(3) and A.2. (a chest radiograph or other imaging technique interpreted as consistent with silicosis).

In December 1992, the NJDOH requested technical assistance from NIOSH to evaluate exposures to pneumoconiotic dusts at the Asbury Graphite Mill. On February 19, 1993, a NIOSH industrial hygienist and occupational medicine physician made an initial site visit to the Asbury Graphite Mill. The NIOSH representatives met with management, employee representatives, and representatives from NJDOH, discussed the request and ensuing evaluation, and conducted a walk-through survey of the mill.

During July 19-23, 1993, environmental and medical surveys were conducted at the facility. The environmental portion of the survey included collection of personal breathing zone and area environmental air samples. The medical portion of the survey consisted of an occupational and medical history questionnaire, spirometry, and a single view (posterior-anterior) chest x-ray. All study participants received individual letters informing them of their chest x-ray and pulmonary function test results.

III. BACKGROUND

The Asbury Graphite Mill, also referred to as the Asbury plant, is located just south of the Asbury city limits in Hunterdon County, New Jersey. It is one of three mill facilities owned by Asbury Graphite Mills, Inc.; the others are located in Bethlehem and Kittanning, Pennsylvania. The Asbury plant has been processing graphite since about 1920. The plant consists of numerous buildings including: Mill 2, the Packing House, Shed 8, the Shipping Warehouse, the Wash House, an office and quality control lab, and several sheds that are primarily utilized for storage of parts, raw materials, and finished products. Within the facility, raw graphite (also known as "stock") is received, ground, screened, occasionally blended with other materials, packaged, and loaded for shipment.

Natural flake, natural amorphous, and synthetic graphite arrive from off-site by truck in small bags or super sacks (up to 2,500 pounds). Often the small bags must be transferred by hand to pallets prior to forklift delivery to a storage shed. The raw graphite ranges in size from powders to 4-inch pieces.

The processing of the raw graphite into finished product takes place in Mill 2 and Shed 8. In these buildings, graphite is introduced into the system at feed hoppers by workers referred to as stock runners. The feed hopper is a chute which is totally enclosed except for an opening in the front. Bags are lifted onto the ledge of the opening and then slit to empty their contents into the hopper. The raw and product materials are conveyed through much of the production process pneumatically and by gravity. In Mill 2, the material is ground in one of three types of mills: ball, roller, and jet mills. Ball and roller mills use metal balls or rollers to grind the material. Jet mills use high velocity air streams to cause material particles to collide with each other and fracture into smaller particles. Prior to being conveyed to one roller mill, large chunks of material are processed in the "breaker," which is a hammer mill. In both buildings, the material is separated according to size. This separation is facilitated by vibrating screens and/or cyclones. The screens consist of a horizontal case containing multiple sieving decks of mesh screens of varying sizes. Cyclones are large cylinders in which dust-laden air is injected; their geometry and the characteristics of the air movement cause larger particles to fall and smaller particles to rise with air exiting the top. Some of the material in Mill 2 also goes through a magnetic dust separator (separates iron particles from screened material) and a stoner (separates silica from raw and product materials by gravity). Shed 8 also contains a blender in which additives are mixed with graphite to fulfill the specifications of buyers. The additives include calcined coal, coke, talc, clays, dextrin, olivine sand, aluminum chip, iron oxide, etc.

Packing of the final product takes place in Mill 2, Shed 8, and the Packing House. The final product, which ranges in size from 3 micrometers (µm) to 5 µm, is loaded into various containers (small bags, super sacks, large boxes, and 55-gallon drums) at packing stations. The bag packing machines include gravity packers, screw packers, and jet flow packers. The filled bags are loaded onto pallets, glued together, shrink wrapped, and brought to the Shipping Warehouse on forklifts. Products are loaded onto trucks for shipment.

IV. EVALUATION METHODS

A. ENVIRONMENTAL

Both personal breathing zone and area air sampling were conducted July 20-22, 1993, during the first shift of each day to measure respirable graphite, respirable dust, respirable crystalline silica, and total dust (respirable dust and silica were to be measured from the same filters). The first shift was chosen because it was the shift with the most workers and production and, therefore, was anticipated to be the most dusty shift of the day. Two personal air samplers were placed in the breathing zone of each worker just prior to starting the shift and retrieved at the end of the shift. A sampler for respirable dust and crystalline silica was worn every day, and the other sampler was alternated between respirable graphite and total dust each day. Baskets containing one of each of the three sampler types were placed in many areas of the mill in close proximity to the operations. All respirable samples were collected on filters mounted in series with 10-mm nylon cyclones as pre-collectors. For all samples, air was drawn through the filters at an approximate flow rate of 1.7 liters per minute (lpm) using battery-powered sampling pumps.

Respirable Graphite

Respirable graphite samples were collected on 37-mm quartz-fiber filters. Graphite on the filters was measured with a thermal-optical analysis method for organic and elemental carbon.[4] In this method a laser and flame ionization detector were used to measure the organic and elemental carbon during several incremental stages of heating portions of the samples. Elemental carbon results were reported as graphite.

Respirable Dust

Respirable dust samples were collected on pre-weighed, 37-mm (diameter), 5-µm (pore size) PVC membrane filters. The filters were measured gravimetrically to obtain respirable dust mass as specified in NIOSH Method 0600.[5]

Respirable Crystalline Silica

After the respirable dust filters were weighed, they were analyzed for respirable crystalline silica. Because graphite is known to be an interference in NIOSH Method 7500[5], the filter samplers were placed in a low temperature oxygen plasma asher (LTA) to remove the filter substrate and the graphite prior to being analyzed by x-ray diffraction (XRD).

Total Dust

In accordance with NIOSH Method 0500[5], total dust samples were collected on open-faced, pre-weighed, 37-mm (diameter), 5-µm (pore size) PVC membrane filters, and mass gain was measured gravimetrically.

B. MEDICAL

The company supplied a list of all employees who had terminated employment at Asbury Graphite in the last 5 years. Each of these prior employees received a letter describing the study. Individuals who were interested in participating in the study were asked to respond via a postage-paid envelope. Respondents were contacted by a NIOSH employee to set up an appointment for spirometry, a single view chest x-ray, and an occupational and medical history questionnaire.

All current employees were invited to participate in the medical survey which consisted of an occupational and medical history questionnaire, spirometry, and a single-view (posterior-anterior) chest x-ray. This testing was performed on-site by NIOSH personnel during the period July 19-22, 1993.

The presence of respiratory symptoms was assessed by questionnaire. Chronic cough was defined as cough occurring on most days totalling 3 or more months during the year. Chronic phlegm was defined similarly. Grade I dyspnea was defined as shortness of breath when hurrying on level ground or walking up a slight hill. Grade II dyspnea was defined as shortness of breath while walking on level ground with people of one's own age, and Grade III dyspnea was defined as having to stop for breath when walking at one's own pace on level ground. Individuals who currently smoked cigarettes were defined as current smokers. Individuals who had smoked five or more packs of cigarettes during their entire life but did not currently smoke cigarettes were classified as ex-smokers.

Spirometry

Spirometry was performed using a dry rolling-seal spirometer interfaced to a dedicated computer. At least five maximal expiratory maneuvers were recorded for each person. All values were corrected to BTPS (body temperature, ambient pressure, saturated with water vapor). The largest FVC and FEV_1 were the parameters selected for analysis, regardless of the curves on which they occurred. Testing procedures conformed to the American

Thoracic Society's recommendations for spirometry.[6] Predicted values were calculated using the Knudson reference equations.[7] Predicted values for blacks were determined by multiplying the value predicted by the Knudson equation by 0.85.[8] Test results were compared to the 95th percentile lower limit of normal (LLN) values obtained from Knudson's reference equations to identify participants with abnormal spirometry patterns of obstruction and restriction.[7] Five percent of a normal non-smoking population will have predicted values that fall below the LLN while 95% will have predicted values above the LLN.

Using this comparison, obstructive and restrictive patterns are defined as:

Obstruction: Observed ratio of FEV_1/FVC% below the LLN.
Restriction: Observed FVC below the LLN; and FEV_1/FVC% above the LLN.

The criteria for interpretation of the level of severity for obstruction and restriction, as assessed by spirometry, is based on the NIOSH classification scheme (available upon request from the Division of Respiratory Disease Studies). For those persons with values below the LLN, the criteria are:

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

Posterior-Anterior (PA) Chest X-rays

Each PA chest x-ray was taken on a full size (14 x 17 inch) film and read independently by two NIOSH-certified pneumoconiosis B Readers who, without knowledge of the participant's age, occupation, or smoking history, classified the films according to the 1980 Guidelines for the use of ILO International Classification of Radiographs of Pneumoconioses.[1] A chest radiograph was defined as positive for (that is, consistent with) pneumoconiosis if each of the two B Readers classified small opacity profusion as 1/0 or greater. In the event of disagreement between the two readers, a third reading was obtained and a consensus reading was generated.

V. EVALUATION CRITERIA AND TOXICOLOGY

A. EXPOSURE CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a 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 this may 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 sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV), and 3) the U.S. Department of Labor (DOL) - Occupational Safety and Health Administration (OSHA) or Mine Safety and Health Administration (MSHA) standards. Often, the NIOSH Recommended Exposure Limits (RELs) and ACGIH TLVs are lower than the corresponding DOL PEL standards. 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 a DOL 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 or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high, short-term exposures.

The evaluation criteria for the substances involved in this evaluation are shown in the following table:

EVALUATION CRITERIA (all values are mg/m^3 * unless noted)			
ANALYTE	NIOSH REL[9]	MSHA PEL[10] (uses 1973 ACGIH TLV's)[11]	ACGIH TLV (1993-94)[12]
Natural Graphite, Respirable	2.5	1.9 @	---
Natural Graphite, Total	---	15 mppcf **	---
Graphite(all forms except fibers), Respirable	---	---	2
Silica , Crystalline (as quartz), Respirable	.05	---	.10
Dust containing ≥ 1% quartz, Respirable	---	$\frac{10}{\%quartz + 2}$	---
Dust containing ≥ 1% quartz, Total	---	$\frac{30}{\%quartz + 3}$	---
Dust containing <1% quartz (Particulate, Not Otherwise Classified), Total	---	10	10

* mg/m^3 = milligrams of contaminant per cubic meter of air

** mppcf = million particles per cubic foot of air counted from impinger samples.

@ The 1973 ACGIH TLV's do not include a value for respirable natural graphite, but rather only have the limit value for total natural graphite (15 mppcf) to be measured by impingers. To be able to use a gravimetric method, MSHA conducted side-by-side sampling at graphite mills (including the Asbury plant) with cyclones and impingers. With the data they derived the following conversion that is applicable to graphite:

8 mppcf (total graphite via impingers) = 1 mg/m^3 (respirable graphite via cyclones)

B. TOXICOLOGY

There are two forms of graphite: natural and synthetic. Natural graphite (plumbago) is crystalline carbon with many different mineral impurities, including silica. The crystalline silica (also referred to as free silica) content varies between 3.6-11%, depending on the country of origin. Other common impurities include iron oxide, clay, and mica. Synthetic graphite is crystalline carbon made by subjecting coal or petroleum coke to temperatures of 2,000-3,000 degrees Centigrade in an electric furnace. It contains only very small quantities of crystalline silica.[3]

As of 1983, approximately 605 cases of pneumoconiosis had been described in graphite-exposed workers. The largest group of cases (261) involved the use of milled graphite in various manufacturing processes including the manufacture of crucibles and electrodes and use in foundries.[3] New cases of pneumoconiosis continue to be diagnosed in carbon electrode workers.[13]

Most epidemiologic studies that have measured the prevalence of pneumoconiosis in graphite workers have involved the mining industry. The prevalence of pneumoconiosis in these studies varies widely, from 1% to 73%. Differences in sampling methods, definition of the population at risk, methods and standards of examination, and classification of pneumoconioses account for much of this variation.[3] There have been no systematic prevalence studies confined to graphite milling operations.

A study of graphite miners in Ceylon found that the average tenure of workers with radiographic lesions on chest x-ray was 21 years and that the peak incidence for lesions was in the fifth decade of life.[14] Engineering controls were instituted to reduce underground dust levels in the Ceylon mines. A systematic survey of miners in 1987 revealed that 3.4% had radiographic changes suggestive of pneumoconiosis compared to 18.3% in a similar population in 1972.[15]

It is unclear whether the pneumoconiosis associated with graphite exposure is caused solely or mainly by carbon or represents a mixed-dust pneumoconiosis caused by concurrent exposure to crystalline silica. Workers exposed to respirable crystalline silica can develop any one of three types of silicosis, depending on the airborne concentration of crystalline silica. Simple silicosis occurs after many (usually 15 or more) years of relatively low exposure to respirable silica. Accelerated silicosis results from exposure to higher concentrations of respirable silica and develops 5 to 15 years after the initial exposure. Acute silicosis may develop in a few weeks to 4 or 5 years after the initial exposure and is associated with very high exposure levels.[16] Simple silicosis and accelerated silicosis manifest as scarring of the lung parenchyma as a result of the fibrogenic reaction to the silica dust. Accelerated silicosis presents earlier due to the higher concentrations over a shorter period of time. The scarring that occurs results in a decreased ability of the lungs to transfer oxygen and in decreased lung volumes. Acute silicosis occurs when the lung is overwhelmed by exposure to crystalline silica and is associated with a proteinaceous fluid accumulating in the lungs as a reaction to the silica dust. Death from acute silicosis is due to filling of the lungs with this proteinaceous fluid and is associated with very little of the scarring that is typical of the other two forms.

Mycobacterial or fungal infections often complicate silicosis cases and in many cases can be fatal.[17] These infections are believed to be due to the reduced ability of silica-filled macrophages to kill the mycobacteria and other organisms.[18] Evidence now suggests that crystalline silica is a potential occupational carcinogen. NIOSH is reviewing the data on its carcinogenicity.[19-21]

VI. RESULTS AND DISCUSSION

A. ENVIRONMENTAL

Air Sampling Results

Respirable Graphite

Thirty-five personal breathing zone samples and 19 area samples were collected for respirable graphite (see Tables 1 and 2). The personal sample concentrations ranged from .01 to 2.46 mg/m^3. One sample was found to exceed the ACGIH TLV for graphite of 2 mg/m^3. Because this sample was collected on a stock runner who worked in an area where both natural and synthetic graphite were being processed in Mill 2 and the analytical method could not distinguish between the two, it can not be determined if the sample exceeded the MSHA PEL of 1.9 mg/m^3 for natural graphite. Area concentrations ranged from .02 to 1.42 mg/m^3; none were found to exceed the evaluation criteria.

In the laboratory analysis, only a small section near the perimeter of the filter was examined. The elemental carbon mass determined from this section was used to estimate the mass of graphite on the entire filter. Particles appeared to be evenly distributed on the majority of the filters; however, approximately 20% of the filters were observed to have heavier loads of particulate in the center. This likely resulted in underestimation of graphite concentrations for several of the samples.

Respirable Dust

Sixty-seven personal breathing zone samples for respirable dust and 16 area samples were collected during the 3 days of the survey. Concentrations determined from the personal samples ranged from "Not Detected" to 3.33 mg/m^3 (see Tables 3 and 4). The range of the area samples was "Not Detected" to 1.58 mg/m^3. There are no applicable evaluation criteria for "respirable dust" for this facility. The samples were collected for use in evaluating exposures to respirable crystalline silica.

Respirable Crystalline Silica

After the respirable dust samples were weighed, they were analyzed for crystalline silica. During this analysis, it was determined that another substance interfered with the analytical method. It was felt that this substance was bentonite clay, which was an additive used in the processing of some graphite products at the mill. As a result, respirable crystalline silica concentrations could not be obtained.

The plant manager reported that silica concentrations in the graphite stock material generally do not exceed 3%. Although not used in all products or on an everyday basis, many of the additive products also contain silica. Since 1990, MSHA collected two respirable dust samples on packers. Those samples contained 2.9 and 3.2% crystalline silica (as quartz). The former sample concentration exceeded the MSHA PEL for respirable dust containing greater than 1% quartz. The respirable dust samples collected during the NIOSH survey that would exceed the NIOSH REL for respirable quartz of .05 mg/m^3 if they contained up to 3.2% quartz are shown in Table 5. As expected, overexposures to respirable quartz would be most probable in samples which measured the highest concentrations of respirable dust. The samples were collected on maintenance workers, stock runners, a packer, and a foreman in various locations of the mill. This analysis does not verify that overexposures to crystalline silica existed during the NIOSH survey; however, with the available data it demonstrates the potential for overexposures at the facility.

Total Dust

Thirty-four personal breathing zone and 20 area samples were collected for total dust (see Tables 6 and 7). The personal sample concentrations ranged from .33 to 12.51 mg/m^3. The sample with the highest concentration, which was collected on a foreman who worked in various locations at the facility, exceeded the ACGIH TLV and the MSHA PEL of 10 mg/m^3 for "total particulate, not otherwise classified." A range of concentrations between .28 and 12.25 mg/m^3 was measured with the area samplers. The two highest (11.27 and 12.25 mg/m^3) exceeded the same evaluation criteria as the personal sample. These samples were collected near Screens 2 & 3 in Mill 2 and near the blender in Shed 8.

Overall Dust Exposure

Table 8 shows rank order listings of geometric mean personal breathing zone dust concentrations for each job group during the survey. Mean concentrations of respirable graphite, respirable dust, and total dust were consistently highest for foremen, stock runners, packers, and maintenance personnel. The mean concentrations of the dusts were lower for forklift operators, shipping personnel, the outside crew, and laboratory technicians.

Observations

Dust Generation and Control

There are several sources of dust generation throughout the facility. These include the transfer of stock material into the system at the feed hoppers, transfer of products into their containers, leakage within the process machinery, and regeneration of settled dust.

Dust generated during transfer of material was highly visible during the evaluation. The feed hoppers were totally enclosed except for an opening in the front. A local exhaust ventilation slot was located on the back wall of the enclosure to capture airborne dust generated during the feeding process. A large proportion of the dust was observed entering the slots; however, the amount of dust that escaped from many of the feed hopper enclosures was substantial. In addition, a considerable amount of dust continued to be generated from the empty bags as they were lifted from the enclosure and placed onto a waste pile.

Sources of dust generation at the bagging operations included the small perforations in the bags that allow release of air as they are being filled, the hole (or lip) in the top of the bag that receives the filling spout, the seams in the top of the bags opposite the filling hole, and the small, screened funnel chute on some of the machines that received product just prior to it entering the bags. Many of the bagging machines were equipped with a local exhaust ventilation hood in which the bags are partially enclosed as they are filled. These appeared to be effective at preventing dust emanating from the bag perforations and from around the filling spouts. However, this arrangement was ineffective for the dust that flowed from the top seams of the bags because the tops of the bags were outside the confines of these hoods. At many of the stations dust was seen leaking slowly out of these folds as the bags were starting to fill; a thicker stream of dust was more forcibly ejected as the bag became nearly full. In addition, many times the workers hit the bags to make them fill properly, causing additional dust to fly from the bag seams. Some of the machines with the screened funnel chutes were equipped with local exhaust ventilation to capture airborne dust at the tops of the chutes, but this ventilation did not capture dust escaping from around the bag-filling spouts. A couple of the local exhaust ventilation ducts located above the bagging machines were disconnected. Local exhaust ventilation had not been provided for some of the bagging machines. The processes of loading products into supersacks, boxes, and drums were equipped with local ventilation systems that totally enclosed the processes and appeared to be effective.

Sometimes bagged raw graphite is repackaged by manually transferring it to drums. This operation which is performed by personnel from the Shipping Warehouse was observed only during the initial site visit. No local exhaust ventilation was provided for this operation in which extremely large amounts of fugitive dust were generated into the face of the worker.

The housekeeping practices at the mill appeared to be very good throughout the facility. A central vacuum system was used at the end of each shift to remove dust from equipment and floors and was likely very effective in minimizing the regeneration of settled dust into the air. This practice was observed in the occupied areas as well as the areas workers occupy infrequently.

Respirators

The company did not have a written respiratory protection program. However, workers are required to wear a respirator if an outstanding MSHA citation exists for a particular piece of equipment from which the worker may be exposed to dust, and respirator training is provided. Many workers wear respirators voluntarily. Workers who were observed with respirators were wearing single-use particulate respirators provided by the company. The company also supplies cartridge respirators to those workers who prefer them. Some workers were observed wearing respirators that held large accumulations of graphite, and they had been told that the accumulation of graphite increased the efficiency of respirators. Although this can be true for particular degrees of dust loading, there is concern that the workers will wear the respirators beyond their useful life and inhale contaminated air which passes the face seals.

Noise

We did not measure the sound levels in the mill. However, we considered them to be high in areas (especially near the ball mills) since we had to raise our voices to communicate even at short distances. Few workers wore hearing protection.

B. MEDICAL

Evaluation of Prior Employees

Fifty-one former employees were sent letters inviting them to participate in the study. There was no response to 20 of these letters, and 27 were returned because of incorrect addresses. Of the four individuals who responded to the letter, either by returning the enclosed form or via telephone, two indicated that they were unable to participate because of the distance between their homes and the testing site. The two remaining individuals indicated that they wanted to participate in the study and scheduled appointments. Neither of them kept their appointment.

Evaluation of Current Employees

Of the 54 current mill employees, one refused to participate and six were on vacation, leaving 47 current mill employees who participated in the NIOSH study. Two additional individuals who worked in the nearby research and development lab asked to participate in the study and were tested, although their results were not included in the analyses. All of the mill employees were men. The median age of the study population was 38 years with a range of 20 to 58 years. The prevalence of current cigarette smoking was 34%. Current smokers had smoked for a median of 20 years, and 81% of them reported smoking one or more packs of cigarettes per day. Thirty-two percent of workers reported that they were former smokers. These individuals had smoked a median of 4 years, and 53% reported that they had smoked one or more packs per day. The remaining workers (34%) reported that they had never smoked cigarettes.

The median employment tenure at Asbury Graphite was 11 years and ranged from less than 6 months to 28 years. Sixty-six percent of those surveyed worked the day shift, 26% worked the evening shift, and 9% worked the night shift. More than half (57%) of the workers were involved in production jobs, and 30% were employed in mill support functions. Smaller numbers of workers were employed in outside jobs (6%), and office jobs (6%).

One participant reported that he had worked at another graphite mill for 9 years. Eighteen participants reported previous work in occupations or industries other than graphite milling that might have resulted in exposure to fibrogenic dusts. For five individuals, tenure in these jobs was less than 6 months. For seven individuals it ranged between 1 and 5 years and the remaining six individuals had worked in such jobs for more than 5 years.

For the medical analyses, each worker was classified as regularly having either higher or lower dust exposure potential based on their job title. Results of dust sampling and observations from the environmental evaluation were used in making these classifications. Foremen, stock runners, packers, and maintenance personnel were classified as having higher exposure potential; forklift operators, shipping personnel, the outside crew, laboratory technicians, and office workers were classified as having lower exposure potential. Classification into a lower exposure potential group does not indicate that those workers may not intermittently experience high exposures.

The symptoms of chronic cough and chronic phlegm were reported more frequently by individuals in the higher exposure potential group than in the lower exposure potential group (see Table 9). Although current smokers were more likely to report respiratory symptoms than were former or never smokers (see Table 10), all never smokers reporting symptoms were employed in jobs with higher exposure potential. The number of individuals reporting any given symptom was too small for stratification by both exposure and smoking status to yield meaningful results.

Eight participants had pulmonary function results that fell below the normal range, including six individuals who exhibited a mild obstructive pattern, and two who had a mild restrictive pattern. Four of these individuals worked in jobs classified as having higher exposure potential and four in jobs with lower exposure potential. One of these individuals was a current cigarette smoker, one had never smoked, and the remaining six were former smokers. Except for current smokers, the mean percent predicted FVC and FEV_1 appeared lower for individuals in higher exposure potential jobs and higher for those with lower exposure potential, although these differences were not statistically significant (see Tables 11 and 12).

Three participants' radiographs had small parenchymal opacities consistent with simple pneumoconiosis. Two of these individuals currently worked in jobs with higher exposure potential, and one currently worked in a job with lower exposure potential. The highest ILO profusion classification among the group was 2/3. This individual had worked at Asbury Graphite for greater than 20 years and had never smoked cigarettes. The second abnormal chest x-ray, with a small opacity profusion of 1/1 consensus reading, also belonged to a man with over 20 years of tenure at Asbury Graphite Mills; this individual smoked for 13 years but quit in the past. The third man with an abnormal chest x-ray (small opacity profusion 1/0) had worked at Asbury Graphite for more than 15 years and was a current cigarette smoker.

At present there is no requirement for medical surveillance of workers exposed to graphite. However, there are regulations pertaining to underground coal mining which are designed to identify workers with early pneumoconiosis with the goal of preventing progression to progressive massive fibrosis (PMF).[22] These regulations require that underground coal miners have an initial chest x-ray within the first 6 months of employment. A second chest x-ray is required 3 years after the initial examination. If this second x-ray shows pneumoconiosis of category 1 or greater, a third x-ray is required 2 years after the second. After the third x-ray (the second, if a third is not required), x-rays are optional and are offered to the miner every 5 years.

NIOSH has made recommendations for the medical surveillance of workers exposed to silica.[23] These include medical examinations that are offered to all workers prior to job placement and at least once every three years thereafter. These examinations include a medical and occupational history, chest x-ray, and spirometry.

VII. CONCLUSIONS

Air sampling revealed a few respirable graphite and total dust samples with concentrations that exceeded evaluation criteria. Laboratory analyses of NIOSH samples for respirable crystalline silica were not successful, but recent limited air sampling by MSHA measured an overexposure to dust containing silica. Using the NIOSH respirable dust concentrations and the silica percentages obtained in the MSHA sampling, it was demonstrated that the potential for overexposure to respirable crystalline silica exists at the facility. Raw graphite and additives used in processing are also known to contain silica. Highly visible dust emissions from some of the operations, including those with engineering controls, indicated a potential for overexposure. It would be prudent to ensure that these obvious sources of dust are effectively controlled.

Forty-seven current mill employees participated in the study. Fifty-one former employees were invited to participate, but none chose to do so. In addition to the index case, three current workers had chest x-ray changes that were consistent with pneumoconiosis. Chronic cough and chronic phlegm were more likely to be reported by individuals with higher potential for exposure than by those with lower exposure potential. The mean percent predicted FVC and FEV_1 were lower for individuals with higher exposure potential and higher for those with lower exposure potential. Based on the findings of this survey, it appears that there may be long-term adverse health effects associated with exposure to silica-containing graphite. The NIOSH investigators have also concluded that, during the time of this evaluation, a potential health hazard from exposure to silica-containing dusts existed at the Asbury Graphite Mill.

VIII. RECOMMENDATIONS

1. Improve engineering controls for processes where dust emissions result from insufficient local exhaust ventilation. Provide effective local exhaust ventilation for processes where potential for overexposure exist and no engineering controls are in place. For the feeding and bagging operations, examples of successful ventilation systems are illustrated in *Industrial Ventilation, A Manual of Recommended Practice*[24] published by ACGIH. An enclosure hood could probably be designed for the operation of manually transferring bagged materials to drums.

2. Conduct air sampling after instituting new control measures to ensure overexposures have been eliminated. Continue monitoring on a regular basis to detect any failures in the control measures.

3. In those areas where effective engineering controls are not present, until they are established, appropriate NIOSH-approved respiratory protective equipment should be used. A formal respiratory protection program should be in place with standard operating procedures for evaluation of each worker's ability to perform work while wearing a respirator and for respirator selection, maintenance, inspection, training, fitting, cleaning, storage and use. The respiratory protection program should meet the requirements of MSHA Standard 30 CFR 56.5005[10] and the recommendations provided in the *NIOSH Guide to Industrial Respiratory Protection.*[25]

4. Employees should be encouraged to wear hearing protection in noisy areas, and personal noise dosimetry should be conducted on the workers. If noise exposures exceed the NIOSH REL, a hearing conservation program should be instituted.

5. Medical surveillance should be instituted based on NIOSH guidelines for workers exposed to crystalline silica.[23] Medical examinations should be made available to all workers subject to exposure to graphite prior to employee placement and at least once each three years thereafter. Examinations should include as a minimum:

   - A medical and occupational history to elicit data on worker exposure to graphite and other agents which can cause pneumoconiosis, and on signs and symptoms of respiratory disease.

   - A chest roentgenogram interpreted according to the ILO International Classification of Radiographs of Pneumoconioses.

   - Pulmonary function tests including forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) to provide a baseline for evaluation of pulmonary function. Pulmonary function testing should be performed according to the criteria of the American Thoracic Society.

6. An employee with roentgenographic evidence of pneumoconiosis or who has respiratory distress and/or pulmonary function impairment should be fully evaluated by a physician qualified to advise the employee whether he should continue working in a dusty trade.

7. Medical records should be maintained for at least 30 years following the employee's termination of employment. These records should be available to the medical representatives of the Secretary of Health and Human Services, of the Secretary of Labor, of the employee or former employee, and of the employer.

IX. REFERENCES

1. ILO [1980]. Guidelines for the use of ILO international classification of radiographs of pneumoconioses, 1980 edition. Geneva, International Labour Office. Occupational Safety and Health Series, No. 22 (rev.).

2. CDC [1990]. Occupational disease surveillance: Silicosis. MMWR 39(25):433-437.

3. Hanoa R [1983]. Graphite Pneumoconiosis: A review of etiologic and epidemiologic aspects. Scand J Work Environ Health 9:303-314.

4. Sunset Laboratory [September 1, 1989]. Description of Sunset Laboratory thermal-optical analysis for organic/elemental carbon aerosol. Sunset Laboratory, 2017 19th Avenue, Portland, Oregon 97116.

5. NIOSH [1989]. NIOSH manual of analytical methods, 3rd rev. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 84-100.

6. American Thoracic Society [1987]. Standardization of Spirometry-1987 Update. American Review of Respiratory Disease 136:1285-1298.

7. Knudson RJ, Lebowitz MD, Holberg CJ, Burrows B [1983]. Changes in the Normal Maximal Expiratory Flow-Volume Curve with Growth and Aging. American Review of Respiratory Disease 127:725-734.

8. Lanese RR, Keller MD, Foley MF, Underwood, EH [1978]. Differences in Pulmonary Function Tests Among Whites, Blacks, and American Indians in a Textile Company. Journal of Occupational Medicine 20:39-44.

9. NIOSH [1992]. NIOSH Recommendations for Occupational Safety and Health: Compendium of Policy Documents and Statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 92-100.

10. CFR. Code of Federal Regulations [1993]. U.S. Department of Labor, Mine Safety and Health Administration. 30 CFR 56. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

11. ACGIH [1973]. Threshold Limit Values for Chemical Substances in Workplace Air Adopted by ACGIH for 1973. Cincinnati, OH. American Conference of Governmental Industrial Hygienists.

12. ACGIH [1993]. Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1993-1994. Cincinnati, OH. American Conference of Governmental Industrial Hygienists.

13. Petsonk EL, Storey E, Becker PE, Davidson CA, Kennedy K, Vallyathan V [1988]. Pneumoconiosis in Carbon Electrode Workers. J Occ Med 30(11):887-891.

14. Ranasinha KW, Uragoda CG [1972]. Graphite Pneumoconiosis. Brit J Industr Med 29:178-183.

15. Uragoda CG [1989]. Graphite pneumoconiosis and its declining prevalence in Sri Lanka. J Tropical Med and Hygiene 92:422-424.

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

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

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

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

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

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

22. CFR. Code of Federal Regulations: Specifications for medical examinations of underground coal miners. Subpart- Chest Roentgenographic Examinations [42 CFR Pt. 37]. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

23. NIOSH [1974]. Criteria for a recommended standard: occupational exposure to crystalline silica. Washington, DC: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 75-120.

24. ACGIH [1992]. Industrial Ventilation, A Manual of Recommended Practice, 21st Ed. Cincinnati, OH. American Conference of Governmental Industrial Hygienists.

25. NIOSH [1987]. NIOSH Guide to Industrial Respiratory Protection. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 87-116.

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1. Asbury Graphite Mill
2. Employee Representative
3. New Jersey Department of Health
4. U.S. Department of Labor / MSHA - Northeastern District (Metal/Nonmetal)

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

Table 1
Personal Respirable Graphite Sampling Results

Asbury Graphite Mills, Inc.
Asbury, New Jersey
July 20-22, 1993

Sample Number	Type of Graphite*	Job Description	Location	Date	Sampling Time (minutes)	8-Hour TWA (mg/m^3)
30gr	nat/syn	Foreman	Mill 2	Jul 21	461	.92
19gr	nat/syn	Foreman	Various	Jul 20	404	.45
14gr	nat/syn	Forklift Operator	Various	Jul 20	461	.16
33gr	nat/syn	Forklift Operator	Various	Jul 21	460	.08
45gr	nat/syn	Forklift Operator	Various	Jul 21	464	.06
39gr	nat/syn	Laboratory Technician	Various	Jul 22	255	.01
31gr	nat/syn	Maintenance	Shop	Jul 21	467	.63
25gr	nat/syn	Maintenance	Shop	Jul 22	443	.04
17gr	nat/syn	Maintenance	Various	Jul 20	447	.48
24gr	nat/syn	Maintenance	Various	Jul 21	455	.28
22gr	nat/syn	Maintenance	Various (mostly Mill 2)	Jul 21	459	1.55
42gr	nat/syn	Maintenance	Various (mostly Mill 2)	Jul 22	445	.21
07gr	nat/syn	NIOSH Investigator	Various	Jul 21	171	.10
43gr	nat/syn	Outside Crew	Outside	Jul 22	440	.14
15gr	nat/syn	Outside Crew	Outside	Jul 20	420	.01
37gr	nat	Packer	Mill 2	Jul 22	466	.76
27gr	nat	Packer	Mill 2	Jul 21	471	.39
32gr	nat/syn	Packer	Mill 2	Jul 22	462	.38
23gr	nat/syn	Packer	Packing House	Jul 21	476	.52
60gr	nat/syn	Packer	Packing House	Jul 21	449	.31
29gr	nat/syn	Packer	Packing House	Jul 22	460	.21
08gr	nat/syn	Packer	Packing House	Jul 20	458	.18
11gr	nat+adds	Packer	Shed 8	Jul 20	464	.83
38gr	nat/syn	Shipping	Shipping Warehouse	Jul 22	456	.11
53gr	nat/syn	Shipping	Shipping Warehouse	Jul 20	195	.05
03gr	nat/syn	Shipping	Shipping Warehouse	Jul 21	354	.04
13gr	nat/syn	Stock Runner	Mill 2	Jul 20	455	2.46
34gr	nat/syn	Stock Runner	Mill 2	Jul 22	432	.94
47gr	nat	Stock Runner	Mill 2	Jul 22	458	.60
18gr	unknown?	Stock Runner	Mill 2	Jul 20	439	.55
49gr	unknown	Stock Runner	Mill 2	Jul 21	477	.44
26gr	nat	Stock Runner	Mill 2	Jul 21	453	.37
20gr	nat/syn	Stock Runner	Mill 2	Jul 22	456	.05
46gr	nat+adds	Stock Runner	Shed 8	Jul 21	474	.73
09gr	nat+adds	Stock Runner	Shed 8	Jul 20	460	.53

* nat = natural   syn = synthetic   nat+adds = natural with additives

Table 2
Area Respirable Graphite Sampling Results

Asbury Graphite Mills, Inc.
Asbury, New Jersey
July 20-22, 1993

Sample Number	Type of Graphite*	Location	Date	Sampling Time (minutes)	8-Hour TWA (mg/m^3)
04gr	syn	Mill 2 - Ball Mill 5&6 Feed	Jul 21	390	.34
01gr	nat/syn	Mill 2 - Center of Feed Areas	Jul 21	386	.22
36gr	nat	Mill 2 - Level 2 - Jet Mill 4	Jul 22	404	.33
51gr	nat/syn	Mill 2 - Level 3 - Screens 2&3	Jul 22	403	1.42
40gr	nat	Mill 2 - Packing from Screen 1	Jul 22	387	.45
02gr	nat	Mill 2 - Packing from Screen 1	Jul 21	393	.29
61gr	nat/syn	Mill 2 - Packing from Screens 2 & 3	Jul 22	405	.52
06gr	nat/syn	Mill 2 - Packing from Screens 2 & 3	Jul 20	422	.46
59gr	nat/syn	Mill 2 - Packing from Screens 2 & 3	Jul 21	427	.33
57gr	nat/syn	Packing House - Center of Packing Area	Jul 21	426	.34
12gr	nat/syn	Packing House - Center of Packing Area	Jul 20	430	.19
28gr	nat/syn	Packing House - Center of Packing Area	Jul 22	418	.14
54gr	nat+adds	Shed 8 - Near Blender	Jul 22	439	1.31
10gr	nat+adds	Shed 8 - Screen 4 Feed	Jul 20	442	.48
48gr	nat+adds	Shed 8 - Screen 4 Feed	Jul 22	416	.19
50gr	nat+adds	Shed 8 - Screen 4 Feed	Jul 21	431	.17
55gr	nat/syn	Shipping Warehouse - Loading Dock	Jul 21	427	.07
16gr	nat/syn	Shipping Warehouse - Loading Dock	Jul 20	437	.02
05gr	nat/syn	Truck - Manual Bag Removal	Jul 20	402	.03

* nat = natural   syn = synthetic   nat+adds = natural with additives

Table 3
Personal Respirable Dust Sampling Results

Asbury Graphite Mills, Inc.
Asbury, New Jersey
July 20-22, 1993

Sample Number	Job Description	Location	Date	Sampling Time (minutes)	8-Hour TWA (mg/m^3)
071	Foreman	Mill 2	Jul 22	400	.59
066	Foreman	Mill 2	Jul 20	375	.37
048	Foreman	Mill 2	Jul 21	486	.17
035f	Foreman	Various	Jul 21	469	1.93
007fw	Foreman	Various	Jul 22	486	.77
060	Foreman	Various	Jul 20	404	.72
021fw	Forklift Operator	Various	Jul 22	455	.42
024fw	Forklift Operator	Various	Jul 21	460	.42
052	Forklift Operator	Various	Jul 20	449	.39
097fw	Forklift Operator	Various	Jul 20	461	.25
009fw	Forklift Operator	Various	Jul 21	464	.14
003fw	Forklift Operator	Various	Jul 22	442	.10
020fw	Laboratory Technician	Various	Jul 20	457	.05
105fw	Laboratory Technician	Various	Jul 22	328	Not Detected
075fw	Maintenance	Shop	Jul 20	441	Void
051	Maintenance	Shop	Jul 21	467	.37
012fw	Maintenance	Shop	Jul 22	443	Not Detected
102fw	Maintenance	Various	Jul 20	447	3.33
068	Maintenance	Various	Jul 20	434	.41
037f	Maintenance	Various	Jul 21	455	.41
018fw	Maintenance	Various (mostly Mill 2)	Jul 22	465	1.64
031f	Maintenance	Various (mostly Mill 2)	Jul 21	459	1.26
015fw	Maintenance	Various (mostly Mill 2)	Jul 22	445	.41
022fw	NIOSH Investigator	Various	Jul 22	329	.05
107fw	Outside Crew	Outside	Jul 22	440	.49
044f	Outside Crew	Outside	Jul 21	419	.23
008fw	Outside Crew	Outside	Jul 22	458	.16
099fw	Outside Crew	Outside	Jul 20	420	Not Detected
075	Packer	Mill 2	Jul 22	466	2.98
047	Packer	Mill 2	Jul 21	477	1.10
072	Packer	Mill 2	Jul 20	457	.93
032f	Packer	Mill 2	Jul 22	462	.45
042f	Packer	Mill 2	Jul 21	471	.41

Continued next page

Table 3 (Continued)
Personal Respirable Dust Sampling Results

Asbury Graphite Mills, Inc.
Asbury, New Jersey
July 20-22, 1993

Sample Number	Job Description	Location	Date	Sampling Time (minutes)	8-Hour TWA (mg/m^3)
076	Packer	Mill 2	Jul 20	449	.26
070	Packer	Packing House	Jul 22	464	1.29
034f	Packer	Packing House	Jul 21	449	.79
057	Packer	Packing House	Jul 20	458	.72
100fw	Packer	Packing House	Jul 20	460	.34
010fw	Packer	Packing House	Jul 22	460	.30
033f	Packer	Packing House	Jul 21	476	.16
109fw	Packer	Shed 8	Jul 20	464	.85
039f	Packer	Shed 8	Jul 21	477	.39
002fw	Packer	Shed 8	Jul 22	472	.12
061	Shipping	Shipping Warehouse	Jul 22	423	.52
025f	Shipping	Shipping Warehouse	Jul 21	431	.31
001fw	Shipping	Shipping Warehouse	Jul 22	456	.27
038f	Shipping	Shipping Warehouse	Jul 21	354	.21
064	Shipping	Shipping Warehouse	Jul 20	418	.09
019fw	Shipping	Shipping Warehouse	Jul 20	195	.05
049	Stock Runner	Mill 2	Jul 21	453	Void
098fw	Stock Runner	Mill 2	Jul 20	455	2.02
023fw	Stock Runner	Mill 2	Jul 22	432	1.51
055	Stock Runner	Mill 2	Jul 22	458	.98
026f	Stock Runner	Mill 2	Jul 21	456	.79
006fw	Stock Runner	Mill 2	Jul 20	439	.70
014fw	Stock Runner	Mill 2	Jul 22	475	.69
067	Stock Runner	Mill 2	Jul 22	456	.65
062	Stock Runner	Mill 2	Jul 20	456	.64
040fw	Stock Runner	Mill 2	Jul 21	430	.60
063	Stock Runner	Mill 2	Jul 21	477	.47
059	Stock Runner	Mill 2	Jul 20	444	.38
011fw	Stock Runner	Shed 8	Jul 22	461	1.75
073	Stock Runner	Shed 8	Jul 22	470	1.06
104fw	Stock Runner	Shed 8	Jul 20	472	.81
028f	Stock Runner	Shed 8	Jul 21	468	.77
101fw	Stock Runner	Shed 8	Jul 20	460	.76
041f	Stock Runner	Shed 8	Jul 21	474	.74

Table 4
Area Respirable Dust Sampling Results

Asbury Graphite Mills, Inc.
Asbury, New Jersey
July 20-22, 1993

Sample Number	Location	Date	Sampling Time (minutes)	8-Hour TWA (mg/m^3)
103fw	Mill 2 - Ball Mill 5&6 Feed	Jul 21	390	.14
110fw	Mill 2 - Center of Feed Areas	Jul 21	386	.16
017fw	Mill 2 - Level 3 - Screens 2&3	Jul 22	403	1.58
065	Mill 2 - Packing from Screen 1	Jul 21	393	.42
027f	Mill 2 - Packing from Screens 2 & 3	Jul 21	427	.83
074	Mill 2 - Packing from Screens 2 & 3	Jul 20	422	.77
043f	Packing House - Center of Packing Area	Jul 21	426	.44
106fw	Packing House - Center of Packing Area	Jul 20	430	.22
004fw	Packing House - Center of Packing Area	Jul 22	418	.04
053	Shed 8 - Screen 4 Feed	Jul 20	442	.61
056	Shed 8 - Screen 4 Feed	Jul 22	416	.14
046	Shed 8 - Screen 4 Feed	Jul 21	431	Not Detected
050	Shipping Warehouse - Loading Dock	Jul 21	427	.01
108fw	Shipping Warehouse - Loading Dock	Jul 20	437	Not Detected
069	Truck - Manual Bag Removal	Jul 20	402	.09
030f	Truck - Manual Bag Removal	Jul 21	442	.09

Table 5
Potential Respirable Crystalline Silica (as Quartz) Overexposures

Asbury Graphite Mills, Inc.
Asbury, New Jersey
July 20-22, 1993

Sample Number	Job Description	Location	Date	Sampling Time (minutes)	Respirable Dust 8-Hour TWA (mg/m^3)	REL* would be exceeded if quartz in sample was over:
102fw	Maintenance	Various	Jul 20	447	3.33	1.50 %
075	Packer	Mill 2	Jul 22	466	2.98	1.68 %
098fw	Stock Runner	Mill 2	Jul 20	455	2.02	2.48 %
035f	Foreman	Various	Jul 21	469	1.93	2.59 %
011fw	Stock Runner	Shed 8	Jul 22	461	1.75	2.86 %
018fw	Maintenance	Various (mostly Mill 2)	Jul 22	465	1.64	3.05 %

* REL for Respirable Quartz = .05 mg/m^3

Table 6
Personal Total Dust Sampling Results

Asbury Graphite Mills, Inc.
Asbury, New Jersey
July 20-22, 1993

Sample Number	Job Description	Location	Date	Sampling Time (minutes)	8-Hour TWA (mg/m^3)
21609	Foreman	Mill 2	Jul 22	469	4.01
21595	Foreman	Various	Jul 22	486	12.51
21619	Foreman	Various	Jul 21	469	3.48
21571	Forklift Operator	Various	Jul 22	442	2.27
21589	Forklift Operator	Various	Jul 22	455	1.32
21577	Forklift Operator	Various	Jul 20	449	1.27
21587	Laboratory Technician	Various	Jul 22	255	.36
21588	Maintenance	Shop	Jul 20	441	1.30
21615	Maintenance	Various	Jul 20	434	.92
21600	Maintenance	Various (mostly Mill 2)	Jul 22	465	8.64
21597	NIOSH Investigator	Various	Jul 21	171	.65
21621	NIOSH Investigator	Various	Jul 21	329	.40
21602	Outside Crew	Outside	Jul 21	419	1.16
21626	Outside Crew	Outside	Jul 21	442	.77
21596	Outside Crew	Outside	Jul 22	458	.54
21581	Packer	Mill 2	Jul 21	477	5.28
21601	Packer	Mill 2	Jul 20	457	3.68
21623	Packer	Mill 2	Jul 20	449	2.45
21590	Packer	Packing House	Jul 20	460	3.08
21583	Packer	Packing House	Jul 22	464	.38
21579	Packer	Shed 8	Jul 22	472	2.01
21569	Packer	Shed 8	Jul 21	477	1.14
21611	Shipping	Shipping Warehouse	Jul 22	423	.86
21575	Shipping	Shipping Warehouse	Jul 20	418	.76
21574	Shipping	Shipping Warehouse	Jul 21	431	.75
21618	Stock Runner	Mill 2	Jul 20	456	4.44
21610	Stock Runner	Mill 2	Jul 21	430	2.66
21582	Stock Runner	Mill 2	Jul 22	475	2.02
21565	Stock Runner	Mill 2	Jul 20	444	2.00
21580	Stock Runner	Mill 2	Jul 21	456	1.18
21617	Stock Runner	Shed 8	Jul 22	461	8.27
21584	Stock Runner	Shed 8	Jul 20	472	1.57
21614	Stock Runner	Shed 8	Jul 21	229	.51
21612	Stock Runner	Shed 8	Jul 22	470	.33

Table 7
Area Total Dust Sampling Results

Asbury Graphite Mills, Inc.
Asbury, New Jersey
July 20-22, 1993

Sample Number	Location	Date	Sampling Time (minutes)	8-Hour TWA (mg/m^3)
21627	Mill 2 - Ball Mill 5&6 Feed	Jul 21	390	1.52
21591	Mill 2 - Center of Feed Areas	Jul 21	386	1.96
21603	Mill 2 - Center of Feed Areas	Jul 22	377	1.02
21567	Mill 2 - Level 2 - Jet Mill 4	Jul 22	404	1.46
21578	Mill 2 - Level 3 - Screens 2&3	Jul 22	403	12.25
21593	Mill 2 - Packing from Screen 1	Jul 22	387	2.93
21585	Mill 2 - Packing from Screen 1	Jul 21	393	1.56
21625	Mill 2 - Packing from Screens 2 & 3	Jul 22	405	3.84
21572	Mill 2 - Packing from Screens 2 & 3	Jul 20	422	3.32
21616	Mill 2 - Packing from Screens 2 & 3	Jul 21	427	1.47
21570	Packing House - Center of Packing Area	Jul 21	426	1.52
21608	Packing House - Center of Packing Area	Jul 20	430	.94
21613	Packing House - Center of Packing Area	Jul 22	418	.47
21568	Shed 8 - Near Blender	Jul 22	439	11.27
21573	Shed 8 - Screen 4 Feed	Jul 20	442	6.47
21576	Shed 8 - Screen 4 Feed	Jul 22	416	1.48
21606	Shed 8 - Screen 4 Feed	Jul 21	431	1.14
21599	Shipping Warehouse - Loading Dock	Jul 20	437	.31
21566	Shipping Warehouse - Loading Dock	Jul 21	427	.29
21605	Shipping Warehouse - Loading Dock	Jul 22	381	.28

Table 8
Geometric Means of Sampled Personal Dust Concentrations
for Job Groups

Asbury Graphite Mills, Inc.
Asbury, New Jersey
July 20-22, 1993

Respirable Graphite		**Respirable Dust**		**Total Dust**	
Job	GM * (mg/m^3)	Job	GM (mg/m^3)	Job	GM (mg/m^3)
Foreman	.64	Stock Runner	.82	Foreman	5.59
Stock Runner	.51	Foreman	.59	Maintenance	2.18
Packer	.39	Packer	.53	Packer	2.00
Maintenance	.32	Maintenance	.45	Stock Runner	1.71
Forklift Operator	.09	Forklift Operator	.25	Forklift Operator	1.56
Shipping	.06	Shipping	.18	Shipping	.79
Outside Crew	.04	Outside Crew	.12	Outside Crew	.79
Laboratory Technician	.01	Laboratory Technician	.02	Laboratory Technician	.36

*GM - Geometric Mean Concentration

Table 9
Prevalence of Respiratory Symptoms by Exposure Potential

Asbury Graphite Mills, Inc.
Asbury, New Jersey

RESPIRATORY SYMPTOM *	EXPOSURE POTENTIAL			
	Higher (Number=30)		Lower (Number=17)	
	Yes	%	Yes	%
Chronic Cough	8	27	3	18
Chronic Phlegm	9	30	1	6
Chronic Dyspnea				
- Grade I	5	17	0	0
- Grade II	2	7	1	6
- Grade III	1	3	0	0
Chronic Wheeze	1	3	1	6
Wheezing/Whistling in Chest	7	23	4	24
Attacks of Dyspnea with Wheeze	2	7	2	12

* See "Medical Evaluation Methods" section of report for symptom definitions

Table 10
Prevalence of Respiratory Symptoms by Cigarette Smoking Habit

Asbury Graphite Mills, Inc.
Asbury, New Jersey

RESPIRATORY SYMPTOM *	CIGARETTE SMOKING HABIT					
	Current (Number=16)		Former (Number=15)		Never (Number=16)	
	Yes	%	Yes	%	Yes	%
Chronic Cough	8	50	1	7	2	12
Chronic Phlegm	6	38	1	7	3	19
Chronic Dyspnea						
- Grade I	3	19	0	0	2	12
- Grade II	3	19	0	0	0	0
- Grade III	0	0	0	0	1	6
Chronic Wheeze	2	12	0	0	0	0
Wheezing/Whistling in Chest	6	38	3	20	2	12
Attacks of Dyspnea with Wheeze	0	0	3	20	1	6

* See "Medical Evaluation Methods" section of report for symptom definitions

Table 11
Percent Predicted FVC stratified by Exposure Potential and Cigarette Smoking Habit

Asbury Graphite Mills, Inc.
Asbury, New Jersey

CIGARETTE SMOKING HABIT	EXPOSURE POTENTIAL	
	Higher (Number=30)	Lower (Number=17)
	% Predicted FVC Mean SD	% Predicted FVC Mean SD
Current Smoker	101.1 14.8	104.2 10.8
Former Smoker	103.1 10.6	108.3 17.5
Never Smoker	94.0 12.2	100.0 13.6
ALL	98.9 13.9	104.9 14.7

Table 12
Percent Predicted FEV_1 stratified by Exposure Potential and Cigarette Smoking Habit

Asbury Graphite Mills, Inc.
Asbury, New Jersey

CIGARETTE SMOKING HABIT	EXPOSURE POTENTIAL	
	Higher (Number=30)	Lower (Number=17)
	% Predicted FEV_1 Mean SD	% Predicted FEV_1 Mean SD
Current Smoker	99.5 11.9	99.2 10.4
Former Smoker	96.3 16.8	97.3 14.3
Never Smoker	90.5 15.7	96.0 11.0
ALL	95.5 14.6	97.4 11.9