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Fiber Release During the Removal of Asbestos-Containing Gaskets: A Work Practice Simulation

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Work practice studies were conducted involving the removal of asbestos-containing sheet gaskets from steam flanges. These studies were performed to determine potential exposure levels to individuals who have worked with these types of materials in the past and may still work with these products today. The work practices were conducted inside an exposure characterization laboratory (ECL) and were performed by scraping and wire brushing, chrysotile-containing (65% to 85%) sheet gaskets from a number of used steam flanges. Airborne asbestos levels were measured by phase contrast microscopy (PCM) and transmission electron microscopy (TEM) for the personnel and area air samples collected during the study. These workplace simulations showed substantial asbestos fiber release using scraping, hand wire brushing, and power wire brushing techniques during the gasket removal process. The range of concentration was 2.1 to 31.0 fibers/cc greater than 5 micrometers when measured by PCM. These results contrasted with the few reported results in the published literature where lower airborne asbestos levels were reported. In these studies the airborne asbestos fiber levels measured in many of the samples exceeded all current and historical Occupational Safety and Health Administration (OSHA) excursion limits (15–30 minutes) and some previous permissible exposure limits (PEL) based on eight-hour time-weighted average (TWA) standards. Also, individuals who performed this type of work in the past may have had exposures higher than previously suspected. The results demonstrated that employees who remove dry asbestos-containing gaskets with no localized ventilation should wear a full face supplied air respirator with a HEPA escape canister and the work area should be designated a regulated area.

Keywords Asbestos, Gasket, Removal, Exposure

Asbestos-containing sheet gaskets have been used in almost every type of industry for the last 60 years. These gaskets had the ability to prevent leakage between different types of couplings, particularly at elevated temperature and pressure.[1] These types of gaskets normally contained 70 percent to 80 percent chrysotile asbestos by weight. In some cases crocidolite asbestos was used for special applications, that is, sealing flanges in acid lines. The remaining non-asbestos component of the gasket was usually constructed of synthetic rubber material that consisted of either neoprene, styrene butadiene rubber (SBR), or a nitrile polymer.[2–4]

Most companies replaced asbestos fibers in their gasket products with other nonmineral fibers in the late 1980s or early 1990s. This coincided with the Environmental Protection Agency's (EPA) 1989 ban on the manufacture, importation, processing, and distribution of these types of products.[5] However, the United States Fifth Circuit Court of Appeals vacated most of the asbestos ban and Phase Out Rule and remanded it back to EPA in October 1991. Although the court vacated and remanded most of the rule, it left intact the portion that regulated asbestos products that were not being manufactured, produced, or imported when the rule was published in December 1989. Since asbestos-containing sheet gaskets were still being imported into this country, they were exempt from the ban and can still be manufactured, purchased, and used in the United States.

Fowler recently described the problem with the use of these products when he demonstrated that the application of asbestos-containing gaskets had the potential to release respirable asbestos fibers well above current OSHA standards. Fowler recommended that these products should not be used in today's industry and that only non-asbestos gaskets should be used in their place.[6]

An issue that faces many former industrial workers is the past use of these types of gaskets. Workers were not informed in most cases that the products they were using had the potential to release elevated levels of respirable asbestos fibers. Legal issues concerning past exposures pose this basic question: Did handling and performing maintenance activities on these gaskets contribute to their asbestos exposure history? Industrial hygienists must rely on a retrospective exposure assessment to make this determination.[7] In this approach the individual's work history is compared to the results of retrospective exposure assessment studies that replicate their work activities.

A review of the peer-reviewed literature found very few published studies involving exposure assessments during the dry removal of asbestos sheet gaskets from flanges.[7–9] The studies of Cheng, Millette, and McKinery were somewhat limited in the information reported. Millette used only a small number of flanges. Cheng's work did not verify that all the gaskets contained asbestos. Additionally, there was only limited information provided in all three studies concerning the size and the history of the flanges used or the length of time required for the gasket removal process.

The most comprehensive study to date was by Spence et al.[10] However, the authors used wetting to control the airborne release of asbestos fibers. This limited the study's value for any retrospective exposure assessment since dust control methods were not used in the workplace historically.

In contrast to the previous studies, the goal of these new work practice studies was to estimate a worker's asbestos fiber exposure during the removal of asbestos-containing sheet gaskets using common removal techniques such as scraping, hand wire brushing, and power wire brushing. The studies were conducted on a large population of steam line flanges and valve assemblies. The compilation of several studies discussed in this article allows a more accurate retrospective exposure assessment for individuals who worked with these products in the past and the assessment of potential exposure to workers who may be removing asbestos-containing gaskets today using these same work practices.

High-intensity lighting and videotaping techniques were used inside an exposure characterization laboratory (ECL) during the work practice studies to visually document the pathway of exposure during the gasket removal process and to help determine what activities produce the airborne asbestos dust.

The methods and procedures described in this report can be applied to assessing past and present industrial hygiene exposures to other dusts, fumes, and fibers besides asbestos. The videotaping of dust, fume, and fiber exposures under high-intensity light can be used as a training tool in visualizing the importance and effectiveness of engineering and administrative controls and respiratory protection.

MATERIALS AND METHODS

A number of valve and flange assemblies were collected in 1994 from a paper mill powerhouse in Oregon and stored under ambient conditions in a protective environment until their use in these studies. A sampling of these flange and valve assemblies was partially opened to confirm the presence of asbestos in the sheet gaskets using polarized light microscopy (PLM) prior to the work practice study.[11] Any opened flanges were reassembled and the outside surfaces of all the flanges were cleaned, sand blasted, and repainted. Interviews with former machinists and pipefitters determined that the most common techniques for removing gasket material tightly adhered to the flange surface were hand scraping, hand wire brushing, and/or electric wire brushing.

The work practice simulations were conducted inside an exposure characterization laboratory (ECL) that was constructed as a containment area to prevent the release of asbestos to the outside environment. The dimensions of this containment area were 6.0 m (length) × 4.5 m (width) × 2.4 m (height). The ECL also contained two viewing ports for videotaping purposes and had a decontamination area for contaminated clothing disposal, an air lock for sample removal, and showers to further control fugitive emissions.

Fresh air was produced by a high efficiency particulate absolute (HEPA) filtered negative air machine manufactured by Aramsco (model #55011) and pulled through the ECL at a ventilation rate of 5.7 cubic meters per minute. This unit was operated at an air exchange rate of five times per hour (ACH) during the work practice studies. The air in the chamber was flushed between studies by increasing the fresh air ventilation to 28.3 cubic meters per minute for a minimum of 24 hours. At the end of the first scraping and hand wire brushing study (Study 1), the ECL was completely decontaminated by HEPA vacuuming all dust and debris and then wet wiping. Also, all inside surfaces were repainted after the decontamination procedure.

High-intensity lighting (700–1000 watts) was used inside the chamber during videotaping of the work practice to document dust generated by various tasks and to observe pathways of exposure to respirable dust. In previous studies the use of high-intensity lighting was found to be an effective tool to display respirable airborne dust released from asbestos-containing products during work activities.[12,13] The authors performed these studies wearing normal work clothes over disposable protective suits and were equipped with supplied air respiratory protection with HEPA escape filters.

Personal and area air samples were collected during the studies using nonconductive three-piece cassettes. The cassettes contained mixed cellulose ester (MCE) filters that were 25 millimeters in diameter and had a 0.8 micrometer pore size. These filters rested on a MCE backing filter (5.0 micrometer pores). The personal and area air sampling pumps were calibrated before and after the completion of each study against a DryCal primary flow meter to air flow rates of two and ten liters per minute, respectively. High-volume air-sampling pumps (Dawson 110 volt) were used for collecting area air samples during the studies. Four area samples were located in four equidistant quadrants at a distance of 2.1 meters from a work bench placed in the center of the ECL. The area sample cassettes were placed on sampling stands at a height of 1.5 meters. The four calibrated high-volume air sampling pumps were placed outside the chamber and each pump was connected to an area air cassette by Tygon tubing passing through the wall of the ECL.

The two investigators performing the studies were each fitted with two calibrated personal GilAir air sampling pumps with the air-sampling cassettes attached to each shoulder and within their breathing zones. Background area samples were collected inside and outside the ECL before each study. The air samples were collected in general accordance with the NIOSH 7400 method entitled, "Asbestos and Other Fibers by PCM."[14] Two air sampling cassettes were opened for 30 seconds inside the ECL to serve as personal field blanks at the end of each study.

Surface morphology of new and used gasket material was examined using a Hitachi S-800 field emission scanning electron microscope (SEM). Photomicrographs were taken of the gasket surfaces to document the degree of gasket degradation and the relative amount of asbestos fibers present on the surface.

Study 1—Scraping and Hand Wire Brushing of Small Flange Assemblies

Seven small flange assemblies were used in this study. The gaskets had outside diameters of approximately 69 mm and working widths of approximately 19 mm. Gaskets were removed from one flange on the first four valve assemblies and then from two flanges on each side of the remaining three valve assemblies for a total of ten gaskets. The flange assemblies were first opened and then the gaskets were scraped using a stiff, four-inch-wide putty knife. Any residual gasket material that could not be removed from the flange faces by scraping was removed by hand wire brushing. Some of the gaskets required repetitive scraping and wire brushing to remove the gasket and to polish the flange face. The sheet gaskets were removed sequentially from each of the 10 flanges.

One of the investigators in the ECL simulated the worker who did all of the gasket removal while the other acted as a "helper." The helper changed the area and personal air sample cassettes periodically throughout the study. Each gasket was collected and retained for analysis to determine both asbestos content and matrix identification after removal. The investigators were in the ECL for 194 minutes. All air sample cassettes in the ECL were exchanged every 15 to 30 minutes. A total of seven sets of air samples were collected.

Study 2—Scraping and Hand Wire Brushing of Large Flange Assemblies

Four large flange assemblies were used for this study. The outside diameter of these gaskets varied from 125 mm to 200 mm and the gaskets were 19 mm to 25 mm wide. The gaskets were removed and collected from the four flanges as described in Study 1. The investigators were in the ECL for 113 minutes. All air sample cassettes in the ECL were exchanged every 15 to 30 minutes. A total of five sets of air samples were taken during this work practice simulation.

Study 3—Power Wire Brushing of Large Flange Assembly

An electric wire brush (Skil electric drill 0.3 Hp with a Columbian 10.2 cm crimped wire wheel) was used during this study to remove gasket residue that could not be removed during the scraping and hand wire brushing of the first flange assembly used in Study 2. The electric wire brush was also used to polish the flange face surfaces. This study was conducted one day after Study 2. The ECL was not decontaminated between the studies. The two flange surfaces were electric wire brushed until the gasket residue was visibly removed. As previously described in Study 1, the two investigators were in the ECL performing the study.

One person did the removal work while the other assisted as the helper. The residual gasket material was not retained since the bulk of the material was collected in Study 2. The investigators were in the ECL for 42 minutes. The air cassettes in the ECL were exchanged every 10 minutes. A total of four sets of air samples were taken during the electric wire brushing activity.

All air filters collected were analyzed by PCM in general accordance with the NIOSH 7400 method using the "A" counting rules. Additionally, all air samples were prepared for TEM examination using the indirect preparation method.[15] The indirect TEM preparation method was chosen because filter overloading rendered the samples unsuitable for direct preparation despite frequent changing of the air sample cassettes. Also, the indirect TEM preparation method enabled data comparisons to other published and unpublished studies previously performed that also used the indirect TEM method.[16–18] The TEM air samples were then analyzed by a modified EPA Level II protocol.[19] Cloth swatches from the work clothing worn by the investigators during the studies were analyzed by the recommended EPA method.[20] Surface dust samples were collected from the work table after each gasket removal study and analyzed according to the ASTM protocol.[15] Background samples from the clothing and the work table surface were also collected before each study was started. The removed gaskets were analyzed for asbestos type and content by the standard PLM method.[11]

RESULTS

It was determined by PLM that the gaskets removed in these studies contained 65 percent to 85 percent chrysotile asbestos (Table I). Table II and Table III, respectively, illustrate the PCM and TEM results for Study 1. The worker in Study 1 had a peak exposure level of 10.1 fibers per cubic centimeter (f/cc) and an 8-hour TWA exposure of 1.5 f/cc. The area air samples were voided after the completion of Study 1 when it was determined that the air-sampling lines into the ECL were obstructed. The

TABLE I
PLM analysis of removed gaskets

Studies	Number of gaskets analyzed	Asbestos type	Concentration of asbestos in volume percent
Study 1	10	Chrysotile	65–80%
Study 2	4	Chrysotile	75–85%
Study 3	1	Chrysotile	85%

TABLE II
Study 1—Scraping and hand wire brushing: small flanges. PCM airborne exposure levels (fibers greater than 5 micrometers)

Sample type	No. of air samples analyzed	Range (f/cc)	Sample time weighed average (f/cc)	8-hr TWA (f/cc)
Background	4	0.0	0.0	N/A
Worker	14	1.5–10.1	3.7	1.5
Assistant	14	1.2–4.2	2.4	1.0
Area samples[A]	36	—	—	—

Total air-sampling time = 194 minutes.
[A]The air-sampling lines into the ECL were obstructed, voiding the area air samples in this study.

results for Study 2 are shown in Tables IV and V. The worker in this study had a peak exposure level of 24.0 f/cc and an 8-hour TWA of 3.6 f/cc. Table VI and Table VII list results for Study 3. The peak exposure level found while power wire brushing was 31.0 f/cc and the calculated 8-hour TWA was 2.3 f/cc. The results for the surface dust samples taken from the work table and the fabric samples are shown in Table VIII. All PCM and TEM data in the tables are expressed for comparison purposes as fibers per cubic centimeter (f/cc) greater than 5.0 micrometers in length.

DISCUSSION

The asbestos concentrations measured in these studies were higher on average than other previously published studies for similar work practices.(7–9) It is believed that the higher concentrations found in these studies were due largely to the gaskets adhering more tightly to the flanges. Tightly adhered gaskets require higher energy for removal. As described by Fowler, the friability of the product is always relative to the energy applied.(6) Only two of the fourteen gaskets removed could have been described as easily detached. The other twelve required extensive effort on one or both of the flange faces. Machinists, pipefitters, steamfitters, and others commonly described sheet gaskets as tightly adhering to flange surfaces and requiring substantial work to remove the gasket material. Unfortunately, the various conditions and the amount of adhesion of the gaskets in the previously published studies were not reported.(7–9) The adhesion of gasket materials generally has been related to its length in service and the conditions of service such as temperature and pressure. The high temperature steam flanges used in this study were from a steam powerhouse that operated for a number of years. The last steamfitter who maintained the steam system indicated that gasket replacement was rare due to infrequent plant downtime and few leaks. Gaskets that could be easily removed would not be expected to produce airborne levels comparable to what was found in these studies. None of the previous studies described the level of difficulty of removing the gaskets from the flange surfaces.

TABLE III
Study 1—Scraping and hand wire brushing: small flanges. TEM airborne exposure levels (asbestos fibers greater than 5 micrometers)

Sample type	No. of air samples analyzed	Range (fibers/cc)
Background	4	0.0
Worker	14	29.9–144.2
Assistant	14	2.2–29.5

Total air-sampling time = 194 minutes.

The air samples collected were analyzed by both PCM and TEM during the gasket removal activities in these studies. The two basic types of sample preparation for TEM air analysis are the direct and indirect methods.(15,16,21–23) Some scientists have suggested that the indirect sample preparation method, particularly the sonication step, causes large complex asbestos structures such as fiber bundles and clusters to break up and bias fiber counts to higher concentrations.(24,25) However, studies performed by the EPA and others have shown that this criticism is not valid and that the indirect technique is an acceptable method to analyze overloaded air samples.(26–28)

The overloading of other particulates on an air filter will obscure fibers that are collected. This condition can lead to the undercounting of asbestos fibers if a direct preparation method is used. Controlling the particulate loading on a filter can be difficult when the disturbance of materials generates large amounts of both fibrous and nonfibrous airborne particulates. The general approach to reduce or eliminate overloading conditions is to alter flow rates and sampling times. However, particulate loading can be controlled by using the indirect preparation method without compromising sampling times. The overloading problem can also affect the direct examination of air filter samples by PCM (NIOSH 7400 method). This was noted in Study 1. The asbestos air concentrations measured by PCM in Study 1 decreased as the study progressed. This would not be consistent with the continued activities that took place inside the ECL during the study. This effect was due to particulate overloading on the filters. However, according to the TEM data from Study 1, the asbestos fiber concentrations tended to increase as the work progressed. The sampling times for Studies 2 and 3 were reduced in an effort to minimize overloading on the PCM air samples.

TABLE IV

Study 2—Scraping and hand wire brushing: large flanges. PCM airborne exposure levels (fibers greater than 5 micrometers)

Sample type	No. of air samples analyzed	Range (f/cc)	Sample time-weighted average (f/cc)	8-hr TWA (f/cc)
Background	4	0.0	0.0	N/A
Worker	10	9.3–24.0	15.3	3.6
Assistant	10	5.2–15.7	8.8	2.0
Area samples[A]	24	2.1–8.4	—	—

Total air-sampling time = 113 minutes.
[A]TWA not calculated for area or "bystander" samples.

However, any further reduction in the sampling time would have had an impact on the work activities. Therefore, the air-sampling times were not decreased any further.

The current OSHA asbestos exposure standards are based on the NIOSH 7400 method. This method measures only fibers longer than 5 micrometers in length and greater than 0.25 micrometers in width. However, these fiber dimensions were not implemented by OSHA with regard to health issues. The minimum dimensions were implemented solely due to the fiber resolution limitations of the PCM technique.[29] OSHA has long recognized that PCM is not fiber-specific or able to resolve fibers that are less than 0.25 micrometers in width. The TEM analysis performed in these studies augmented the PCM measurements by obtaining more complete and accurate measurements of the airborne asbestos concentrations.

A comparison of the air data collected from the PCM and TEM analyses showed fiber concentrations approximately 30 times greater in the TEM analysis. The differences between TEM and PCM measurements have been recognized by others and are primarily due to the resolution limitations of the optical microscope.[30,31] The deficiencies of PCM measurements are especially acute when products such as sheet gasket materials that contain high percentages of chrysotile fibers are the source of the airborne fibers. It has been shown that free respirable chrysotile fibers are released when asbestos-containing products are abraded in some manner.[6]

Work by the EPA demonstrated that single chrysotile fibers have an average diameter of between 0.03 and 0.07 micrometers.[32] This average diameter is approximately five times below the resolution of a phase contrast microscope. Therefore, single chrysotile fibers cannot be seen or counted using the PCM method, irrespective of their lengths. Because of the inherent errors in PCM analysis, it was suggested by the director of the Health Effects Institute for Asbestos Research that OSHA should consider changing to TEM air sample analyses for occupational workplace compliance to adequately protect workers' health.[33]

An SEM examination of the sheet gaskets was performed to better understand the relationship between the physical activity of removal and the measured asbestos air levels found in this study. Generally, sheet gaskets are comprised of approximately 70 percent chrysotile asbestos bundles in a synthetic rubber matrix. The SEM micrograph (Figure 1) shows large bundles of asbestos protruding from the matrix of new sheet gasket material. Any minimal disturbance or abrasion of these bundles can release asbestos fibers into the air. Another problem with asbestos gaskets is that the synthetic rubber matrix begins to deteriorate after installation. In most cases installed sheet gaskets are subjected to high temperature and pressure that will increase the rate of thermal decomposition of the rubber matrix. This produces cross-linking of the polymer molecules. The cross-linking process increases the gasket material's friability by causing the rubber matrix to degrade and become brittle.[34]

A comparison of the surface of a new gasket (Figure 1) to that of a used gasket removed from one of the flanges in Study 2 (Figure 2) demonstrates how the rubber matrix material is degraded. This degradation provides more opportunity for the release of asbestos fibers during the removal process. The fiber concentrations measured in Study 2 were higher than those measured in Study 1 even though more gaskets were removed in the first study. Factors believed to lead to these results were as follows: (1) The total gasket surface area removed in Study 2 was much larger than in Study 1, (2) The gaskets in Study 2 were observed to be more friable and more deteriorated, and (3) All the gaskets in Study 2 tore apart and remained adhered or attached to both of the flange faces when the flanges were opened.

An electric powered drill equipped with a wire brush was used to remove some residual gasket material from two flange faces in Study 3. The resulting exposures during the work activities

TABLE V

Scraping and hand brushing: large flanges. TEM airborne exposure levels (asbestos fibers greater than 5 micrometers)

Sample type	No. of air samples analyzed	Range (fibers/cc)
Background	4	0.0
Worker	14	199.6–842.7
Assistant	14	13.6–101.0
Area samples	24	3.3–108.8

Total air-sampling time = 113 minutes.

TABLE VI
Study 3—Power wire brushing. PCM airborne exposure levels (fibers greater than 5 micrometers)

Sample type	No. of air samples analyzed	Range (f/cc)	Sample time-weighted average (f/cc)	8-hr TWA (f/cc)
Background	4	0.09–0.12	0.11	N/A
Worker	7	14.9–31.0	21.8	2.3
Assistant	8	12.8–21.2	15.9	2.0
Area samples[A]	16	7.6–15.7	—	—

Total air-sampling time = 42 minutes.
[A]TWA not calculated for area or "bystander" samples.

were higher even though the residual gasket material was far less than the gasket materials removed in Study 1 and Study 2. It was observed in Study 3 that the mechanical action generated from the power wire brush tore loose more asbestos fibers and propelled them greater distances into the air. This observation supported the higher asbestos air concentrations of the area samples measured in Study 3 compared to those measured in Study 2. The results from the surface dust and fabric samples (Table VIII) showed that the surface asbestos levels measured can be classified as "highly contaminated" and pose additional exposure problems to the worker throughout the workday. Additional asbestos exposure can occur to both the worker and other family members if the clothes are worn away from the job or taken home.[35]

CONCLUSIONS AND RECOMMENDATIONS

These studies, as well as the other studies previously discussed, demonstrate that there can be wide variability in airborne asbestos fiber levels generated during the removal of asbestos-containing gaskets from flanges. The variability of fiber levels released is most likely dependent on the condition of the asbestos gasket, the size of the gasket surface area and the method of removal. The condition to which a gasket is subjected determines the degree of adhesion of the gasket to the flange surface and the friability of the gasket. This impacts the amount of energy required to remove the gasket and release asbestos fibers. The determining factors that seem to affect the condition of the gasket are: length of service, temperature and pressure conditions, and composition of the gasket matrix.

Our data show that dry removal methods typically used by machinists and pipefitters (past and present) result in significant airborne asbestos fiber exposures. For retrospective asbestos exposure assessments, the exposures measured by PCM in Studies 1, 2, and 3 exceed all historical OSHA excursion limits and some previous permissible exposure limits (PEL) based on an eight-hour TWA. The exposures also far exceed current OSHA levels. Therefore, former machinists and pipefitters that performed this type of work as part of their job activities would have had significant airborne asbestos exposures when removing tightly adhered gaskets on flange surfaces.

Under normal lighting, airborne dust is invisible even though the asbestos levels measured are above OSHA excursion limits. Therefore, an individual removing asbestos-containing gaskets will be unaware of any airborne exposure problems under normal working conditions. High-intensity lighting (Tyndall Effect) was used by the investigators in these studies to observe exposure mechanisms for workers performing normal work activities. The Tyndall Effect documented fiber release mechanisms and the pathways of exposure to the individuals removing the gaskets. Tyndall lighting is an alternative technique that industrial hygienists can use to check potential airborne dust emissions in the workplace. The Tyndall lighting technique can visually demonstrate to workers and employers if there is a need for air sampling, additional ventilation, respiratory protection, and/or special work practices.

There are still significant numbers of asbestos gaskets currently being used in the United States. OSHA classifies the

TABLE VII
Study 3—Power wire brushing. TEM airborne exposure levels (asbestos fibers greater than 5 micrometers)

Sample type	No. of air samples analyzed	Range-fibers/cc
Background	4	0.0–0.2
Worker	7	877.1–1636.1
Assistant	8	60.4–364.4
Area samples	16	56.9–801.9

Total air-sampling time = 42 minutes.

TABLE VIII
TEM fabric and surface dust contamination levels

Studies	Fabric-fibers/cm^2	Surface dust-fibers/cm^2
Study 1	981 thousand	8.5 million
Study 2	3.2 million	27.8 million
Study 3	19.3 million	57.4 million

All background control samples and field blanks analyzed were below the analytical detection limit.

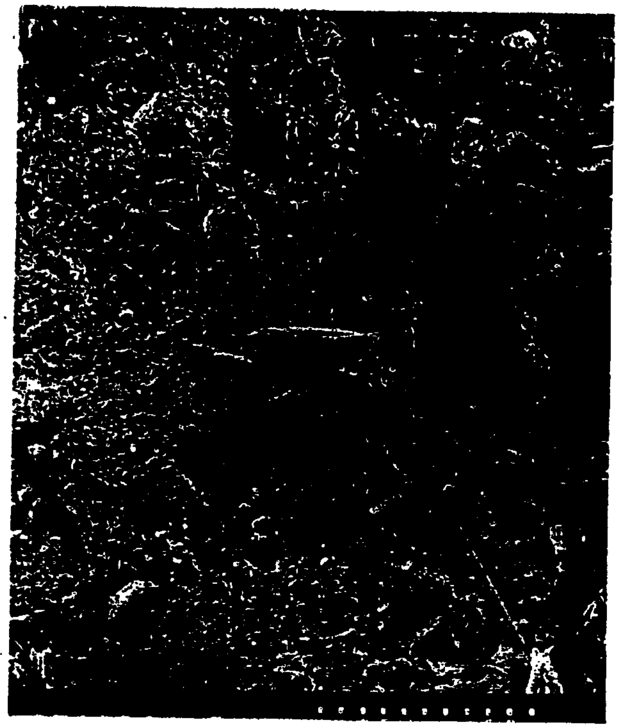

FIGURE 1
Scanning electron micrograph of the surface of a new asbestos-containing gasket. Both the chrysotile fibers and polymer matrix are visible. Magnification 1000×.

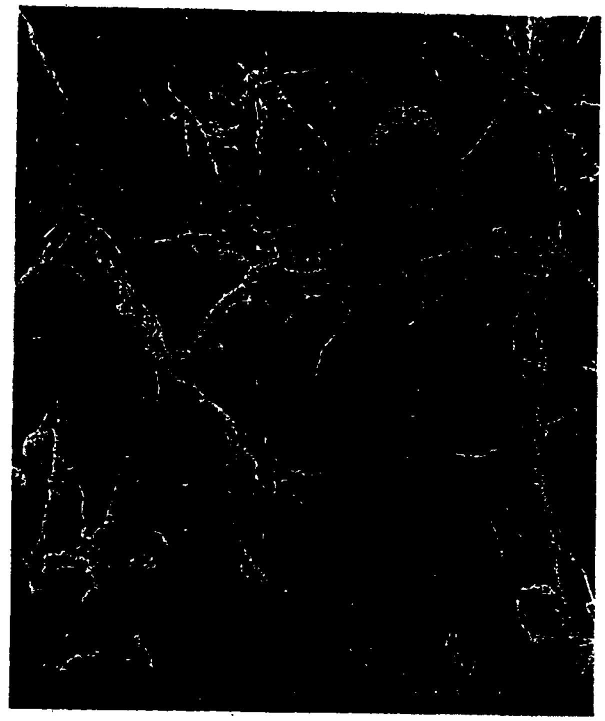

FIGURE 2
Scanning electron micrograph of the surface of a used asbestos-containing gasket. The majority of the material present is only chrysotile asbestos. Magnification 1000×.

removal of asbestos-containing gaskets as Class II work of short duration.[36] This specification by OSHA only addresses a single gasket removal project. However, interviews with pipefitters and machinists indicate that only removing one gasket at a time was not a typical occurrence. Under current OSHA regulations, the removal of asbestos-containing gaskets requires the use of a glove bag and wetting methods to contain the release of asbestos fibers into the workplace. Unfortunately, the glove bag and wetting methods are not always practical in an actual workplace due to production and maintenance schedule pressures and the difficulty in wetting a rubber based gasket.

The results of these studies indicate that employers need to determine if asbestos-containing gaskets are present in their equipment. The employer must immediately comply with OSHA's Class II provisions by implementing a safe operating procedure that includes employee training, assessment/monitoring, containment, and good work practices. The following actions are recommended if asbestos-containing gaskets are removed without a glove bag and wetting: (1) A negative pressure enclosure should be used, (2) The enclosure should have a HEPA filtering/air blower system, (3) A HEPA vacuum cleaner and wetting agents should be used, and (4) The worker should wear a respirator appropriate for the airborne asbestos concentrations generated by the activities.

The data presented here demonstrate that the work surfaces in these studies as well as the clothing worn by the investigators were highly contaminated with asbestos fibers. An asbestos-contaminated workplace can lead to additional asbestos exposures. The disturbance of the dust around the work area by other work activities and housekeeping activities will re-entrain asbestos fibers into the air.[35] The wearing, changing, and washing of the contaminated clothing can also lead to asbestos exposures for both a worker and family members.

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