AN EVALUATION OF GLOVE BAG CONTAINMENT IN ASBESTOS REMOVAL

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PREFACE

Under the Occupational Safety and Health Act of 1970, the National Institute for Occupational Safety and Health (NIOSH) has been given a number of responsibilities including the identification of occupational safety and health hazards, evaluation of these hazards, and recommendation of standards to regulatory agencies to control the hazards. Located in the Department of Health and Human Services (formerly DHEW), NIOSH conducts research separate from the standard setting and enforcement functions conducted by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards. The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering has been given the lead within NIOSH to study the engineering aspects relevant to the control of these hazards in the workplace.

In 1984, researchers from the Division of Physical Sciences and Engineering conducted a pilot study to survey the use of engineering controls in asbestos removal. A major recommendation from that study was to obtain documentation of the effectiveness of control techniques in current use. The use of glove bags was selected as the first control to be evaluated. Because the Environmental Protection Agency (EPA) also needed information as to the efficacy of glove bag removal technology, a joint study of the control of asbestos emissions from pipe lagging removal was conducted in June and July of 1985.

This report presents an evaluation of glove bag control techniques used to contain the emission of asbestos fibers during the removal of asbestos-containing pipe lagging. The data were obtained during week-long surveys in each of four public school buildings. Reports detailing the specific conditions and operations observed at each pipe lagging removal site surveyed were prepared.[1-4] Copies of these reports may be purchased from the National Technical Information Service (NTIS), Port Royal Road, Springfield, Virginia 22161.

ABSTRACT

This report examines the effectiveness of the glove bag control method to prevent asbestos emissions during the removal of asbestos-containing pipe lagging. Glove bags have been used for asbestos removal without supplemental engineering controls or respiratory protection. This study has two objectives: (1) to evaluate the efficacy of glove bags to contain asbestos fibers, thereby protecting abatement workers from exposure to asbestos and preventing subsequent contamination of the building and environment during the removal of asbestos-containing materials; and (2) to evaluate aggressive vs. nonaggressive sampling methods for determining the efficacy of asbestos abatement.

Workplace airborne asbestos exposures were determined during asbestos removal operations in four public schools. The same work crew removed asbestos-containing pipe lagging in all four schools. Personal exposures to airborne fibers were determined using NIOSH Method 7400 phase contrast microscopy (PCM) methods. Exposure measurements determined from personal samples indicated short-term exposures as high as 9.0 f/cc (9,000,000 f/m^3) and time-weighted average exposures of 0.3 f/cc (300,000 f/m^3) occurred during asbestos removal operations.

In conjunction with the U.S. Environmental Protection Agency (EPA), additional evaluations were made to measure residual work site contamination resulting from incomplete glove bag containment. Airborne asbestos contamination was determined in the work area before and after removal. Aggressive and nonaggressive sampling techniques were used for collecting area samples both before removal, and after removal and subsequent cleaning. Sample analysis was performed using both PCM and transmission electron microscopy (TEM) methods. Samples taken during nonaggressive sampling procedures and analyzed by PCM typically indicated concentrations below 0.01 f/cc (10,000 f/m^3), both for pre- and post-removal. TEM analysis of side-by-side samples detected much higher asbestos concentrations than PCM for both pre- and post-removal because PCM does not detect fibers less than about 0.25 μm in diameter.

Higher fiber concentrations were also observed when TEM analysis was compared with PCM analysis for both nonaggressive and aggressive sampling. In addition, samples collected by aggressive sampling demonstrated a greater magnitude of asbestos contamination following asbestos removal with glove bags compared to the pre-removal samples. The choice of sampling method (aggressive or nonaggressive) and of analytical method (PCM or TEM) could thus have an effect on the perceived level of asbestos contamination. It could lead to different conclusions regarding the presence or absence of low level asbestos contamination.

Exposure concentrations found at these four schools indicate that glove bags, as used during this study, did not completely contain the asbestos being removed. In three of the four facilities studied, workers were exposed to airborne asbestos concentrations above the OSHA PEL. The asbestos concentrations observed in the last of the surveys indicated that glove bags may provide some degree of containment under certain conditions. Although worker training and experience are important components of a reliable system of control measures, the present study does not provide a basis to specify conditions under which adequate containment can be assured. It is prudent to assume that the use of glove bags results in unpredictable exposure levels that may present an exposure hazard to workers and contamination of the work site.

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GLOSSARY

NOTE: This study was conducted using both NIOSH and EPA analytical methods. In general, NIOSH methods were used for occupational exposures. Both NIOSH and EPA methods were used to determine asbestos abatement evaluations. For PCM samples analyzed by Method 7400,[17] the total count is reported as fibers. For TEM samples analyzed by the revised Yamate Method,[19] separate counts are made for fibers, bundles, clusters, and matrixes and the sum of these categories is reported as structures. The original NIOSH Method 7402[20], in place at the time of this study, also followed this method of reporting. (In May 1989, a revision of Method 7402[21] was issued, wherein only particles fitting the definition of Method 7400 are counted and are reported as fibers.) The terminology used in the present study is fibers for PCM results and structures for TEM results.

Abatement	Removal or otherwise treating ACM to prevent contamination of buildings with asbestos.
Aggressive sampling	A sampling method using blowers and/or fans to keep particulates suspended during the sampling period.
Amended water	Water containing wetting agents, penetrants, and/or other agents to enhance the wetting of ACM and thereby reduce the generation of dust.
Asbestos	A group of impure magnesium silicate minerals which occur in fibrous form. These heat and chemical resistant materials with high tensile strength have been fabricated into a multitude of forms to utilize these characteristics. The more common mineral forms are known as: actinolite, amosite, anthophyllite, chrysotile, crocidolite, and tremolite.
Aspect ratio	The ratio of the length to the width of a particle or fiber.
Bundle	EPA:[11] A structure composed of three or more fibers in a parallel arrangement with each fiber closer than one fiber diameter. NIOSH:[20] A compact arrangement of parallel fibers in which separate fibers or fibrils may only be visible at the ends of the bundle. Asbestos bundles having aspect ratios of 3:1 or greater and less than 3 μm in diameter are counted as fibers.

Glossary (Continued)

Cluster	EPA:[11] A structure with fibers in a random arrangement such that all fibers are intermixed and no single fiber is isolated from the group. Groupings must have more than two intersections. NIOSH:[20] A network of randomly-oriented interlocking fibers arranged so that no fiber is isolated from the group. Dimensions of clusters can only be roughly estimated and clusters are defined arbitrarily to consist of more than four individual fibers.
Field Blank	A clean filter cassette assembly which is taken to the sampling site, handled in every way as the air samples, except that no air is drawn through it.
Fiber	EPA:[11] A structure having a minimum length equal to 0.5 μm and an aspect ratio (length to width) of 5:1 or greater with substantially parallel sides. NIOSH:[14] "A Rules" - Count only fibers longer than 5 μm. Measure the length of curved fibers along the curve. Count only fibers with a length-to-width ratio equal to or greater than 3:1. "B Rules" - Each fiber must be longer than 5 μm and less than 3 μm in diameter . . . with a length-to-width ratio equal or greater than 5:1.
f/cc	Fibers per cubic centimeter.
f/m^3	Fibers per cubic meter.
Filter background level	The concentration of structures per square millimeter of filter that is considered indistinguishable from the concentration measured on a blank (filters through which no air has been drawn).
Grid	An open lattice for mounting on the sample to aid in its examination by TEM. The term is used by the EPA to denote a 200-mesh copper lattice approximately 3 mm in diameter.
Intersection	Nonparallel touching or crossing of fibers, with the projection having an aspect ratio of 5:1 or greater.
Lpm	Liters per minute.
Matrix	EPA:[11] Fiber or fibers with one end free and the other end imbedded in or hidden by a particulate. The exposed fiber must meet the fiber definition. NIOSH:[20] One or more fibers attached to or imbedded in a nonasbestos particle.
Nonaggressive sampling	An environmental sampling method performed in a quiescent atmosphere.

Glossary (Continued)

Operations & Maintenance Program (O&M P)	A program of training, work practices, and periodic surveillance to maintain friable ACBM in good condition, ensure cleanup of asbestos fibers previously released, and prevent further release by minimizing and controlling friable ACBM disturbance or damage.
Pipe lagging	ACM used to insulate pipes carrying heated or refrigerated liquids or vapors.
Poly	Polyethylene sheeting.
Structure	A microscopic bundle, cluster, fiber, or matrix which may contain asbestos.[11]
s/cc^3	Structures per cubic centimeter.
s/mm^2	Structures per square millimeter.

ACRONYMS

ACBM	Asbestos-containing building material.
ACM	Asbestos-containing material.
AHERA	Asbestos Hazard Emergency Response Act.
CV	Coefficient of variation.
EDXA	Energy dispersive X-ray analysis.
EPA	The Environmental Protection Agency.
FAM	Fibrous aerosol monitor.
HEPA	High efficiency particulate air -- a designation for a type of filter capable of filtering out particles of 0.3 μm or greater from a body of air at 99.97 percent efficiency or greater.
LOD	Limit of detection.
LOQ	Limit of quantification.
MSHA	The Mine Safety and Health Administration.
NIOSH	The National Institute for Occupational Safety and Health.
OSHA	The Occupational Safety and Health Administration.
PBZ	Personal breathing zone. Breathing zone samples are commonly collected by a device secured to the lapel of a worker's uniform.
PCM	Phase contrast microscopy.
PEL	Permissible exposure limit, an OSHA standard designating the maximum occupational exposure permitted, as an 8-hour TWA.
REL	Recommended exposure limit, the NIOSH recommendation for maximum occupational exposure.
RSD	Relative standard deviation.
SAED	Selected area electron diffraction.
SEM	Scanning electron microscope or microscopy.
STD	Standard deviation.
STEM	Scanning transmission electron microscope.
TEM	Transmission electron microscope or microscopy.
TWA	Time-weighted average.

1. INTRODUCTION

Under the Occupational Safety and Health Act of 1970, the National Institute for Occupational Safety and Health (NIOSH) was assigned responsibilities for conducting research in occupational safety and health, for disseminating information emerging from those studies, for recommending standards to regulatory agencies, and for supporting the training of professionals in occupational safety and health. It was placed in the Department of Health and Human Services (formerly, the Department of Health, Education, and Welfare) to conduct research and education programs separate from the standard setting and enforcement functions conducted by the Occupational Safety and Health Administration (OSHA) in the Department of Labor.

An important area of NIOSH research deals with methods for controlling occupational exposure to potential biological, chemical, and physical hazards. The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering has been given the lead within NIOSH to study the engineering aspects relevant to the control of these hazards in the workplace. Since 1976, the ECTB has conducted assessments of control technology methods used in industry on the basis of controls used within a selected industry, controls used for common industrial processes, or specific control techniques. The objective of these studies has been to document and evaluate effective control techniques (e.g., isolation or the use of local ventilation) that reduce the risk of potential health hazards, and to create an awareness of the need for or the availability of effective hazard control measures. A number of these studies on control assessments, including the present research study on the use of glove bags in asbestos removal, have been performed in collaboration with the Environmental Protection Agency (EPA).

The original objective for this study was concerned primarily with control of occupational exposure; however, in collaboration with the EPA, environmental aspects were also included. Because the EPA was preparing legislation for asbestos abatement, that Agency was interested not only in the efficacy of glove bags for asbestos containment, but also in the development of test methods to evaluate asbestos contamination at very low concentrations. As a result, the study was undertaken with two objectives:

- To evaluate the efficacy of the use of glove bags as a control technique to prevent occupational exposure to airborne asbestos during the removal of asbestos-containing pipe lagging, and as a control technique to prevent contamination of the building environment. NOTE: The occupational exposure and building contamination aspects are discussed separately in the present report because they involve different analytical methods and regulatory agencies.

- To evaluate sampling and analytical techniques for determining concentrations of airborne asbestos for asbestos abatement clearance, specifically: (a) to compare airborne asbestos concentrations determined by "aggressive" and "nonaggressive" sampling methods, and (b) to compare analytical results determined by PCM and TEM procedures.

The evaluations were conducted during the removal of asbestos-containing pipe lagging in four public school buildings; all removal operations were conducted by the same work crew. The authors have attempted to accurately describe the operations and conditions observed during the surveys and to delineate the major difficulties encountered in the evaluations of the sampling and analytical methodologies. In many cases, the high variability of asbestos analytical results precluded the ability to obtain sufficient data to determine statistical differences; however, the data and observations reported indicate trends and other information useful to members of the asbestos removal industry for reducing asbestos emissions.

1.1. BACKGROUND

1.1.1. Technical

A pilot study of asbestos abatement operations conducted in 1984 revealed novel approaches that have been and are being developed to control asbestos fiber exposure of workers engaged in the removal of asbestos-containing materials (ACM).[5] Two principle methods currently used to control airborne exposure are wetting the ACM and the use of negative air pressure in the workplace. Wetting methods utilize fluids to saturate ACM before and during the removal of these materials to reduce the potential for asbestos fibers to become airborne. Exposure control by negative pressure is accomplished by the use of fans or exhaust devices to remove contaminated air from enclosed or controlled areas and to draw clean air into these areas. In order to contain and reduce airborne asbestos, this exhausted air is filtered through high efficiency particulate air (HEPA) filters before being released to the atmosphere.

The evaluation of source controls, such as containment or local ventilation applied at the source of the emission, is of particular interest because these are generally the most effective in controlling both occupational exposure and environmental releases. An asbestos abatement activity that is frequently performed is the removal of pipe lagging (i.e., ACM used to insulate pipes carrying heated or refrigerated liquids or vapors). Glove bags are often used as source controls during the removal of pipe lagging. These are large plastic bags which contain long gloves sealed into the body. The worker seals the bag around the material to be removed and then manipulates various tools within the bag by means of the gloves sealed into the side of the bag to remove the lagging. The debris falls to the bottom of the bag, where it is contained for final disposal as asbestos waste in accordance with regulations promulgated by the EPA and by State and local governments. Glove bags may also be used for general plant maintenance. They are often used without other means of containment, such as total enclosure of the removal area with plastic barriers and/or the use of negative pressure. The effectiveness of glove bags to control asbestos emissions is extremely important to assure the health of workers and to prevent contamination of the adjoining workplaces and the environment.

This study was initiated to determine if the use of glove bags can reliably control asbestos emissions during abatement operations. In addition, EPA methodologies for measuring room contamination levels of airborne asbestos for post-abatement clearance were evaluated.

1.1.2. Environmental Regulation

The EPA has been involved in regulatory activities to reduce asbestos emissions and contamination of the environment since 1972.[6,7] A major concern of this Agency is that degradation or disturbance of in-place ACM in buildings may cause asbestos to contaminate the buildings. The debris may become airborne from repeated episodes of agitation and thereby create a potential for exposure to the occupants. Although the application of asbestos fireproofing material is not permitted in buildings today, the eventual management and removal of in-place ACM poses a technical and economic dilemma. A part of the Toxic Substances and Control Act, the Asbestos-in-Schools Rule,[8] requires administrators of primary and secondary schools, both private and public, to have all buildings inspected for ACM; to document its presence and condition; and to inform their employees, the PTA or parents, and the State authority.

In the past, rather than promulgate specific regulations for asbestos abatement activities, the EPA has issued "Guidance Documents"[9,10] which have presented the "best engineering judgment" approach at that time. Based on these guidelines and on the present requirements of the Asbestos Hazard Emergency Response Act (AHERA),[11] ACM must be routinely monitored through an established operation and maintenance program. If abatement is needed, the accepted methods are: (1) encapsulation with a penetrating or bridging chemical; (2) enclosure to prevent access to public or to airflow disturbances; or (3) removal. EPA regulations also require the removal of ACM prior to demolition of a building,[12] so eventual removal of ACM is virtually inevitable.

Because the efficacy of certain control methods for asbestos removal is not well known, EPA and NIOSH initiated an Interagency Agreement to add to the planned evaluations of glove bag containment by NIOSH researchers. The added work involved documenting the effectiveness of glove bags in controlling airborne emissions that could potentially add to long term, low level building contamination. This required the determination of the airborne asbestos concentrations in work areas before asbestos removal was started and also after the activities were completed in order to determine whether there was a release of airborne asbestos during the removal. Two sampling methods, "aggressive" and "nonaggressive", were used to compare the effectiveness of these methods in evaluating asbestos contamination for building clearance assessment. They are described in detail in the Section 4.1.5, Pre- and Post-Removal Air Sampling.

1.1.3. Analytical Methods

At the time of the study, phase contrast microscopy (PCM) was the primary method used to determine airborne asbestos concentrations in the workplace.

Several investigators had developed transmission electron microscopy (TEM) methods with the capability of detecting fibers smaller than those visible by PCM. Another part of the Interagency Agreement was to provide some evaluation of these methods for detecting airborne asbestos at the very low concentrations encountered in environmental evaluations by using side-by-side sampling and subsequent analysis by both PCM and TEM.

1.1.3.1. Phase Contrast Microscopy--
PCM has historically been used for the purpose of analyzing occupational exposures to airborne asbestos. It was developed for determining occupational exposure in industrial environments where airborne fibers were known to consist essentially of asbestos. Epidemiologic studies have correlated health effects to PCM fiber counts. However, PCM does not differentiate between asbestos and other fibrous matter such as organic textile or cellulose fibers, nor does it detect very thin or small fibers. The Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) is based on a method that utilizes PCM to manually count the number of fibers greater than 5 micrometers (μm) in length and with an aspect ratio of at least 3:1 (length to width) collected on cellulose ester filter media.[13]

NIOSH Method 7400 describes sampling and analytical procedures for determining fiber concentrations by PCM. This method was first issued February 15, 1984.[14] It was revised May 15, 1985,[15] and a second revision was made August 15, 1987;[16] the third and current revision was issued May 15, 1989.[17] The NIOSH Method 7400, in place at the time of the study,[14] included two sets of counting rules: "A" rules and "B" rules. PCM samples from this study were analyzed using the "B" rules, which define a fiber as having an aspect ratio of 5:1 or greater. A note under the "B" rules in this version states: ". . . The B rules are preferred analytically because of their demonstrated ability to improve the reproducibility of fiber counts." In the third and current revision of Method 7400,[17] the "B" rules are only included as Appendix C and an introductory note concludes: "NIOSH recommends the use of the 3:1 aspect ratio in counting fibers." (As discussed in Section 2.1, Occupational Exposure Criteria, it is not possible to estimate accurately "A" rule fiber counts based on "B" rule results.)

A note on the applicability of NIOSH Method 7400[17] states: ". . . The method gives an index of airborne fibers . . . Fiber [less than about] 0.25 μm diameter will not be detected by this method." The method requires a microscopist to count the number of fibers collected on several very small areas of the filter used to capture these fibers. Unfortunately, the deposition of the fibers on the filter is not uniform. Baron and Deye[18] note that ". . . The change in particle trajectories caused by [electrostatic] charge effects can result in nonuniform deposits on the collecting filter surface and net loss of sample . . . ." Therefore, in spite of attempts to randomize counting areas, the specific fields counted may not be representative of the entire filter. For this and other reasons as discussed in Section 5.2, Confidence Limits, the interlaboratory coefficient of variation (CV = 0.45) is quite large. The term "index" is properly applied to the result of microscopic fiber counts, because quantitation of analytical results contains more uncertainty than does the analysis of most chemicals. However, this method does have the capability of producing results rapidly (less than 24 hours) and relatively inexpensively.

1.1.3.2. Electron Microscopy--
In addition to PCM, transmission electron microscopy (TEM) was evaluated for asbestos counting both because of the greatly enhanced resolution and contrast, and of the analytical capability to differentiate between asbestos and nonasbestos structures. The greater power of the TEM method becomes important where the airborne fibers with diameters less than 0.25 µm (the limit of the resolving power of PCM) are present. For example, in relatively clean buildings and in the surrounding ambient environment, there is a proportionately lower concentration of airborne fibers greater than 0.25 µm because of the rapid settling of the heavier material. Even though a proportionately higher concentration of airborne fibers <0.25 µm in diameter may be present in these circumstances, they will not be observed at all with PCM. Thus, under these conditions, no conclusion can be made about their presence or absence. Because of the lower resolving power of the PCM method, the EPA requires the TEM method to be used for quantitating asbestos fibers.[11,19]

Widespread use of TEM has been limited by the relative high cost of analysis, the availability of equipment and trained personnel, and the absence of a standardized method of analysis. NIOSH Method 7402,[20] in place at the time of this study, used the same cellulose ester filter medium as does the PCM method. (Method 7402 was revised on May 15, 1989,[21] but the use of a cellulose ester filter is still required.) The EPA has developed a provisional method for TEM analysis of asbestos which requires a polycarbonate filter medium.[19] This method was further modified for regulatory purposes when the Asbestos Hazard Emergency Response Act (AHERA)[11] was promulgated in 1986, and is considerably different than the NIOSH method 7402 and the requirements of the OSHA Standard;[13] this is discussed further in Section 2.2, Environmental Exposure Criteria.

1.1.4. Facilities Surveyed

In the summer of 1983, a public school board employed a consultant to survey the school buildings to determine the type, location, and condition of ACM. Asbestos-containing pipe and/or boiler lagging was found in 90% of the buildings surveyed; asbestos-containing acoustical plaster, fireproofing, and/or acoustical ceiling tile were found in only a few buildings.[22] In addition, there were numerous occurrences of miscellaneous building materials (pressed asbestos-board, asbestos-cement sheeting, etc.) and other products (asbestos protective clothing, pot holders, gaskets, etc.) observed in these buildings. The consultant's recommendations for minimizing the risk of asbestos exposure included the removal of significantly deteriorated acoustical plaster and fireproofing, the repair and repainting of acoustical plaster in some areas, and the repair or removal of damaged and/or exposed asbestos pipe and boiler insulation. The establishment of an asbestos hazard management program was recommended to provide for employee training, monitoring, and management of all ACM that remained in these buildings. These recommendations were implemented by the school board and the priority asbestos removal and repair projects were completed. In 1985, a contractor was employed to remove all remaining asbestos-containing pipe lagging and materials. Arrangements were made with the school board for the NIOSH research team to conduct surveys at four school buildings and to collect samples to determine airborne asbestos contamination levels before, during, and after the removal of pipe lagging.

2. DISCUSSION OF THE HAZARD AND EXPOSURE CRITERIA

2.1. OCCUPATIONAL EXPOSURE CRITERIA

Because of the potential carcinogenicity of asbestos NIOSH recommends that exposure of workers to asbestos be reduced to the lowest feasible limit. In 1984, NIOSH reaffirmed its previously recommended exposure limit (REL) not to exceed 100,000 fibers greater than 5 μm in length per cubic meter (f/m^3) or 0.1 fibers per cubic centimeter (f/cc) based on the limit of quantification for analysis of samples by PCM.[23] On May 9, 1990, at the hearing on OSHA's Notice of Proposed Rulemaking on Occupational Exposure to Asbestos, Tremolite, Anthrophyllite, and Actinolite,[24] this position was summarized as follows:

> ". . . On June 21, 1984, NIOSH testified at the OSHA public hearings on occupational exposure to asbestos and presented supporting evidence that there is no safe airborne fiber concentration for any of the asbestos minerals.[23] NIOSH stated that not even the lowest fiber exposure limit could assure all workers of absolute protection from exposure-related cancer. This conclusion was consistent with previous positions taken by NIOSH in the 1976 criteria document on asbestos[25] and the joint NIOSH/OSHA report of 1980.[26] In the NIOSH/OSHA report, NIOSH also reaffirmed its position that there is no scientific basis for differentiating health risks between types of asbestos fibers for regulatory purposes. In its 1984 testimony, NIOSH urged that the goal be to eliminate asbestos fiber exposures.[23] Where exposures cannot be eliminated, exposures should be limited to the lowest concentration possible.
>
> "When recommending an occupational exposure limit in its 1984 testimony, NIOSH acknowledged the limitations imposed by currently accepted methods of sampling and analysis. NIOSH concluded that for regulatory purposes, phase contrast microscopy (PCM) was still the most practical technique for assessing asbestos fiber exposures when using the criteria given in NIOSH Analytical Method 7400.[17] NIOSH also recognized that phase contrast microscopy (1) lacked specificity when asbestos and other fibers occurred in the same environment, and (2) was not capable of detecting fibers with diameters less than approximately 0.25 micrometers. NIOSH further stated that it might be necessary to analyze samples by electron microscopy where both electron diffraction and microchemical analysis can be used to help identify the type of mineral and assist in ascertaining asbestos fiber concentrations."

In the 1990 testimony, NIOSH recommends the following to be adopted for regulating exposures to asbestos:

> "The current NIOSH asbestos recommended exposure limit is 100,000 fibers greater than 5 micrometers in length per cubic meter of air, as determined

in a sample collected over any 100-minute period at a flow rate of 4L/min. This airborne fiber count can be determined using NIOSH Method 7400, or equivalent. In those cases when mixed fiber types occur in the same environment, then Method 7400 can be supplemented with electron microscopy, using electron diffraction and microchemical analysis to improve specificity of the fiber determination. NIOSH Method 7402[21] provides a qualitative technique for assisting in the asbestos fiber determinations. Using these microscopic methods, or equivalent, airborne asbestos fibers are defined, by reference, as those particles having (1) an aspect ratio of 3 to 1 or greater; and (2) the mineralogic characteristics (that is, the crystal structure and elemental composition) of the asbestos minerals and their nonasbestiform analogs . . . ."

NIOSH also includes the following statement on asbestos in pertinent Health Hazard Evaluations:

"NIOSH recommends as a goal the elimination of asbestos exposure in the workplace; where it cannot be eliminated, the occupational exposure to asbestos should be limited to the lowest possible concentration.[23] This recommendation is based on the proven carcinogenicity of asbestos in humans and on the absence of a known safe threshold concentration.

"NIOSH contends that there is no safe concentration for asbestos exposure. Virtually all studies of workers exposed to asbestos have demonstrated an excess of asbestos-related disease. NIOSH investigators therefore believe that any detectable concentration of asbestos in the workplace warrants further evaluation and, if necessary, the implementation of measures to reduce exposures.

"NIOSH investigators use phase contrast microscopy (NIOSH Method 7400[17]) to determine airborne asbestos exposures, and electron microscopy (NIOSH Method 7402[21]) to confirm them. The limits of detection and quantitation depend on sample volume and quantity of interfering dust. The limit of detection is 0.01 fiber/cc [10,000 fibers/m^3] in a 1,000-liter air sample for atmospheres free of interferences. The quantitative working range is 0.04 to 0.5 fiber/cc [40,000 to 500,000 fibers/m^3] in a 1,000-liter air sample.

"The Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for asbestos limits exposure to 0.2 fiber/cc [200,000 f/m^3] as an 8-hour TWA.[13] OSHA has also established an asbestos excursion limit for the construction industry that restricts worker exposures to 1.0 fiber/cc [1,000,000 f/m^3] averaged over a 30-minute exposure period.[27]"

At the time of this study (1985), the OSHA PEL was 2.0 fibers greater than 5 μm in length per cubic centimeter (2,000,000 f/m^3), averaged over an 8-hour work day, with a ceiling concentration of 10.0 f/cc (10,000,000 f/m^3), not to be exceeded over a 15-minute period.[27] There was also a provision for medical monitoring of workers routinely exposed to fiber concentrations in excess of 0.1 f/cc (100,000 f/m^3).

On June 20, 1986, OSHA issued a revised standard which reduced the PEL to 0.2 f/cc (200,000 f/m^3) greater than 5 µm in length, as an 8-hour time-weighted average (TWA) exposure.[13] It also set an action level of 0.1 f/cc (100,000 f/m^3) that triggers other requirements, including worker training and medical monitoring; in 1988 the standard was revised to establish a 1.0 f/cc (1,000,000 f/m^3) excursion limit.[27]

Many employees of local, state, or federal governmental agencies are exempt from OSHA regulations. To protect all workers in public schools where asbestos removal is performed, the EPA first adopted the provisions of the OSHA standard in effect in 1985 and then the June 1986 OSHA revisions in February 1987.[29]

As stated, the determination of occupational exposure to asbestos according to the criteria contained in the NIOSH REL and the OSHA PEL are based on the use of the PCM analytical method. This method has inherent limitations based on the optics of the microscope and upon the ability of the microscopist to reliably discriminate fiber length to width ratios in a complex sample matrix. NIOSH Method 7400[14] stipulated that only fibers longer than 5 µm be counted with a length to width ratio of either 3:1 (A rules) or 5:1 (B rules). The A rules use the same aspect ratio required in the earlier NIOSH analytical method P&CAM 239[30] and the current OSHA PEL, and thus have the advantage of relating fiber concentrations to current and historical exposure data. There is no means to generically extrapolate fiber concentrations determined from the use of the B rules to that which may have been derived if the A rules had been used, because the distribution of fibers may vary from case to case. However, fiber counts of samples collected in this study at two schools were compared using TEM analysis to determine fiber dimensions and type of fiber. Using the fiber size distribution determined by TEM for samples in the present study, the difference between the number of fibers counted having aspect ratios greater than 5:1 and those having aspect ratios greater than 3:1 was under 20%.

There are several other factors in addition to aspect ratio that can affect the result of asbestos counting methods. Perhaps the most important is that PCM is used for counting <u>total</u> fibers greater than 5 µm in length and 0.25 µm in diameter. On the other hand, TEM counts include only fibers verified by crystalline asbestiform identification. Furthermore, the minimum fiber diameter that can be routinely observed by PCM is approximately 0.25 µm. Because many asbestos fibers have diameters less than 0.25 µm, they are not usually visible during PCM analysis. Thus the use of TEM provides the opportunity to identify and characterize all airborne fibers present in the work environment. <u>Total</u> fiber counts by TEM are often far higher than counts of the same sample obtained by PCM. However, once fibers are speciated, TEM counts of <u>asbestos</u> fibers could actually be lower than the PCM count, especially for relatively low concentrations of mixed fiber type containing a high proportion of nonasbestos fibers. In spite of these limitations, PCM analysis is recognized by occupational health professionals as an appropriate index of exposure for approximating disease potential.

Exposures to airborne asbestos fiber concentrations are usually reported as the number of fibers per cubic centimeter (f/cc) of air. In this report, concentrations are also expressed as fibers per cubic meter (f/m^3), because the amount of inspired air over the work shift of asbestos removal workers would typically be 1 to 2 cubic meters of air per hour. In an environment contaminated at the OSHA PEL of 0.2 f/cc [200,000 f/m^3], a worker with no respiratory protection could inhale over 2 million fibers visible by PCM during an 8-hour work shift! As noted above, because of the small size of airborne fibers, fibers observed and counted by PCM often represent only a small percentage of the total number of fibers inhaled by an unprotected worker.

2.2. ENVIRONMENTAL EXPOSURE CRITERIA

The EPA had established "clearance" guidelines for determining when reoccupancy may occur after asbestos removal. These guidelines were initially published as "recommended practices."[9,10] In 1984 and 1985, the recommended practice was to perform visual inspection of the work area after asbestos removal, followed by quiescent air sampling using PCM for fiber analysis. Fiber concentrations were required to be below the lower quantifiable limit of detection using NIOSH Method P&CAM 239.[30] This limit ranged from 30,000 to 10,000 f/m^3 (0.03 to 0.01 f/cc) at the recommended sample volumes of 1,000 to 3,000 liters. If fiber concentrations in the building, after asbestos abatement activities, exceeded this limit, then the work areas were required to be recleaned until exposures were brought under control.

The revised EPA guidelines issued in 1985[9] recognized NIOSH Method 7400 and recommended a 3,000 liter sample in order to provide a minimum quantification limit of 0.01 f/cc (10,000 f/m^3). These guidelines also recommended using aggressive sampling and the use of TEM analysis to determine asbestos concentrations. To permit reoccupancy using this evaluation methodology, the average fiber concentration of five samples collected from a "homogenous" area was to be statistically equal to or less than the ambient background fiber concentration. A typical ambient asbestos concentration is approximately 0.005 f/cc (5,000 f/m^3).[31]

The field work for the present study was conducted in June and July of 1985, based on the 1985 revised EPA guidelines,[9] for sampling and analysis. For the sake of completeness, a discussion of legislative revisions of environmental exposure criteria which have occurred since 1985 that affect current asbestos removal work is given in the following text.

In October 1986, the Asbestos Hazard Emergency Response Act (AHERA)[11] was passed which required the EPA to regulate asbestos in schools. On October 30, 1987, the final rule "Asbestos-Containing Materials in Schools" was published in the Federal Register.[32] This rule requires the use of aggressive air sampling to determine if a response action (an asbestos containment or removal operation and clearance procedure for reoccupancy) has been satisfactorily completed. For the first 2 years after the effective date of the rule (December 14, 1987), ". . . a local education agency (LEA) may analyze air monitoring samples for clearance purposes by PCM to confirm completion of removal, encapsulation or enclosure of ACBM [asbestos-containing building material] that is less than or equal to 3,000 square feet or 1,000 linear feet. The section [response action] shall be considered complete when the result of samples collected in the affected functional space show that the concentration of asbestos for each of five samples is less than or equal to the limit of quantitation for PCM, or 0.01 f/cc [10,000 f/m^3] of air."

After the first 2 years or if the job exceeds the minimum size criteria, the regulation requires a three-step process using TEM analysis for determining successful completion of a response action. After visual inspection, the final two steps involve a sequential evaluation of five samples taken inside the work site, five samples taken outside the work site, two field blanks, and one sealed blank. Final clearance is granted if the average asbestos fiber concentration determined from the samples collected in the work site is below the prescribed limit of detection (LOD) for the TEM method. Additional evaluations are required if the LOD test fails.

A previous EPA guidance publication[33] noted that the basis for collecting five samples was to increase the statistical confidence in the measurement and thus reduce the possibility of wrongly approving a contaminated facility. Statistically, <u>seven</u> samples are required for a method with a CV of 1.5 to provide a 90% confidence of detecting a fivefold difference from the ambient concentration; however, for practical reasons, a minimum sample size of <u>five</u> was recommended. The same EPA publication also recommended that samples from the work site should be taken from one <u>homogeneous area</u> which is defined as "a contiguous area in which one type of abatement procedure was performed to remove the same type of ACM." Asbestos removal at most abatement sites is performed using various removal procedures to remove different types of ACM from a number of separated areas within a building. Even within contiguous areas, several different types of abatement procedures may be employed. The "homogenous area" requirement was omitted in the enactment of the AHERA regulation.

In addition to these changes in the sampling protocol and clearance strategy, AHERA prescribed a new TEM protocol which differs from NIOSH method 7402 and OSHA reference method (Appendix A of the revised standard[13]) in several ways:

<u>Aspect Ratio</u> - Fibers must have a 5:1 or greater aspect ratio to be counted, as opposed to the 3:1 ratio prescribed by NIOSH and OSHA for evaluating airborne exposure. A review[34] of several EPA studies (including this project) indicated that fiber counts based on a 5:1 aspect ratio ranged from 13 to 61 percent lower than fiber counts obtained using a 3:1 aspect ratio. Thus, lower airborne asbestos concentrations are reported when the 5:1 aspect ratio is used.

<u>Filter Media</u> - Air samples may be collected either on polycarbonate or cellulose ester media; however, the cellulose ester media specified is a 0.45 μm pore size filter with a 5.0 μm pore size backing filter. Both NIOSH Method 7402 and the OSHA standard specify a 0.8 μm pore size filter. This difference may affect the distribution and orientation of the fibers collected.

<u>Filter Blank Contamination and Interlaboratory Variability</u> - A more complicated issue involves the analysis of fiber contamination found on unused (blank) filters and the determination of the LOD. In 1985, the EPA provided polycarbonate filters from the same production lot for this and several other studies. The investigators for these studies reported high and variable fiber counts on blank filters as they were received from the EPA. A peer review

workshop to discuss the topic was convened by the EPA in April 1986. The findings were presented in "Filter Blank Contamination in Asbestos Abatement Monitoring Procedures: Proceedings of a Peer Review Workshop."[35] Two major consequences of this contamination were identified: One was the need for improved quality control to reduce contamination in the polycarbonate media during its manufacture. The other was the high interlaboratory variability which became obvious when analyses of contaminated blank polycarbonate filter media were compared. Figure 2-1, which is reproduced from the report of this workshop, illustrates these comparisons.

In addition to variable contamination of the filters, a major confounding source of interlaboratory variability was the lack of standardization for sample preparation and analysis used between laboratories. Although the polycarbonate filters were analyzed by the Yamate modified EPA provisional method,[19] subtle differences in the preparation, instrumentation, and procedural interpretation by the analyst greatly affected the fiber count.[35] A fundamental treatment of this subject is presented in "Accuracy of Transmission Electron Microscopy for the Analysis of Asbestos in Ambient Environments."[36]

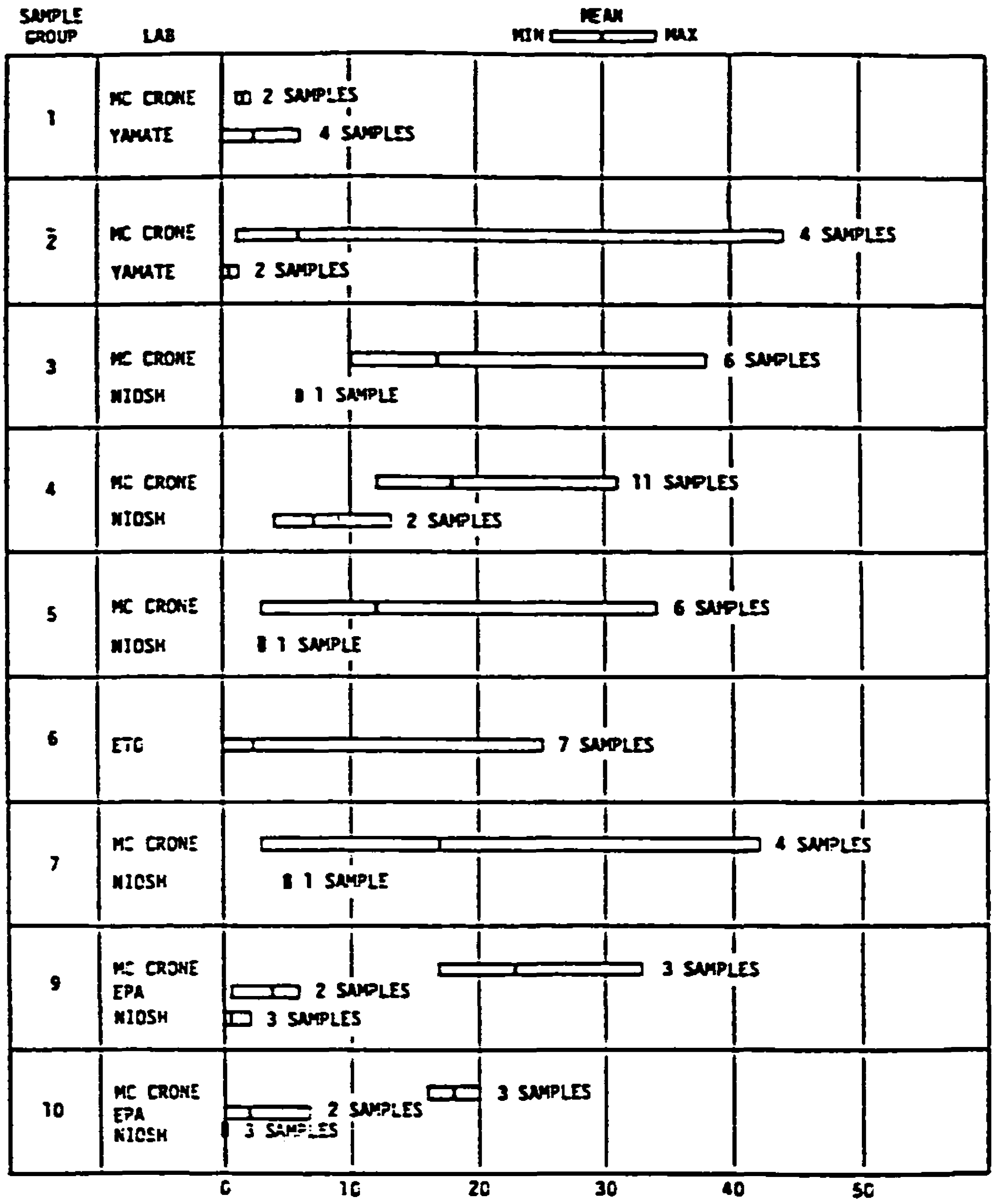
As a result of the workshop, the EPA evaluated asbestos contamination in a batch of newly-manufactured polycarbonate filters that were manufactured using improved quality controls to reduce asbestos contamination. This was compared to a batch of typical cellulose ester filters (which were not expected to show appreciably contamination based on past experience). Two laboratories analyzed 50 samples of each type. The mean asbestos contamination was found to be 10 fibers in 1,000 grids for the cellulose ester media, and 180 fibers per 1,000 grids for the polycarbonate. These values correspond to 2 structures/mm^2 and 35 structures/mm^2, respectively.

The ACM in Schools Regulation[32] states: "When volumes greater than or equal to 1,199 L for a 25 mm filter and 2,799 L for a 37 mm filter have been collected and the average number of asbestos structures on samples inside the abatement area is no greater than 70 s/mm^2 of filter, the response action may be considered complete without comparing the inside samples to the outside samples. EPA is permitting this initial screening test to save analysis costs in situations where the airborne asbestos concentration is sufficiently low so that it cannot be distinguished from the filter contamination/background level (fibers deposited on the filter that are unrelated to the air being sampled). . . . The value of 70 s/mm^2 is based on the experience of the panel of microscopists who consider one structure in 10 grid openings (each grid opening with an area of 0.0057 mm^2) to be comparable with contamination/background levels of blank filters . . . ." This "experience" refers to analyses of the contaminated polycarbonate filter medium described above. The analytical method requires laboratories to determine the actual contamination of the blank filters for each media lot. As noted above, however, AHERA permits a contamination level of 70 s/mm^2 to be assumed for clearance purposes, i.e., if the sample filters contain 70 or fewer s/mm^2, the room may be reoccupied.

If the average indoor sampling concentrations are greater than 70 s/mm^2, the area may be recleaned, retested, and analyzed as described above, or a Z-test may be performed. The Z-test is a statistical comparison of indoor clearance

Figure 2-1

Comparison by Laboratory of Asbestos Structure Counts on Blanks*



* From: Filter Blank Contamination in Asbestos Abatement Monitoring Procedures: Proceedings of a Peer Review Workshop.[26]

samples vs. outdoor ambient samples. It is used to determine whether the abatement response action is complete, i.e., if clearance has been achieved for reoccupancy. Powers and Cain reported the probability of passing the Z-test for various room, filter media, and ambient asbestos structure concentrations, as shown in Figures 2-2 and 2-3.[37] To illustrate the use of these figures, suppose that the filter media are contaminated with 70 s/mm^2 and a room is cleaned to the 0.005 s/cc (5,000 s/m^3) ambient asbestos concentration. The probability of passing is only 70%, whereas if the filter media contamination is less than 17 s/mm^2, the probability of passing is 99%. Thus the media contamination can lead to false positives for room contamination which would potentially require additional but unwarranted cleaning.

As noted above, the ACM in Schools Regulation states that clearance can be achieved without comparing inside samples to the outside samples if the inside samples pass a screening clearance criteria of 70 s/mm^2. This is done ". . . to save analysis costs where airborne asbestos concentration is sufficiently low so that it can not be distinguished from the filter contamination . . . ."[32] The value, 70 s/mm,^{2} is 4 times the analytical sensitivity of the polycarbonate method. The analytical sensitivity is stated to be no greater than 1 fiber in 10 grids, or 0.005 s/cc (5,000 s/m^3) for a 37 mm filter. Based on these assumptions, the clearance limit for TEM, using a 3,000 liter sample and a 37 mm filter, is 4 x 0.005 s/cc, or 0.02 s/cc (20,000 s/m^3). Ambient asbestos concentrations are usually an order of magnitude lower than this, typically in the range of 0.002 to 0.005 s/cc (2,000 to 5,000 s/m^3).[31]

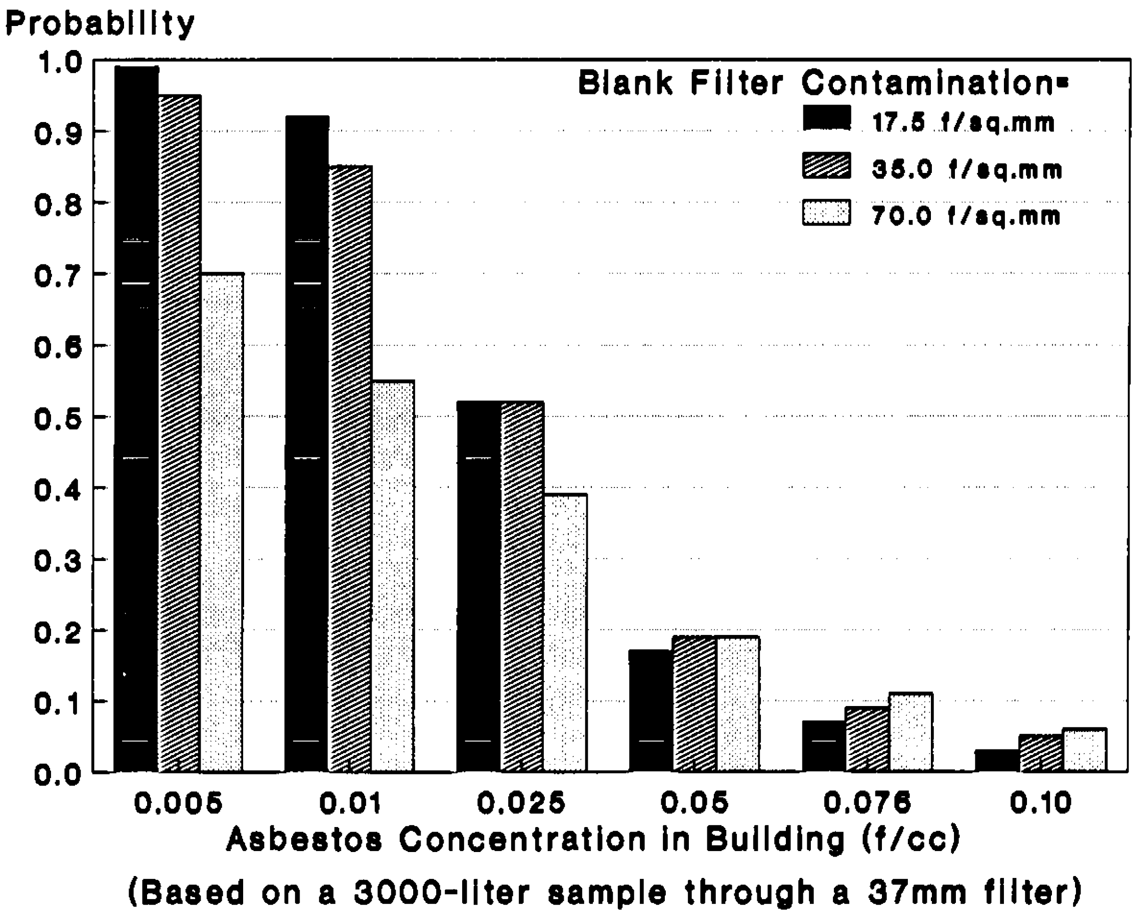


Fig 2-2 Probability of Passing the Z-Test for Asbestos Abatement Clearance when Outdoor Ambient Concentration is 0.005 (f/cc)

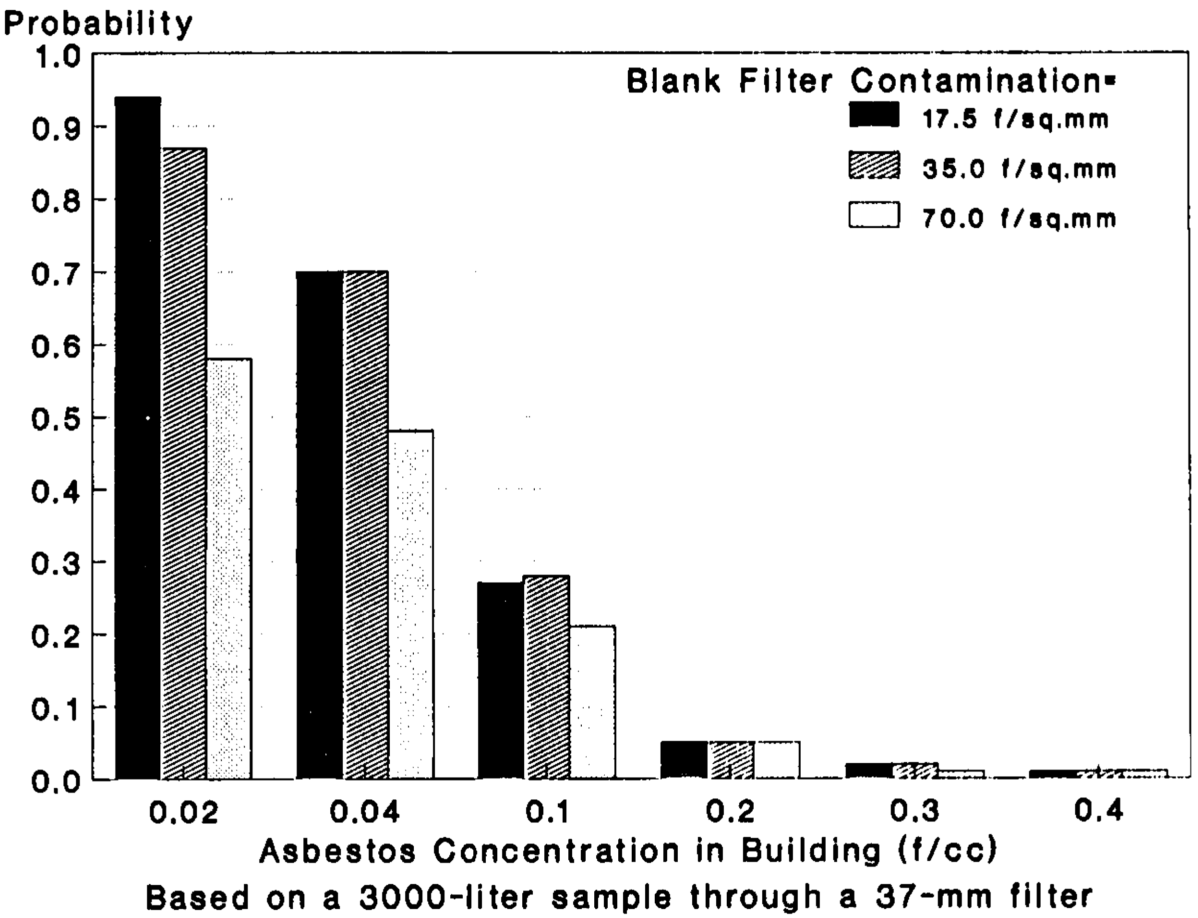


Fig 2-3 Probability of Passing the Z-Test for Asbestos Abatement Clearance When Outdoor Ambient Concentration is 0.02 (f/cc)

3. SITE AND PROCESS DESCRIPTION

3.1. SITE DESCRIPTION

This study was conducted in public school buildings typical of those found in a large city. Two rooms in each of four schools were selected for the measurement of airborne asbestos concentrations. The rooms were visually inspected and found to be fairly clean, having no apparent damage to the pipe lagging and little potential for contamination from the other types of fibers, e.g., textile and cellulose fibers from drapes, carpets, ceiling, etc. These "controlled areas" were isolated to restrict interaction with areas and activities outside the study area. All air ducts, holes, and windows in these rooms were sealed with polyethylene sheeting (poly) and duct tape; door openings were sealed off with a two-sheet poly baffle. After sealing the rooms, pre-removal asbestos levels were determined in each room using nonaggressive, then aggressive sampling methods. During ACM removal, personal and area samples were taken to determine asbestos exposures of removal workers during these operations. Finally, after the rooms were cleaned, but before final inspection by the removal contractor, nonaggressive and aggressive sampling methods were again used to determine asbestos in each room after the removal was completed.

Table 3-1 lists the survey dates and the dimensions of the rooms in which the asbestos abatement was performed and evaluated. The analyses of bulk samples taken from the pipe lagging indicated varying percentages of chrysotile (Table 3-1). No actinolite, tremolite, amosite, or anthophyllite asbestos were detected in these samples. Table 3-2 lists the number and types of pipe fittings and the linear feet of pipe from which lagging was removed at each site. The renovation included concurrent removal of ACM from other areas in the buildings at the time of these surveys. As can be determined by Table 3-2, the amount of pipe lagging removed from the rooms designated for study was roughly 10 to 40% of the total asbestos removal work performed in any one building. Personal and area samples of airborne asbestos were obtained during removal work in a third room in two buildings in order to increase the amount of data collected.

3.2. PROCESS DESCRIPTION

Asbestos removal is a complex and labor-intensive task which requires special knowledge, training, experience, and exceptional care to be performed safely. There is a need for careful planning and coordination of the activities involved. If an expert in asbestos removal is not available within the responsible organization, a competent consultant should be engaged to assure that the building owner, occupants, and removal workers are protected by a definitive and complete specification of work and that a reputable asbestos removal contractor is selected. On-site monitoring and control by a

TABLE 3-1. ASBESTOS-CONTAINING PIPE LAGGING REMOVAL STUDY

Facility	Survey Dates				Location	Dimensions (Feet)	Volume (Cubic Feet)	Bulk Sample Analysis	
	Walk-Through	Pre-Removal	Removal	Post-Removal				Chrysotile Asbestos	Cellulose/ Other fiber
#1	06/04	06/14	06/18-21	07/09	Room A	35 x 23 x 13.5	10,868	3-inch Pipe Lagging 1%	---
								2-inch Pipe Lagging 20-25%	---
					Room B	35 x 33 x 12.5	14,438		
					Room C	116 x 35 x 12.5	50,750	Pipe Lagging 30-35%	---
#2	06/04	06/12	06/25-28	07/11	Room D	33 x 22 x 15	10,890	Pipe Lagging 20-25%	---
					Room E	41 x 36 x 15	22,140		
#3	06/04	06/13	07/01-03	07/10	Room F	32 x 23 x 12	8,832	Airseal lagging 30-40%	40-50%
								Joint cement 10-15%	1-2%
					Room G	42 x 25 x 12	12,000	Pipe lagging 10-15%	1-2%
#4	06/04	07/12	07/15-17	07/18	Room H	29 x 25 x 11	7,975	Pipe lagging 5%	10-15%
					Room I	30 x 25 x 9	6,750	Pipe lagging 5-7%	2-3%
					Room J	29 x 24 x 11	7,656	Pipe lagging 20%	10-15%

TABLE 3-2. DESCRIPTION AND LINEAR FEET OF PIPE LAGGING REMOVED

Facility/ Room	Pipe Fittings: Ells No.	Pipe Fittings: Tees No.	Pipe Fittings: Flanges No.	Pipe Hangers No.	Pipe*/ Surfaces No.	Linear Feet Removed During Survey — Pipe Size: 6-in	5-in	4-in	3-in	2-in	1.5-in	Total Feet	Removal Contract**: Linear Feet	Number of Room/Areas
Facility #1														
Room A	15	5	-	7	7	-	-	-	45	53	-	98		
Room B	13	5	-	6	5	-	40	-	-	25	-	65		
Room C	10	5	-	7	4	-	-	91	9	25	-	125		
									Total			288	1800	15
Facility #2														
Room D	21	7	2	7	6	-	58	-	70	15	-	143		
Room E	9	4	1	3	6	45	-	-	12	2	-	59		
Room E***	13	4	1	5	6	30	-	-	45	2	-	77		
									Total			279	1230	13
Facility #3														
Room F	13	6	-	10	9	30	-	15	30	85	-	160		
Room G	18	6	-	4	8	45	-	15	9	-	-	69		
									Total			229	2350	12
Facility #4														
Room H	10	4	-	4	5	-	-	-	42	9	14	65		
Room I	10	5	-	4	9	-	30	-	50	28	5	113		
Room J	11	6	-	4	6	-	-	-	50	28	4	82		
									Total			260	710	10

* Intersections of pipe with walls or ceiling.

** Total linear feet of asbestos pipe lagging removed and number of areas cleaned in each facility.

*** Work completed by the removal crew prior to the post-removal study, but not observed by the survey team. In addition, approximately 27' of 6-inch pipe lagging was reportedly removed from a storage area adjacent to the original poly enclosure without the use of glove bag control techniques and while the poly barriers were open to the controlled area.

knowledgeable representative of the owner is also critical. These prerequisites should be provided prior to the start of the removal operations.

Typically, the removal work involves three phases: preparation, removal, and decontamination. A generic description of these activities is given below to provide an overview of industry practices; however, each abatement project will vary with the specific circumstances. A summary of the removal procedures observed at the four buildings surveyed in this study follows the generic description.

3.2.1. Generic Overview of an Asbestos Removal Activity

3.2.1.1. Preparation--

The site is cleaned, cleared of all movable materials, and isolated. Entrance and egress contamination control facilities are established: one with showers and change rooms for personnel; the other for waste material handling. All other access is sealed off by taping poly over windows, air vents, unused doors, etc. Surfaces, immovable furnishings, and structures not involved in the removal are covered and sealed with poly and the lighting fixtures are removed.

3.2.1.2. Removal--

The ACM are wetted (saturated, if possible) prior to and during their removal. Removal typically involves cutting, scraping, brushing, or other operations performed with hand tools to separate the ACM from the ceilings, beams, pipes, and other structures to which they were originally applied. The wet debris is collected, placed in sealed and properly labeled bags, and removed from the controlled area. Work is performed in small increments to avoid accumulation of waste. In order to contain the fibers and to prevent contaminating the outside air, the containment enclosure is maintained under "negative pressure," i.e., there is a net exhaust from the room or enclosure through HEPA filters to the outside of the building to provide a pressure differential. Air should be exhausted in sufficient quantity with the introduction of clean make-up air to achieve effective dilution. The airflow patterns within the enclosure should also be optimized to provide maximum benefit of the dilution air in reducing fiber concentration. The EPA recommends four air changes per hour;[9] however, some contractors use twice this amount. When large air volumes cannot be exhausted, a portion of the air which has passed through the HEPA filters is sometimes recirculated to the work area. Work should begin at the point furthest from the exhaust and proceed toward the exhaust. Local exhaust ventilation or vacuum pick-up may be used in the immediate proximity of the removal operation or other fiber release points. The workers inside the containment area must wear appropriate protective equipment, including approved respiratory protection and protective clothing.

3.2.1.3. Decontamination--

The asbestos fibers remaining after the removal operations must be removed from all surfaces and from the air. This usually requires several cycles of cleaning separated by sufficient time to allow the airborne fibers to settle. Some contractors include a "blowdown" similar to that used for "aggressive sampling" before the final cleaning procedure. These actions are combined with continuous air filtration in the containment area. All contaminated waste must be disposed of in accordance with EPA and local government regulations.

3.2.2. Asbestos Removal Practices Observed in this Study

For the present study, in which only asbestos pipe lagging was removed, glove bags were used as the primary control of asbestos release. Observations are summarized below. Based on these observations, many of the techniques delineated in Section 6 Recommendations should be considered.

3.2.2.1. Preparation--

The contract for asbestos removal in the buildings that were studied specified the use of glove bags as the primary emission control in lieu of total room containment and ventilation. It also required the installation of poly barriers in stairways and hallways to separate work areas from the rest of the building. Decontamination showers were not required. The floors beneath the pipes being abated were covered with poly to facilitate cleanup, except where concrete floors contained a floor drain. As noted previously, the rooms in which abatement clearance measurements were made were also enclosed in poly barriers, but neither exhaust nor make-up air was supplied to the enclosed areas.

Before starting the removal, the contractor enclosed all of the piping in an envelope fabricated from poly sheeting and duct tape. The surface of the lagging was misted with amended water (water containing wetting agents, penetrants, and/or other agents to enhance the wetting-down process) to control surface dust prior to enclosing it in the poly. A length of poly sheeting was brought up from underneath the pipe and draped over the pipe lagging. The two edges were rolled together and stapled at the top of the lagging to form a loose-fitting, cylindrical envelope around the pipe. Duct tape was used to seal the longitudinal seam and the ends of the envelope to the pipe lagging. Figure 3-1 shows two workers making an enclosure of poly around a pipe and a room ready for removal activity.

3.2.2.2. Removal--

Workers donned disposable work clothing and approved respirators before entering areas where the asbestos removal took place. Although the work crew in this study had had experience in the general removal of asbestos, they were not trained in the proper use of glove bags. During the first day of asbestos removal, the glove bags were hung at widely separated intervals and taped to the poly envelope over the pipe lagging with duct tape. The workers did not use the gloves in the bags, but rather used the bags as receptacles for collecting the debris. The top of the bag was left open and the workers reached in through the open top to cut away the poly envelope, loosen the lagging and allow it to drop into the bag. The bag was then moved along the pipe and the process was repeated. The lagging was wetted as it was removed from the pipe. Water sprayers (2- to 3-gallon, hand-pump garden sprayers) fitted with 30-inch hoses were elevated to the working level and were often hung from the pipes. This required workers on ladders and platforms to climb down periodically to refill the sprayer with amended water and pump up the pressure. The pipe was washed with water and rags, usually after the bag had been moved to the next location.

As the work progressed, the workers learned to better utilize the glove bags based on recommendations from the survey team, on trial and error, on

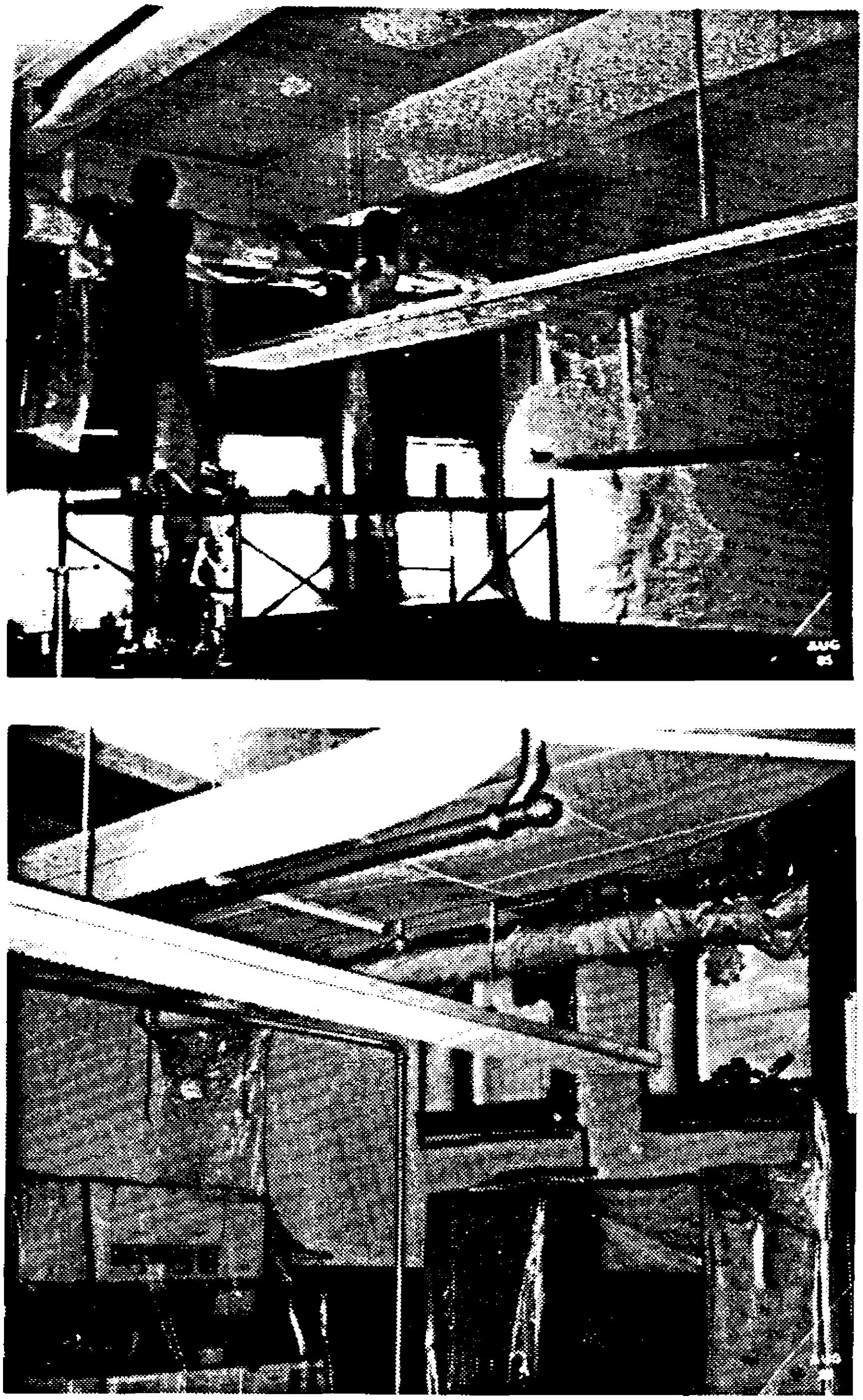


Figure 3-1. Preparation for Removal of Asbestos-Containing Pipe Lagging.

In the upper photograph workers are wrapping a pipe with polyethylene. The insulation had been previously misted with water to reduce the potential for generating dust. The lower photograph shows a room ready for removal operations to begin. Pipes and immovable objects are covered and windows and ducts are sealed with poly and duct tape. An empty glove bag is in place at the wall/pipe intersection at the left.

videotaped instructions,[38] and on training by a National Asbestos Council glove bag instructor.[39] Although the study was not designed to provide these instructions, it was the opinion of the NIOSH researchers that much improvement in work practices had been achieved by the end of the study. The following techniques were in general use by the end of the study, and the authors believe them to be appropriate work practices and procedures:

- Tools for cutting metal bands and lagging were placed inside the glove bag, and the bag was hung from the poly wrapped, lagged pipe. Depending on the type of bag, it was taped or zipped to form a seal along the length of pipe and the bag ends (sleeves) were taped or strapped to the poly-jacketed pipe. The workers preferred to use straps for sealing the bag ends.

- The poly-envelope and metal bands enclosed within the sealed bag were first cut and removed. Then the lagging was wetted, cut longitudinally along the full length of one preformed block, and circumferential cuts were made with a wire saw or blade, preferably at the block joints. The asbestos block was pried apart at the seam, rewetted, and dropped to the bottom of the bag. Amended water was sprayed onto the lagging and the bare pipe within the glove bag was washed clean with wet rags.

- Hard-to-clean places were brushed with a nylon-bristle bottle brush. All work was performed within the bag using the gloves (Figure 3-2). The end sleeve straps were loosened or the sleeves were untaped and the bag was slid along the poly-covered pipe to the next removal site (Figure 3-3).

- The spray nozzles and wands were inserted into the bags through special ports and sealed with duct tape if necessary. They were fitted with 10- to 15-foot hoses, so that the tanks did not have to be elevated to the working level. A support worker, at floor level, refilled the sprayer tank with amended water and pumped up the pressure. It greatly enhanced the ability and inclination of the removal workers to use sufficient wetting for control of fiber emissions.

- After sufficient debris had been collected, the interior surface of the bag was washed down; a HEPA-filtered vacuum system was used to evacuate air from the bag and a strap was used to cinch the bag closed prior to release of the seal and removal from the pipe. The bags were then resealed and then placed in a second bag on which asbestos warning labels were printed. The outer bag was also sealed and subsequently removed for disposal.

3.2.2.3. Decontamination--
Spilled material was removed from the floor with a HEPA-filtered vacuum cleaner throughout the shift. As work was completed in each area, the floor was wet mopped. The sealed bags of waste were removed from the enclosure prior to post-removal air sampling, but the poly seals on windows, vents, and doors were kept in place to minimize contamination from other areas and activities.

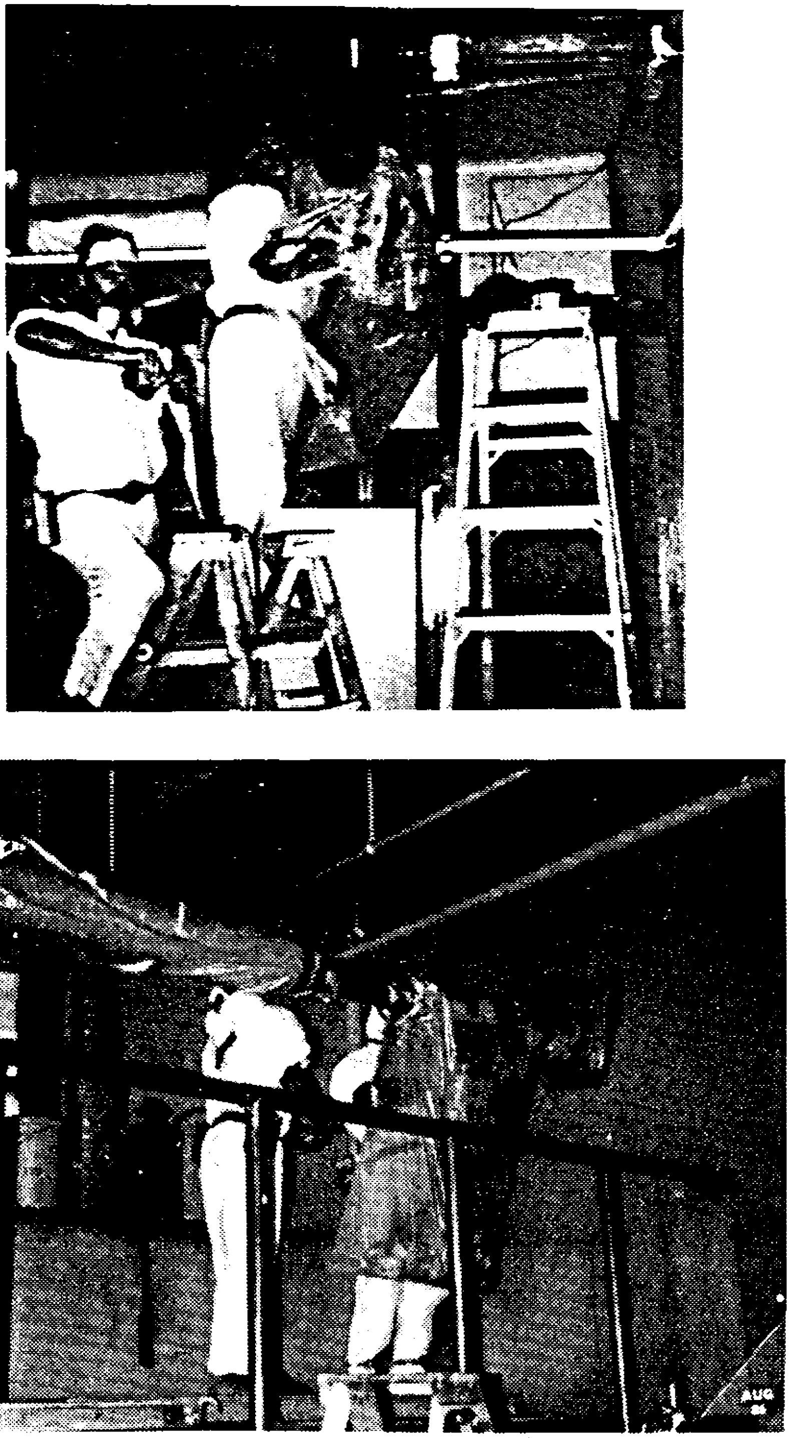


Figure 3-2. Working in a Glove Bag

The upper photograph shows two workers working on ladders. One worker has his hands inside the glove bag and is removing asbestos pipe lagging. The other worker is assisting by taping up a loose enclosure point. In the lower photograph workers are on a scaffold. The second worker is using a portable sprayer to wet down debris in the bag.

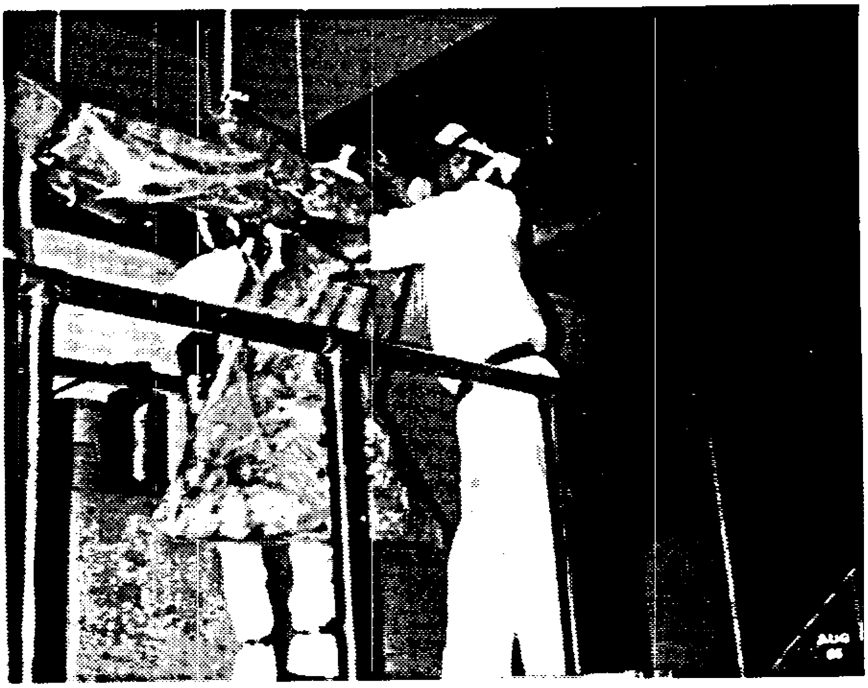


Figure 3-3. Moving a Glove Bag

This is a critical task. The inside walls of the bag and the debris contained have been washed down with water and the top of the bag opened to move it down the pipe. The photo shows the top untaped and the two workers are supporting its weight and maneuvering it over the next section of poly-wrapped pipe. Obstructions such as pipe hangers, pipe fittings, and valves make this a difficult task. Workers must use very good work practices to reduce the potential for fiber release.

4. METHODOLOGY

4.1. AIR SAMPLING STRATEGY

4.1.1. Overview

In order to characterize the effectiveness of containment by glove bags, personal breathing zone (PBZ) samples were collected on workers and area air samples were taken within the work enclosure. Area samples were also taken in adjoining hallways outside the work enclosure to determine the potential interaction with other removal activities occurring outside and within the controlled areas. Ambient samples were taken outside the building to establish background fiber concentrations. To assess the overall efficacy of the asbestos removal and cleanup operations, additional samples were taken prior to and following the completion of the removal work. Because of time constraints, the post-removal samples were collected after initial cleaning by the removal crew, but prior to the clearance testing performed by the contractor.

4.1.2. Personal Air Samples

PBZ samples were collected only while workers were actively engaged in site preparation, asbestos removal, and other associated activities including waste collection and disposal, decontamination, and equipment operation and maintenance. Normally, two sequential 2- to 3-hour personal samples were taken daily for each of the four workers to determine time-weighted-average exposures. In addition, six to eight 15-minute, short-term exposure samples were collected during the performance of work tasks. As a result, about 14 to 16 PBZ samples were collected during each 5- to 6-hour work shift.

4.1.3. Area Air Samples

Area samples were collected both inside and outside the controlled work area on approximately the same schedule as the personal samples. Two 2- to 3-hour interior samples were collected daily using a cart-mounted, mobile, sampling tree that was positioned proximate to the removal activity. These samples were located so as to provide an indication of the effectiveness of the source controls and the magnitude of exposure during different activities. A similar series of area samples was collected in the middle of the room, away from the workers, during the removal activity to determine the fiber concentration in the room during preparation and removal. Figure 4-1 is a photograph showing both the cart-mounted apparatus used to collect samples proximate to the work site and the stationary sampling tree used to obtain background samples of the general room contamination. Daily samples were collected in the hall adjacent to the survey area, and ambient samples were taken by drawing outside air through filters located in open windows well removed from the work area.

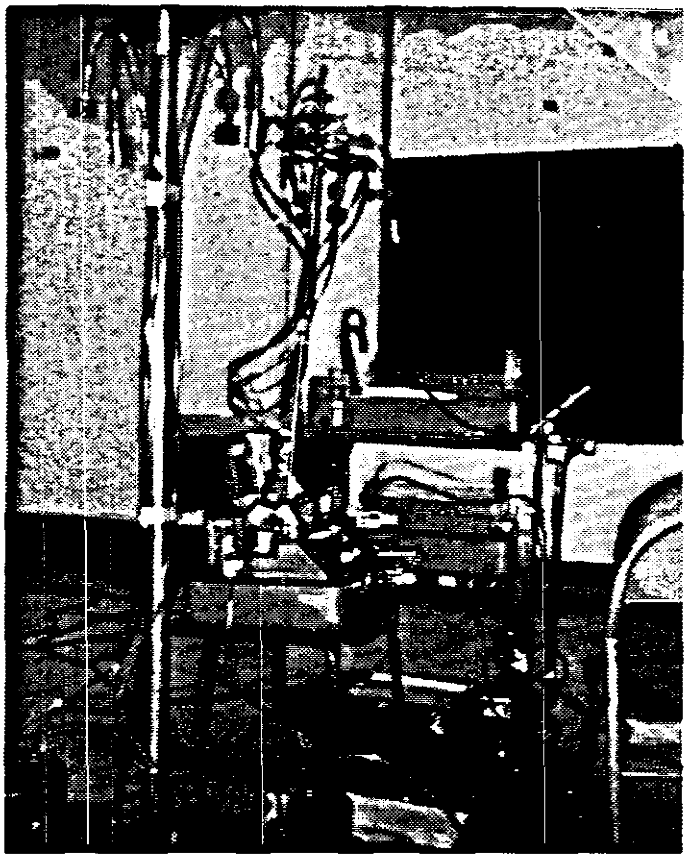


Figure 4-1. Area Sampling Equipment.

In the foreground is a sampling tree used for obtaining room background air samples at a point remote from the removal activity. A sampling tree mounted on a mobile cart, shown in the background, was used to obtain samples proximate to the work activity.

4.1.4. Direct-Reading Monitors

Direct-reading GCA Fibrous Aerosol Monitors (FAM), Model No. 1, were used to observe short-time fluctuations in fiber concentrations and to determine if a correlation existed between the work practices and exposure levels. One FAM (with a data logger for storing the output from the FAM) was positioned adjacent to the interior work area sample tree. This data logger recorded the background fiber count inside the enclosure at 1-minute intervals. Two cart-mounted, mobile FAMs were used to detect changes in fiber concentration every 10 minutes in the vicinity of the various work activities. The removal operations were also videotaped to assist in subsequent interpretation of the FAM readings.

4.1.5. Pre- and Post-Removal Air Sampling

To compare the two contamination assessment methods, both pre- and post-removal air samples were obtained by sampling for an 8-hour period in the nonaggressive mode, followed immediately by sampling for an 8-hour period in the aggressive mode. Nonaggressive (static) sampling was performed in a quiescent atmosphere, allowing at least 24 hours for the room to dry out when the sampling followed removal and cleaning. For aggressive (dynamic) sampling, dust and fibers were dislodged from surfaces during a 5- to 10-minute blowdown with a leaf blower; two oscillating pedestal fans were then operated to keep the dust and fibers suspended during the entire 8-hour sampling period. Two samples were collected adjacent to, but outside, the poly-baffled entrance to the room during both the nonaggressive and aggressive sampling periods. Two side-by-side outdoor ambient samples were collected throughout the 16-hour period in which these sampling methods were performed.

4.2. EVALUATION METHODS

4.2.1. Personal Sampling

The sequential 2- or 3-hour, PBZ samples were collected using DuPont P-4000 pumps at a measured flow rate between 2.5 and 3.5 lpm; each sample involved approximately 400 liters of air. The sampling device consisted of a 25 mm diameter three-piece cassette, in an open-face mode with a 50 mm extension cowl. The cassette contained a 0.8 μm pore size, cellulose ester filter, Type AA, and a backup pad, both manufactured by the Millipore Corporation. The cassettes were wrapped with metal foil, as a precaution to minimize possible localized effects of static electricity; conductive cowls were not available at that time.

4.2.2. Workplace Area Sampling

Duplicate area samples were taken using side-by-side 37 mm diameter polycarbonate and 25 mm diameter cellulose ester filters. The 25 mm sampling devices were the same as those described for personal sampling. The 37 mm sampling device consisted of a three-piece cassette using a 0.4 μm pore size polycarbonate filter with a 5.0 μm pore size cellulose ester backup filter and a supporting pad. The polycarbonate filters, manufactured by Nucleopore Corporation, were supplied by the EPA Manufacturing and Service

Industries Branch. During sampling, the cassette covers were removed to provide open-face sampling. DuPont P-4000 pumps, as described above, were used to collect these samples. The same sampling array and flow rate was also used to collect area samples adjacent to but outside the poly-baffled entrance to the room.

The ambient outdoor samples were collected at a measured flow rate between 2.0 and 3.5 lpm to obtain approximately 1,500 liter samples (ca. 8 hours).

4.2.3. Pre- and Post-Removal Air Sampling

Nine 8-hour samples were collected simultaneously using three different media: (1) 37 mm diameter, 0.4 μm pore size, polycarbonate filters followed by a 5.0 μm pore size, cellulose ester filter between the primary filter and the backup pad, (2) 37 mm diameter cellulose ester filters (0.8 μm pore size) with a backup pad, and (3) 25 mm diameter cellulose ester filters, as described under "Personal Sampling." All samples were collected in three-piece open-face cassettes. The 25 mm cassettes were wrapped with metal foil to minimize possible effects of static electricity. Six of the nine samples at each station were collected at a measured flow rate between 3.0 and 3.5 lpm, utilizing individual limiting orifices. The vacuum source for the nine samples was a manifold connected to a Gast 0485 vacuum pump in parallel with a smaller Thomas 106-83F pump. One sample of each filter type was also collected at each station using DuPont P-4000 pumps at a measured flow rate between 2.5 and 3.5 lpm. The sample cassettes were hung face down in alternated positions from a ring which was supported approximately 5 feet above the floor (Figure 4-1).

The outdoor ambient samples and the samples located in the corridor outside the surveyed rooms were collected on 25 mm cellulose ester filters for 8 to 16 hours to obtain approximately 1,500 to 3,000 liter samples.

4.2.4. Real-Time Fiber Monitoring

GCA Fibrous Aerosol Monitors (FAM), Model No. 1, were used to monitor variations of fiber concentrations during the work shift. Two units were placed near the removal operations to observe variations in fiber concentrations as a result of work practices; a third unit was used to monitor airborne fiber contamination in the removal area. Metrosonics Model No. 331 Data Loggers were utilized to record sequential FAM readings.

Air temperature and relative humidity were determined using an aspirated psychrometer.

4.3. ANALYSIS

4.3.1. Phase Contrast Microscopy

4.3.1.1. Manual--

The 25 mm cellulose ester filters were analyzed by PCM in accordance with NIOSH Method 7400.[14] All fibers with a 5:1 (or greater) length-to-width ratio were counted using the B counting rules. Analyses were performed by NIOSH in Cincinnati, OH and by UBTL Inc. (now Datachem) in Salt Lake City, UT.

4.3.1.2. Magiscan II--
A Magiscan II (M-II) image analysis system with asbestos fiber counting software was used to augment the PCM. The M-II system is attached to a standard phase contrast light microscope and an image of the particulates collected on the filter is displayed on a video monitor. A computer program produces a fiber count based on the aspect ratio and length.

4.3.2. Transmission Electron Microscopy

Polycarbonate filters were analyzed by the Yamate Revision to the EPA Provisional TEM Method.[19] All structures were identified and sized, and were categorized as individual fibers, fiber clusters, bundles, and clumps. The sum of all these categories was reported as the total asbestos structures. Selected area electron diffraction (SAED) was used to identify fibers as either amphiboles, chrysotile, or nonasbestos. When a diffraction pattern could not be evaluated, Energy Dispersive X-ray Analysis (EDXA) was performed to further assist in the identity of these structures.

The TEM analyses were performed by NIOSH scientists and personnel from PEI, Inc., using facilities in the NIOSH laboratory. Some analyses were performed in another laboratory, but they did not correlate well with the results from the NIOSH laboratory. Because the work performed in the NIOSH laboratory was carefully scrutinized and quality controlled, a number of these samples were reanalyzed in the NIOSH laboratory. All TEM sample results reported are from analyses made in the NIOSH laboratory.

Several cellulose ester filter samples which PCM analysis had indicated to contain high, medium, and low fiber were also analyzed in the NIOSH laboratory by TEM using the modified Burdett and Rood[40] or the NIOSH 7402 method.[20] All structures were identified in the same manner as that described above for the samples collected on polycarbonate.

5. RESULTS AND DISCUSSION

5.1. FIELD BLANKS AND LOWER LIMITS OF DETECTION

In Sections 1 and 2, some of the uncertainties of the analytical methods were discussed. In this section, further delineation of these issues and how they affected the interpretation of the analytical results is presented.

5.1.1. Phase Contrast Microscopy

Only one of 74 field blanks analyzed by PCM was above the limit of detection (LOD); thus, no correction for fiber contamination of the cellulose ester filters was necessary. The estimated LOD for Method 7400 is 7 fibers/mm^2 of filter area.[14-17] This is equivalent to about 1,500 fibers per filter for 25 mm diameter filters and 3,500 fibers per filter for 37 mm diameter filters; thus, for a 1,500 liter sample, the LOD is 1,000 and 2,000 f/m^3, respectively. When sample results were reported to be "less than the detection limit," a value of one-half of the LOD was used for statistical computations.

5.1.2. Transmission Electron Microscopy

As discussed in Section 2.2, two problems affecting the validity of TEM analyses were identified by the EPA: high interlaboratory variability of analytical results and asbestos contamination of the polycarbonate sampling media during manufacture. Both of these problems were encountered in the present study. First, analysis of samples obtained from two of the buildings surveyed and analyzed in the EPA laboratory were reported to have very low fiber counts and many were reported nondetectable. When reanalyzed in the NIOSH laboratory, substantial numbers of fibers were found. Second, the analyses of the blank polycarbonate filters from this study exhibited the same range of asbestos contamination as did the polycarbonate filters supplied by the EPA to other laboratories (illustrated in Figure 1). To overcome this difficulty and to reduce the cost of analyses, the EPA has assumed that for clearance purposes the contamination level of the filter media is 70 f/mm^2. A 37 mm filter has an effective collection area of 855 mm^2; therefore, for the contamination level assumed, about 60,000 fibers per filter, the LOD for a 3,000 liter sample is 20,000 f/m^3.

5.2. CONFIDENCE LIMITS

5.2.1. Phase Contrast Microscopy

For PCM fiber analysis, the coefficient of variation, CV (also known as the relative standard deviation, RSD), has two components. One component of the CV for counting randomly (Poisson) distributed fibers on a filter surface is a function of the number of fibers counted. This is related to the sample loading (the number of fibers on the filter) and, hence, the CV may differ for each sample collected. The other component of the CV, termed the subjective component of variability, is a function of differences in the counts of the analyst(s) due to the amount of training and experience of the microscopist, differences in microscope equipment, and quality assurance practices.

The two laboratories used in this study showed a PCM analysis correlation coefficient of 0.91 and an interlaboratory coefficient of variation of 0.41 was demonstrated based on a 25-sample comparison. Additional discussion of interlaboratory comparability is included in NIOSH method 7400.[17] Because of the wide variation of interlaboratory results and in the absence of a known CV between laboratories, a value of 0.45 is used in this method for the subjective component of variability. A graph is included in the method to illustrate the interlaboratory precision of fiber counts, whereby a 90% confidence interval on the mean count can be estimated from a single sample fiber count. Immediately preceding the graph, it is stated that ". . . a further approximation is to simply use +213% and -49% as the upper and lower confidence values of the mean for a 100 fiber count." These percentages can be applied directly to the air concentrations as well.

Table 5-1 was prepared to demonstrate the range of upper and lower 90% confidence limits which would be expected if a group of laboratories having an interlaboratory CV of 0.45 analyzed identical samples. The table shows the confidence limits for a 10 grid or 100 fiber count. (Part A of Table 5-1 is for use with 25 mm filters and Part B is for 37 mm filters.) Because the range varies with the number of fibers counted and the sample volume, computations were also made for several fiber counts using the three sample volumes that are relevant to the present study: 400 liters, the approximate volume collected for personal samples; 1,500 liters, for pre- and post-removal and daily ambient samples; and 2,500 liters, for ambient samples. These tables may be used to approximate the range of values to be applied with 90% confidence when interpreting the results of individual samples analyzed by the same laboratory with respect to an occupational exposure or clearance standard.

5.2.2. Transmission Electron Microscopy

An intralaboratory CV of 0.35 was calculated for the fiber analysis by TEM used in this study. In general, there is insufficient experience with TEM to fully establish interlaboratory confidence limits. EPA has reported results of similar studies which indicate an overall CV of about 1.5 with an analytical component of about 1.0.[33] The assumptions used in the preparation of the range of PCM confidence limits presented in Table 5-1 may not hold for the greater variability associated with TEM. To provide some insight as to how a CV of 1.5 affects the 90% confidence limits, it is assumed, for the purpose of illustration, that the (natural) logarithm of the asbestos counts as determined by TEM is normally distributed. If this is the case, then the approximate 90% confidence limit for a true mean count of 1,250,000 f/m^3 by TEM on a 37 mm filter would be 378,000 to 13,500,000 f/m^3. As seen in Table 5-1, the corresponding interval for a 1,250,000 f/m^3 PCM count on a 37 mm filter is 638,000 to 3,913,000 f/m^3. These intervals are an indication of the uncertainty that can arise when interpreting the result of a single field sample with respect to an exposure or clearance standard.

TABLE 5-1. 90% CONFIDENCE LIMITS FOR A SINGLE PCM ANALYSIS BY NIOSH METHOD 7400-B
(ASSUMING AN INTERLABORATORY SUBJECTIVE COMPONENT OF .45)

Fibers counted/ 100 grids	Fibers per Filter	Factor for: Lower Limit	Factor for: Upper Limit	Mean and (Range) of Fiber Concentrations (f/m^3) within 90% Confidence Limits for Sample Volumes: 400 liters	1500 liters	2500 liters
A. LIMITS FOR 25-mm CELLULOSE ESTER FILTERS						
*	500,500	0.51	3.13	1,251,000 (638,000 - 3,916,000)	334,000 (170,000 - 1,045,000)	200,000 (102,000 - 626,000)
100	49,045	0.51	3.13	123,000 (63,000 - 385,000)	33,000 (17,000 - 103,000)	20,000 (10,000 - 63,000)
50	24,522	0.51	3.18	61,000 (31,000 - 194,000)	16,000 (8,000 - 51,000)	10,000 (5,000 - 32,000)
10	4,904	0.43	3.57	12,000 (5,000 - 43,000)	3,000 (1,000 - 11,000)	2,000 (1,000 - 7,000)
7 (NIOSH LOD)	3,433	0.40	3.78	9,000 (4,000 - 34,000)	2,000 (1,000 - 8,000)	1,000 (0 - 4,000)
3 (UBTL LOD)	1,471	0.31	4.66	4,000 (1,000 - 19,000)	1,000 (0 - 5,000)	1,000 (0 - 5,000)
B. LIMITS FOR 37-mm CELLULOSE ESTER FILTERS						
*	1,111,500	0.51	3.13	2,779,000 (1,417,000 - 8,698,000)	741,000 (378,000 - 2,319,000)	445,000 (227,000 - 1,393,000)
460	500,000	0.51	3.13	1,250,000 (638,000 - 3,913,000)	333,000 (170,000 - 1,042,000)	200,000 (102,000 - 626,000)
100	108,917	0.51	3.13	272,000 (139,000 - 851,000)	73,000 (37,000 - 228,000)	44,000 (22,000 - 138,000)
50	54,459	0.51	3.18	136,000 (69,000 - 432,000)	36,000 (18,000 - 114,000)	22,000 (11,000 - 70,000)
10	10,892	0.43	3.57	27,000 (12,000 - 96,000)	7,000 (3,000 - 25,000)	4,000 (2,000 - 14,000)
7 (NIOSH LOD)	7,624	0.40	3.78	19,000 (8,000 - 72,000)	5,000 (2,000 - 19,000)	3,000 (1,000 - 11,000)
3 (UBTL LOD)	3,268	0.31	4.66	8,000 (2,000 - 37,000)	2,000 (1,000 - 9,000)	1,000 (0 - 5,000)

* Maximum Allowed Loading = 1300 fibers/sq mm.

5.3. SAMPLING RESULTS

Subsequent tables summarize data from the four survey reports.[1-4] Appendix A consists of the tables included in each of the facility reports. The tables in Appendix A are based on analytical data obtained by PCM and Magiscan II, tabulated in Appendix B, and by TEM, tabulated in Appendix C.

5.3.1. Work Activity Samples

Although this study was not undertaken to determine compliance with asbestos standards, the OSHA PEL (200,000 f/m^3) and the NIOSH REL (100,000 f/m^3) concentrations are used in the following discussion as points of reference.

5.3.1.1. Personal Samples--

Daily time-weighted-average (TWA) asbestos concentrations for each worker at each facility are shown in Table 5-2. The TWA values reported are the sum of two sequential samples (morning and afternoon of the same day) averaged over the total time of the sampling periods (approximately 5 to 6 hours):

$$TWA = (C_{am} \times T_{am} + C_{pm} \times T_{pm}) \;/\; (T_{am} + T_{pm}); \quad C = \text{Concentration},\ T = \text{Time}.$$

If one or both of the daily samples were overloaded with particulates so that the fibers could not be counted, the TWA exposures were not calculated. The normal workday consisted of one half-shift (morning) of preparation and one half-shift (afternoon) of removal activities. However, on 4 days (6/20, 6/26, 6/28, and 7/2) both shifts were spent in removal activities and on 4 other days (6/21, 7/3, 7/16, and 7/17) the crew only worked a half shift doing removal activities. As would be expected, the TWA concentrations appear to be somewhat higher on these days (except at Facility 1 on 6/21). Figure 5-1 illustrates the range of the TWA exposures, whereas Figure 5-2 illustrates exposures due to preparation and removal activities, separately.

Included in Table 5-2 are daily area sampling results calculated as a TWA in the same manner as the personal samples. The "Prox" samples were taken proximate to the work activity; the "Dist" samples were taken in the middle of the room at a distance from the work activity. The average concentrations of the personal samples and both types of area samples on any given day are not statistically different (at the 5% significance level), although the actual personal sample measurements are usually somewhat higher.

The upper confidence limits for the PBZ samples were below the 2.0 f/cc (2,000,000 f/m^3) OSHA PEL in effect at the time of this study. However, only exposures which occurred in Facility 4 were below the current PEL of 0.2 f/cc (200,000 f/m^3). The average TWA exposure over the 3 or 4 days worked in each facility are shown in Table 5-3. Of the 45 daily TWA exposures, 3 (7%) were in excess of 626,000 f/m^3, 17 (38%) were in excess of 313,000 f/m^3, and 27 (60%) were in excess of 200,000 f/m^3; only 13 (29%) were less than 100,000 f/m^3.

Table 5-4 shows the average fiber concentrations, as analyzed by PCM, for each room during the preparation activities. These concentrations averaged about 20,000 f/m^3. As shown in Table 5-5, fiber concentrations during removal

TABLE 5-2. DAILY TWA SAMPLES DURING ASBESTOS ABATEMENT

Date/ Activity	Worker	Concentration (f/m^3) TWA*	Prox+	Dist#	Date/ Activity	Worker	Concentration (f/m^3) TWA*	Prox+	Dist#
Facility 1					**Facility 2**				
6/18	A	250,000			6/25	A	30,000		
Half Shift	B	-			Half Shift	B	340,000		
Preparation	C	-			Preparation	C	220,000		
Half Shift	D	210,000			Half Shift	D	-		
Removal	Avg	230,000	190,000	220,000	Removal	Avg	200,000	270,000	310,000
6/19	A	300,000			6/26	A	-		
Half Shift	B	100,000			Full Shift	B	350,000		
Preparation	C	250,000			Removal	C	-		
Half Shift	D	320,000				D	290,000		
Removal	Avg	240,000	240,000	240,000		Avg	320,000	140,000	170,000
6/20	A	470,000			6/27	A	-		
Full Shift	B	330,000			Half Shift	B	-		
Removal	C	490,000			Preparation	C	310,000		
	D	310,000			Half Shift	D	-		
	Avg	400,000	270,000	260,000	Removal	Avg	310,000	200,000	-
6/21	A	170,000			6/28	A	250,000		
Half Shift	B	120,000			Full Shift	B	200,000		
Removal	C	120,000			Removal	C	350,000		
	D	150,000				D	-		
	Avg	140,000	110,000	110,000		Avg	270,000	170,000	180,000
Facility 3					**Facility 4**				
7/1	A	350,000			7/15	A	11,000		
Half Shift	B	300,000			Half Shift	B	10,000		
Preparation	C	340,000			Preparation	C	3,000		
Half Shift	D	160,000			Half Shift	D	13,000		
Removal	Avg	290,000	230,000	220,000	Removal	Avg	9,000	7,000	8,000
7/2	A	550,000			7/16	A	15,000		
Full Shift	B	560,000			Half Shift	B	13,000		
Removal	C	660,000			Removal	C	-		
	D	640,000				D	-		
	Avg	600,000	620,000	630,000		Avg	14,000	13,000	32,000
7/3	A	800,000			7/17	A	9,000		
Half Shift	B	410,000			Half Shift	B	5,000		
Removal	C	480,000			Removal	C	8,000		
	D	610,000				D	10,000		
	Avg	570,000	620,000	550,000		Avg	8,000	4,000	9,000

* Time-Weighted Average over actual working time = 4 to 6 hours.
+ Average of area samples taken proximate to removal operations.
\# Average of area samples taken in the room but at a distance from operations

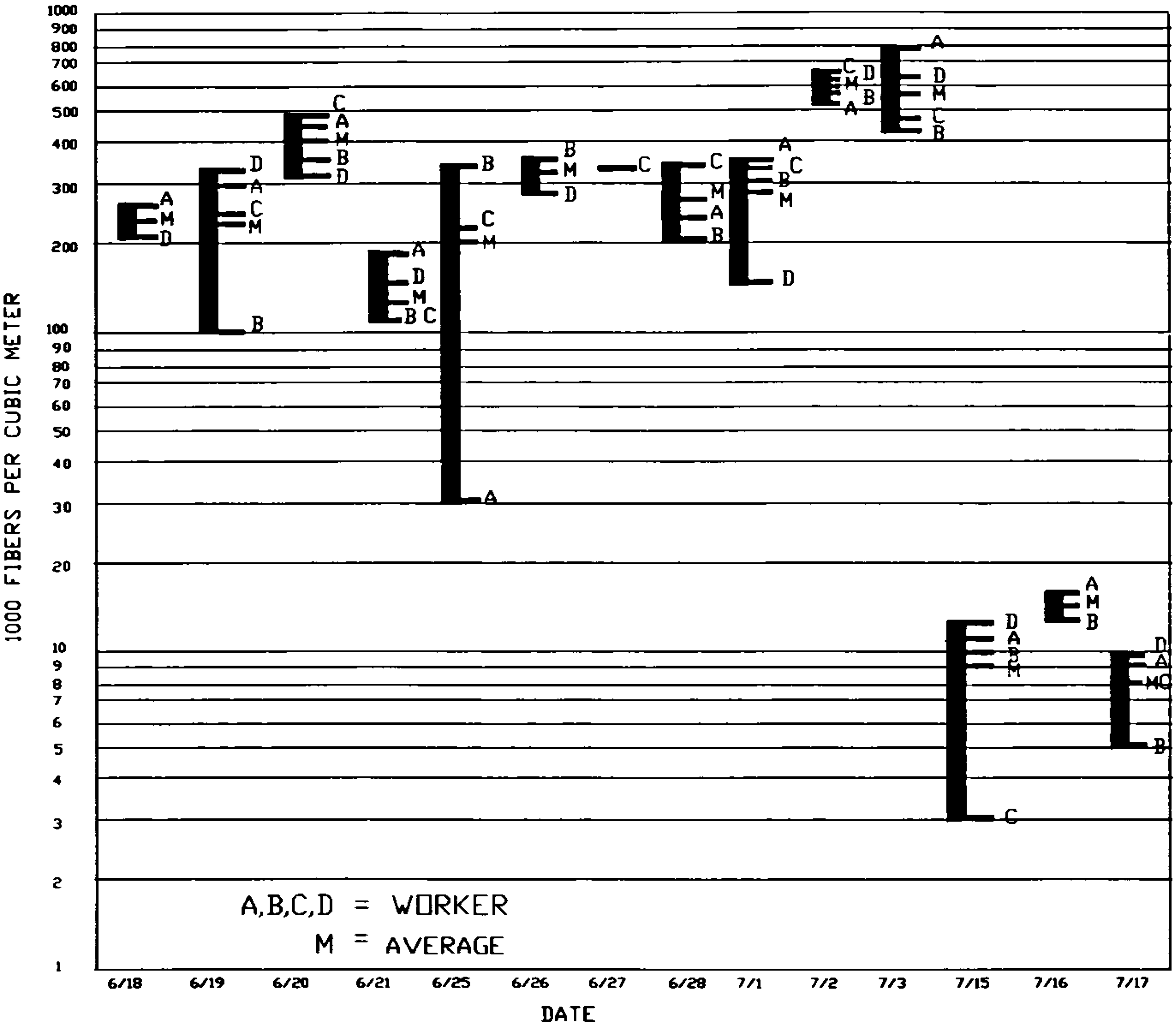


FIGURE 5-1. TWA PERSONAL SAMPLES DURING ASBESTOS ABATEMENT

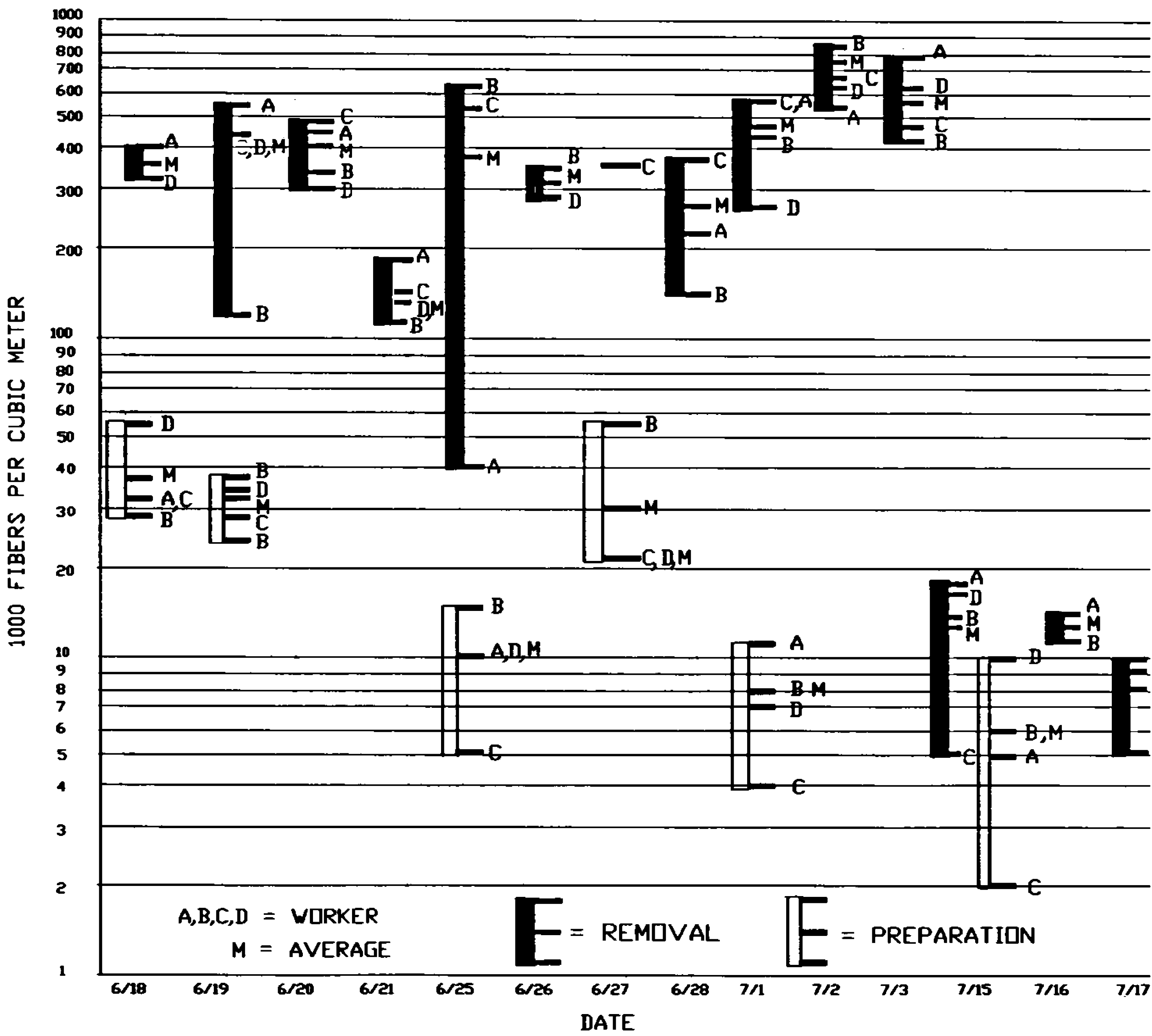


FIGURE 5-2. PERSONAL EXPOSURE DURING PREPARATION AND REMOV
OF ASBESTOS-CONTAINING PIPE LAGGING

TABLE 5-3. AVERAGE TWA* PERSONAL SAMPLES DURING ASBESTOS ABATEMENT

Worker	Concentration (f/m^3) Average	Concentration (f/m^3) Range	Total Samples	Number of Samples Having Concentration (f/m^3) Greater Than 626,000	313,000	200,000	100,000
Facility 1							
A	300,000	170,000 - 470,000	4	0	1	3	4
B	180,000	100,000 - 330,000	3	0	1	1	2
C	290,000	120,000 - 490,000	3	0	1	2	3
D	250,000	150,000 - 320,000	4	0	1	3	3
Facility	260,000	100,000 - 490,000	14	0	4	9	12
Facility 2							
A	140,000	20,000 - 250,000	2	0	0	1	1
B	290,000	200,000 - 350,000	3	0	2	2	3
C	300,000	220,000 - 350,000	3	0	1	3	3
D	290,000	290,000	1	0	0	1	1
Facility	260,000	20,000 - 350,000	9	0	3	7	8
Facility 3							
A	560,000	350,000 - 800,000	3	1	3	3	3
B	420,000	300,000 - 560,000	3	0	2	3	3
C	490,000	340,000 - 660,000	3	1	3	3	3
D	470,000	160,000 - 640,000	3	1	2	2	3
Facility	490,000	160,000 - 800,000	12	3	10	11	12
Facility 4							
A	12,000	9,000 - 15,000	3	0	0	0	0
B	9,000	5,000 - 15,000	3	0	0	0	0
C	6,000	3,000 - 8,000	2	0	0	0	0
D	12,000	10,000 - 13,000	2	0	0	0	0
Facility	10,000	3,000 - 15,000	10	0	0	0	0
Overall							
Average	250,000						
Range		3,000 - 800,000					
Total			45	3	17	27	32

* Time-Weighted Average over actual working time = 4 to 6 hours.

TABLE 5-4. SUMMARY OF SAMPLING RESULTS DURING PREPARATION FOR PIPE LAGGING REMOVAL

Facility/ Location	Samples Type	Number	Concentration (f/m^3) Average	Minimum	Maximum
1/Room A	Personal	4	33,000	26,000	37,000
	Personal - Short Term	1	30,000		
	Area - Proximate	2	19,000	9,000	29,000
	Area - Distant	2	13,000	9,000	17,000
1/Room B	Personal	4	37,000	29,000	54,000
	Personal - Short Term	0			
	Area - Proximate	4	30,000	23,000	40,000
	Area - Distant	2	20,000		
1/Room C was prepared by a different work crew.					
2/Room D	Personal	4	10,000	5,000	16,000
	Personal - Short Term	3	20,000	17,000	25,000
	Area - Proximate	2	12,000	11,000	14,000
	Area - Distant	2	14,000	13,000	16,000
2/Room E	Personal	4	30,000	22,000	54,000
	Personal - Short Term	4	39,000	33,000	45,000
	Area - Proximate	2	23,000	23,000	23,000
	Area - Distant	2	16,000	12,000	19,000
3/Room F	Personal	4	8,000	4,000	11,000
	Personal - Short Term	2	17,000	16,000	17,000
	Area - Proximate	2	4,000	3,000	4,000
	Area - Distant	2	6,000	4,000	8,000
3/Room G was prepared by a different work crew.					
4/Room H+I	Personal	4	6,000	2,000	10,000
4/Room I	Personal - Short Term	4	9,000	2,000	16,000
4/Room H	Area - Proximate	2	7,000	6,000	8,000
4/Room H	Area - Distant	2	8,000	3,000	13,000

TABLE 5-5. SUMMARY OF SAMPLING RESULTS DURING PIPE LAGGING REMOVAL

Facility/ Location	Samples Type	Samples Number	Concentration (f/m^3) Average	Concentration (f/m^3) Minimum	Concentration (f/m^3) Maximum	Concentration (f/m^3) STD
1/Room A	Personal	8	430,000	120,000	640,000	160,000
	Personal - Short Term	8	000,000	520,000	1,190,000	220,000
	Area - Proximate	4	410,000	280,000	490,000	90,000
	Area - Distant	4	470,000	360,000	590,000	140,000
1/Room B	Personal	2	360,000	320,800	400,000	
	Personal - Short Term	0				
	Area - Proximate	2	360,000	310,000	410,000	
	Area - Distant	2	410,000	380,000	440,000	
1/Room C	Personal	8	800,000	120,000	530,000	150,000
	Personal - Short Term	7	470,000	140,000	1,120,000	330,000
	Area - Proximate	4	150,000	180,000	800,000	50,000
	Area - Distant	4	160,000	90,000	230,000	60,000
2/Room D	Personal	10	330,000	43,000	610,000	170,000
	Personal - Short Term	16	790,000	190,000	2,920,000	680,000
	Area - Proximate	8	300,000	80,000	590,000	180,000
	Area - Distant	7	280,000	30,000	770,000	250,000
2/Room E	Personal	7	270,000	60,000	450,000	130,000
	Personal - Short Term	7	540,000	70,000	1,930,000	640,000
	Area - Proximate	4	170,000	90,000	330,000	120,000
	Area - Distant	4	180,000	90,000	340,000	120,000
3/Room F	Personal	8	470,000	170,000	1,030,000	230,000
	Personal - Short Term	9	960,000	160,000	2,440,000	640,000
	Area - Proximate	6	450,000	20,000	940,000	350,000
	Area - Distant	6	440,000	260,000	560,000	120,000
3/Room G	Personal	12	670,000	280,000	1,410,000	340,000
	Personal - Short Term	8	2,660,000	620,000	9,290,000	2,830,000
	Area - Proximate	4	710,000	570,000	960,800	120,000
	Area - Distant	4	670,000	470,000	820,000	150,000
4/Room H	Personal	4	14,000	5,000	18,000	6,000
	Personal - Short Term	5	31,000	22,000	43,000	9,000
	Area - Proximate	2	7,000	6,000	8,000	
	Area - Distant	2	7,000	5,000	8,000	
4/Room I	Personal	2	14,000	13,000	15,000	
	Personal - Short Term	4	92,000	16,000	000,000	77,000
	Area - Proximate	1	13,000			
	Area - Distant	2	32,000	13,000	51,000	
4/Room J	Personal	6	10,000	1,000	23,000	8,000
	Personal - Short Term	6	24,000	16,000	44,000	12,000
	Area - Proximate	4	4,000	1,000	7,000	3,000
	Area - Distant	4	6,000	2,000	11,000	4,000

operations averaged about 350,000 f/m^3 and were an order-of-magnitude greater than exposures observed during preparation, except in Facility 4.

Results from the 15-minute, short-term samples are also shown in Tables 5-4 and 5-5. Of the 70 short-term samples reported in Table 5-5, 15 (21%) exceeded 1,000,000 f/m^3. The highest exposure exceeded 9,000,000 f/m^3. This occurred during the second day at Facility 3 when a 10-foot section of lagging suddenly separated from the pipe and fell into the poly envelope. A worker cut the envelope to reach in and push large pieces of lagging into the glove bag at the end of the envelope. Although this action was quickly curtailed and the envelope was resealed with tape, the personal exposures were undoubtedly elevated by this episode. Exposures would certainly have been even higher had the lagging fallen to the floor and shattered.

All of the above fiber concentrations were determined by PCM. In order to provide a comparison with TEM analyses, 16 PBZ samples collected on cellulose ester filters in Facility 1 were analyzed by both PCM and by TEM. These were selected to include two sequential daily samples for each worker and also to provide a variety of high to low concentrations as determined by PCM; the results are compared in Table 5-6. The TEM analyses reported for total asbestos structures indicate levels an order-of-magnitude higher than for the fibers reported when the same samples were analyzed by PCM. The sample collected on 6/18 for Worker B, erroneously reported to be <LOD, was later found to be actually obscured by particulate so that the fibers could not be counted by PCM. Particulate did not obscure asbestos structures for the TEM analysis because of the greater power of resolution.

5.3.1.2. Area Samples--

As stated previously, the results of area samples analyzed by PCM indicated fiber concentrations of the same magnitude as the PBZ samples collected during removal; this is shown in Tables 5-2 and 5-5.

The fiber concentration measured by the area samples taken in the corridors adjacent to the poly-baffled door openings varied greatly in relation to the interior area samples (Appendix A, Tables 3A-1 through 4A-4). The frequency of entry and exit through the baffles should affect these sampling locations. In addition, activities including asbestos removal were taking place in other parts of the building. However, with one exception, all were lower (from 5% to 67%) than concentrations measured within the rooms during asbestos removal operations, indicating that the poly baffles were fairly effective in controlling the escape of airborne fibers released in the survey rooms. Twenty four of twenty eight ambient samples taken outside the buildings were below the LOD (1,000 to 2,000 f/m^3).

5.3.1.3. Discussion of Work Activity Exposure Results

Data shown in Tables 5-2 through 5-5 indicate that during the preparation (covering) of the pipe lagging workers were exposed to relatively low concentrations of airborne asbestos. In the rooms included in this survey, most of the pipe lagging was in good condition. In other situations, where lagging is deteriorated or damaged, it is quite probable that higher concentrations of airborne asbestos would be encountered during these operations.

TABLE 5-6. TWA* CONCENTRATIONS CALCULATED FROM TEM AND PCM ANALYSES

Worker	Date	Activity	TEM Analysis: Structures (s/m^3) Total	TEM Analysis: Structures (s/m^3) Asbestos	TEM Analysis: Fibers (f/m^3) Total	TEM Analysis: Fibers (f/m^3) Asbestos	PCM Analysis: Fibers (f/m^3)
A	6/19	Preparation	10,000	10,000	10,000	10,000	26,000
	6/19	Removal	6,850,000	1,830,000	4,110,000	720,000	550,000
	TWA		3,570,000	960,000	2,140,000	380,000	470,000
	6/21	Removal	3,750,000	1,910,000	2,100,000	560,000	170,000
B	6/18	Preparation	370,000	250,000	290,000	180,000	29,000
	6/18	Removal	4,920,000	3,600,000	2,040,000	1,020,000	----
	TWA		3,040,000	2,220,000	1,320,000	670,000	----
	6/19	Preparation	0	0	0	0	37,000
	6/19	Removal	4,370,000	2,170,000	2,560,000	550,000	120,000
	TWA		3,130,000	1,550,000	1,830,000	400,000	100,000
	6/20	Removal	3,360,000	1,840,000	2,310,000	890,000	360,000
	6/20	Removal	4,540,000	2,340,000	2,480,000	570,000	300,000
	TWA		4,000,000	2,110,00	2,400,000	710,000	330,000
C	6/20	Removal	6,550,000	2,900,000	4,530,000	1,320,000	550,000
	6/20	Removal	5,670,000	4,040,000	3,310,000	1,890,000	430,000
	TWA		6,070,000	3,520,000	3,860,000	1,630,000	490,000
	6/21	Removal	3,780,000	2,270,000	2,460,000	1,210,000	120,000
D	6/18	Preparation	1,270,000	50,000	1,140,000	10,000	54,000
	6/18	Removal	5,080,000	2,870,000	3,340,000	1,220,000	320,000
	TWA		3,510,000	1,710,000	2,430,000	720,000	210,000
	6/20	Removal	4,250,000	2,590,000	2,050,000	660,000	320,000
	6/20	Removal	4,140,000	2,110,000	2,660,000	930,000	290,000
	TWA		4,190,000	2,330,000	2,370,000	800,000	310,000

* Time-Weighted Average over actual working time = 4 to 6 hours.

As described in Section 3.2.2.2., poor work practices were used by the workers at the beginning of the survey. The survey team attempted to instruct the workers in proper techniques the first week. During the second week, the workers were shown a training video, and proper techniques to be used in removing asbestos pipe lagging in glove bags were demonstrated by an instructor from the National Asbestos Council. The workers were observed to adopt many of the demonstrated techniques at the third facility, but the accident described above quite likely increased exposure levels. The high short-time exposure measured (greater than 9,000,000 f/m^3) would take some time to dissipate in the sealed room, thereby increasing the TWA exposures. Removal at the last facility was observed to be performed by the application of most of the proper techniques demonstrated by the instructor most of the time.

Sampling results shown in Table 5-5 indicate that fiber concentrations were in the same range for Rooms A through F when lagging was being removed. Average personal exposures in Rooms A and F were about 400,000 f/m^3 during these activities; Room G exhibited the highest concentrations (average 850,000 f/m^3) which were probably caused by the accidental release. Rooms H, I, and J in Facility 4 were all well below 100,000 f/m^3. Fiber concentrations in this facility were significantly lower ($p = 0.05$) than the other facilities.

Although factors such as a different type of lagging (e.g., lower asbestos content, less friable), improved cleanliness of the site before removal, etc., could have influenced the results, it was the opinion of the research team that these conditions were about equivalent in all of the facilities. The low exposure concentrations measured in Facility 4 may have occurred as result of changes in work practice that were observed during the removal of the pipe lagging. The present study did not permit a clear association between work practice and exposure level, however, due to the small number of sites that were studied.

5.3.2. Environmental Sampling

A comparison of pre- and post-removal sampling by both aggressive and nonaggressive procedures was made for two rooms in each of the four facilities. For each comparison, samples were taken using three 25 mm diameter cellulose ester filters, three 37 mm cellulose ester filters, and three 37 mm polycarbonate filters. The cellulose ester filters were analyzed using PCM; approximately 60% at UBTL and 40% in the NIOSH laboratory. About 15% of these samples were split and analyzed by both laboratories. The arithmetic mean of the NIOSH results was about 1.5 times that of the UBTL results, but this difference is not surprising in view of the interlaboratory CV of 0.45.

The post-removal samples were collected after the room had been cleaned, but before the visual inspection and final clearance sampling by the contractor. The results shown in Table 5-7 are the arithmetic means for the PCM samples broken down by location, sampling method, filter type, and pre- or post-removal status. A separate tabulation also groups the samples by facility. Much higher fiber concentrations were obtained by aggressive sampling than by nonaggressive sampling. Of 109 nonaggressive samples, 44 (48.6%) were at levels greater than 1,000 f/m^3. Of the 111 aggressive samples, 97 (87.4%) were greater than 1,000 f/m^3. The aggressive sampling data indicate that

TABLE 5-7. AVERAGE ASBESTOS CONTAMINATION IN ROOMS AND FACILITIES (PCM ANALYSES)

		Non-Aggressive Sampling						Aggressive Sampling					
ROOM	Sampling Conditions	25-mm Filter f/m^3	n	37-mm Filter f/m^3	n	Average f/m^3	n	25-mm Filter f/m^3	n	37-mm Filter f/m^3	n	Average f/m^3	n
A	Pre-Removal	2,000	3	2,000	3	2,000	6	12,000	3	31,000	5	23,000	8
	Post-Removal	4,000	3	3,000	3	4,000	6	14,000	3	20,000	3	17,000	6
B	Pre-Removal	9,000	6	6,000	3	8,000	9	20,000	5	29,000	5	24,000	10
	Post-Removal	3,000	3	11,000	3	7,000	6	42,000	3	27,000	3	35,000	6
D	Pre-Removal	1,000	3	1,000	3	1,000	6	2,000	3	1,000	3	2,000	6
	Post-Removal	2,000	4	1,000	3	2,000	7	11,000	5	19,000	6	15,000	11
E	Pre-Removal	2,000	3	1,000	3	2,000	6	11,000	3	22,000	3	17,000	6
	Post-Removal	3,000	4	4,000	5	4,000	9	22,000	3	53,000	6	43,000	9
F	Pre-Removal	1,000	3	2,000	3	2,000	6	3,000	2	12,000	3	8,000	5
	Post-Removal	1,000	3	1,000	3	1,000	6	15,000	3	25,000	3	20,000	6
G	Pre-Removal	1,000	3	5,000	3	3,000	6	51,000	3	100,000	3	76,000	6
	Post-Removal	1,000	3	1,000	3	1,000	6	1,000	3	3,000	3	2,000	6
H	Pre-Removal	1,000	3	2,000	3	1,000	6	3,000	3	6,000	3	4,000	6
	Post-Removal	2,000	4	3,000	5	2,000	9	2,000	4	2,000	3	2,000	7
I	Pre-Removal	2,000	3	1,000	3	2,000	6	6,000	3	17,000	2	10,000	5
	Post-Removal	2,000	4	2,000	5	2,000	9	4,000	4	3,000	4	4,000	8
FACILITY													
1	Pre-Removal	7,000	9	4,000	6	6,000	15	17,000	8	30,000	10	24,000	18
	Post-Removal	3,000	7	7,000	6	5,000	12	28,000	6	24,000	6	26,000	12
2	Pre-Removal	2,000	6	1,000	6	1,000	12	7,000	6	12,000	6	9,000	12
	Post-Removal	3,000	8	3,000	8	3,000	16	15,000	8	36,000	12	28,000	20
3	Pre-Removal	1,000	6	4,000	6	2,000	12	10,000	5	56,000	6	45,000	11
	Post-Removal	1,000	6	1,000	6	1,000	12	8,000	6	14,000	6	11,000	12
4	Pre-Removal	2,000	6	2,000	6	2,000	12	5,000	6	10,000	5	7,000	11
	Post-Removal	2,000	8	3,000	10	2,000	18	3,000	8	3,000	7	3,000	15

* This table shows average asbestos contamination in rooms and facilities by PCM analysis using 25- and 37-mm filters applying both aggressive and nonaggressive sampling methods.

after initial cleaning, fiber contamination increased in Rooms D, E, and F as a result of the removal operations, but that Rooms G and I were less contaminated after cleaning.

Outdoor ambient asbestos concentrations were determined using two 25 mm diameter cellulose filters on each day of testing. Asbestos concentrations of two samples were 1,000 f/m^3 and the other 16 were less than the LOD.

TEM results are reported as structures per cubic centimeter (s/cc). Structures include fibers, bundles (compact arrangements of parallel fibers in which separate fibers or fibrils may be visible at the ends or edges of the bundle), clumps (networks of randomly oriented interlocking fibers arranged so that no fiber is isolated from the group), and matrices (one or more fibers attached to or embedded in a nonasbestos particle). The analyses indicate that most of the structures in this study were individual fibers. Total structures determined by TEM should be approximately comparable to fibers as determined by PCM if only fibers visible to PCM were collected on the filter. However, because there are no studies that the authors are aware of to demonstrate the comparability of TEM counts to PCM counts, the use of "structures" for TEM analyses and "fibers" for PCM analyses is used in the present study for clarity. In practice, there are normally many small fibers visible by TEM but not PCM, so that TEM counts are often much higher than the PCM counts.

The polycarbonate filters from the first two facilities were analyzed by TEM in the NIOSH laboratory. Samples collected in Facilities 3 and 4 were originally analyzed in another laboratory using an older electron microscope and, in most cases, the presence of asbestos structures was not identified. A few of these samples were reanalyzed in the NIOSH laboratory and asbestos structure concentrations comparable to those in Facilities 1 and 2 were found. Although it would have been desirable to have all of the samples analyzed in the NIOSH laboratory, only the aggressive sampling filters collected in Facilities 3 and 4 were reanalyzed because of limits on time and resources.

Table 5-8 shows the arithmetic mean of the analytical results for total structures, asbestos structures, total fibers, and asbestos fibers reported for pre- and post-removal, aggressive, and nonaggressive sampling. The average fiber concentrations by PCM (from Table 5-7) are also included in Table 5-8 for ease of comparison. The averages of the asbestos structure analyses are plotted graphically in Figure 5-3.

Figure 5-4 is a graphic comparison of total fibers by PCM and TEM. The TEM counts for nonaggressive sampling are one to two orders of magnitude greater than the PCM counts and about one order of magnitude greater for aggressive sampling. Because the PCM analyses do not discriminate between asbestos and nonasbestos fibers, PCM results are compared to the total fiber concentrations identified by TEM. It is important to note, however, that using Method 7400B[14] only fibers greater than ca. 0.25 in diameter and 5 μm in length with a 5:1 aspect ratio were counted, whereas the TEM total fiber counts include all fibers having a minimum length of 0.5 μm and an aspect ratio of 5:1.[19] The relationship between TEM and PCM analytical results clearly needs better definition; however, it is beyond the scope of the present study.

TABLE 5-8. AVERAGE ASBESTOS CONTAMINATION BY ROOM AND FACILITY (TEM ANALYSES)

ROOM	Sampling Conditions	Non-Aggressive Sampling					Aggressive Sampling				
		TEM Structures (s/m^3)		PCM (f/m^3)	TEM Fibers (f/m^3)		TEM Structures (s/m^3)		PCM (f/m^3)	TEM Fibers (f/m^3)	
		Total	Asbestos	Total	Total	Asbestos	Total	Asbestos	Total	Total	Asbestos
A	Pre-Removal	290,000	90,000	2,000	280,000	80,000	900,000	140,000	23,000	850,000	130,000
	Post-Removal	240,000	70,000	4,000	180,000	60,000	610,000	250,000	17,000	530,000	210,000
B	Pre-Removal	70,000	70,000	8,000	60,000	50,000	350,000	190,000	24,000	310,000	150,000
	Post-Removal	370,000	230,000	7,000	350,000	220,000	840,000	560,000	35,000	610,000	410,000
D	Pre-Removal	310,000	110,000	1,000	290,000	100,000	140,000	50,000	2,000	140,000	50,000
	Post-Removal	920,000	350,000	2,000	870,000	330,000	1,710,000	360,000	15,000	1,540,000	300,000
E	Pre-Removal	90,000	60,000	2,000	80,000	50,000	1,130,000	180,000	17,000	1,050,000	170,000
	Post-Removal	320,000	170,000	4,000	280,000	140,000	1,820,000	210,000	43,000	1,450,000	130,000
F	Pre-Removal			2,000			230,000	60,000	8,000	200,000	40,000
	Post-Removal			1,000			260,000	100,000	20,000	230,000	80,000
G	Pre-Removal			3,000			440,000	200,000	76,000	310,000	120,000
	Post-Removal			1,000			230,000	150,000	2,000	200,000	130,000
H	Pre-Removal			2,000			1,140,000	240,000	4,000	1,030,000	200,000
	Post-Removal			3,000			280,000	70,000	2,000	240,000	60,000
I	Pre-Removal			2,000			520,000	310,000	10,000	400,000	210,000
	Post-Removal			2,000			1,130,000	90,000	4,000	910,000	70,000
FACILITY											
1	Pre-Removal	180,000	80,000	6,000	170,000	70,000	630,000	170,000	24,000	580,000	140,000
	Post-Removal	300,000	150,000	5,000	270,000	140,000	700,000	380,000	26,000	560,000	310,000
2	Pre-Removal	200,000	90,000	1,000	190,000	70,000	640,000	120,000	9,000	590,000	110,000
	Post-Removal	620,000	260,000	3,000	570,000	230,000	1,760,000	280,000	28,000	1,490,000	220,000
3	Pre-Removal			2,000			340,000	130,000	45,000	260,000	80,000
	Post-Removal			1,000			250,000	130,000	11,000	210,000	110,000
4	Pre-Removal			2,000			830,000	270,000	7,000	710,000	200,000
	Post-Removal			2,000			700,000	80,000	3,000	570,000	60,000

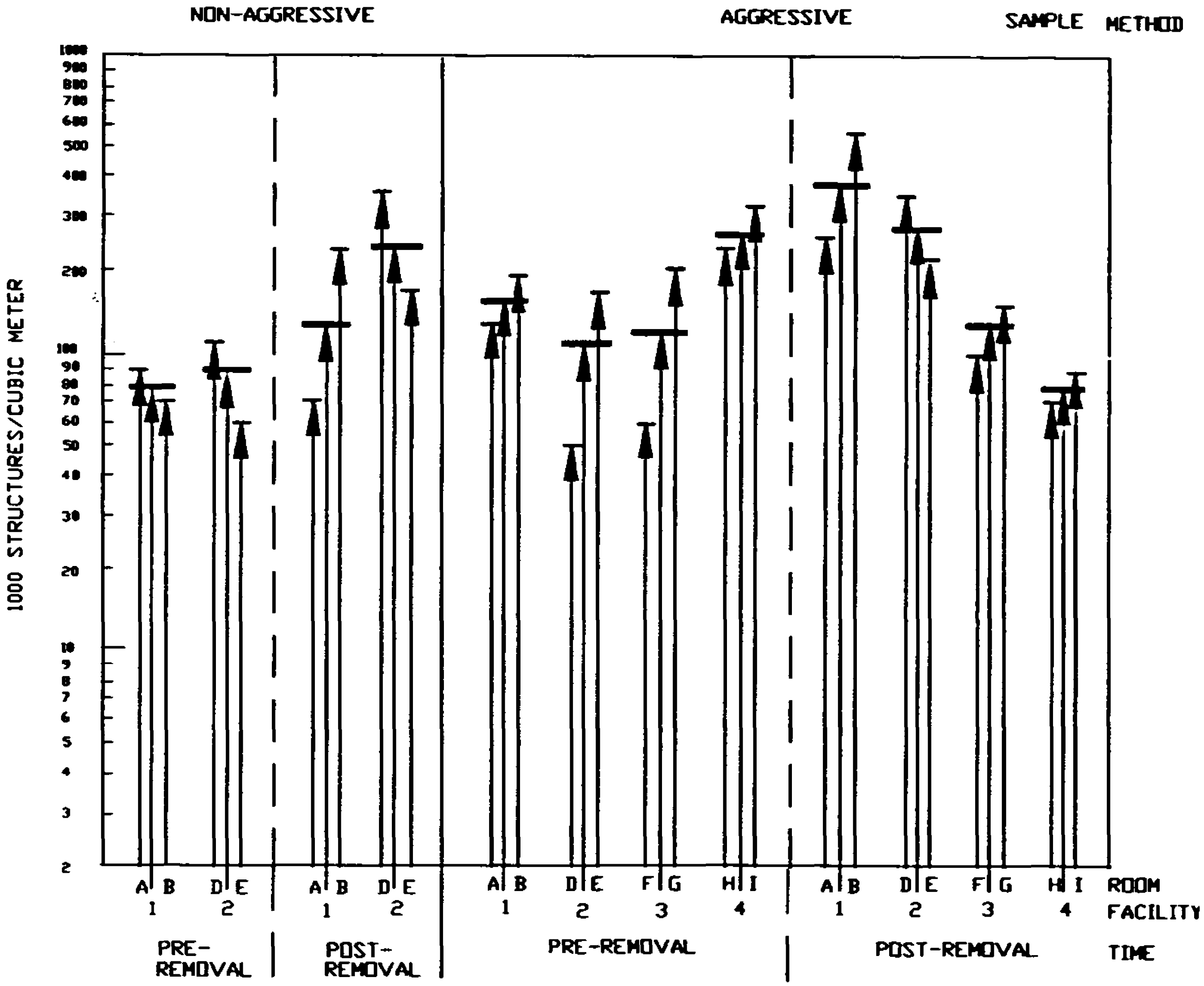


FIG 5-3. AVERAGE ASBESTOS STRUCTURES BY TEM ANALYSIS

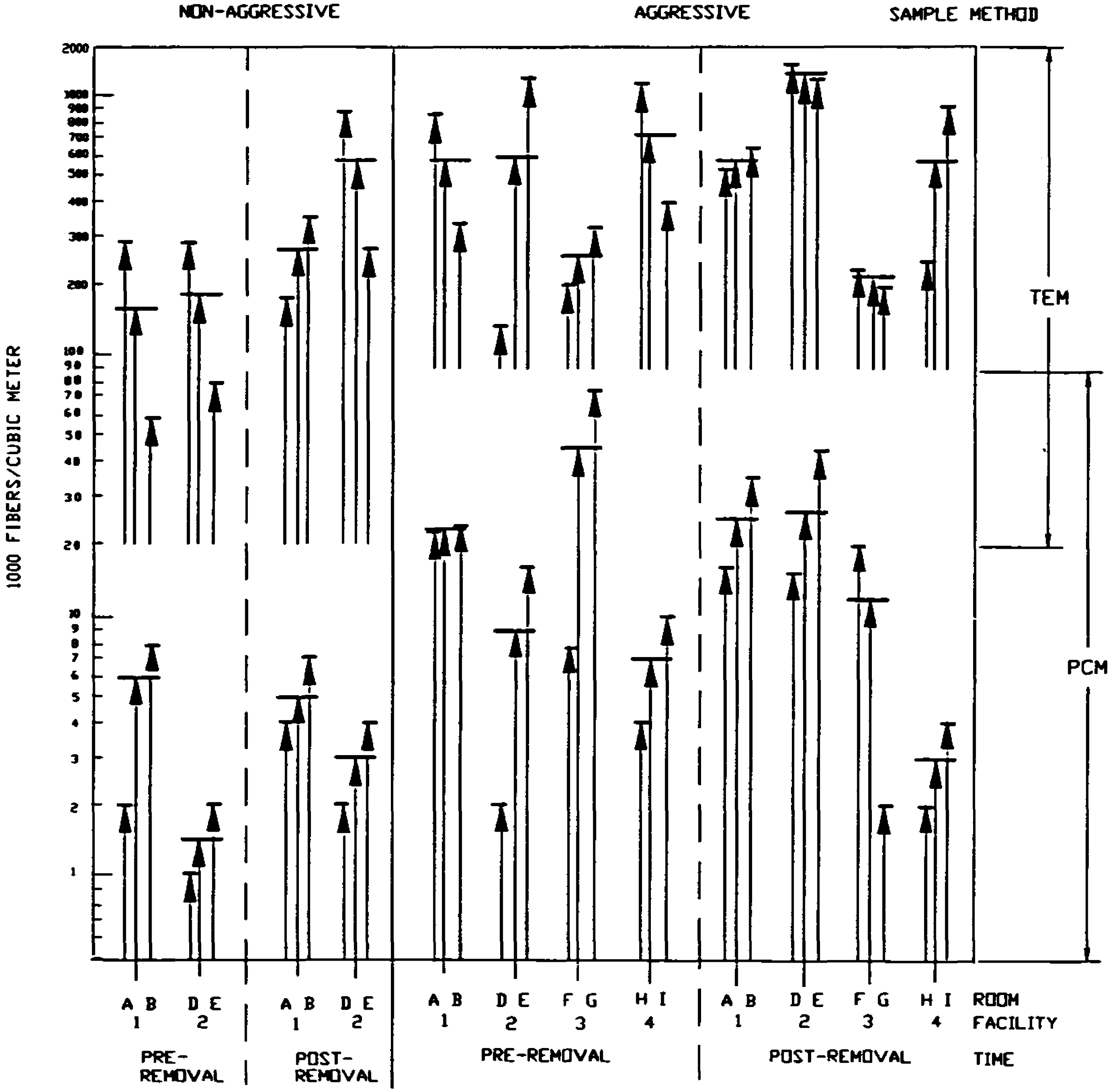


FIG 5-4. COMPARISON OF TOTAL FIBERS BY PCM AND TEM ANALYSIS

NOTE: Using Method 7400B[14] only fibers greater than about 0.25 µm in diameter and 5 µm in length with a 5:1 aspect ratio were counted, whereas the TEM total fiber counts include all fibers having a minimum length of 0.5 µm and an aspect ratio of 5:1.[11] The large difference in fiber concentrations are mainly due to the preponderance of small fibers not visible by PCM.

An analysis of the TEM data was made to determine whether the asbestos levels increased as a result of removal operations. The following comparisons were made using analysis of variance (ANOVA) on the log-transformed data:

a.) pre-removal asbestos nonaggressive structure and fiber counts were compared to post-removal counts,
b.) pre-removal asbestos aggressive structure and fiber counts were compared to post-removal counts,
c.) pre-removal aggressive and nonaggressive data were compared, and
d.) post-removal aggressive and nonaggressive data were compared.

In addition, two comparisons were made on untransformed data:

e.) the fraction of fibers that are asbestos in pre-removal samples were compared to that of post-removal samples, and
f.) the fraction of structures that are asbestos in pre-removal samples were compared to that of post-removal samples.

(The fractions (%) of asbestos structures in the total structures and of asbestos fibers in the total fibers are shown in Table 5-9.)

The Summary of this analysis (Appendix D) is as follows:

> In summary, a main question here is the effectiveness of glove bags in containing asbestos material during the removal process, the conclusion that the first two facilities show signs of additional asbestos after removal, whereas the fourth facility shows signs of decrease in such material allows the possibility that the removal crew did improve its removal techniques, so that the glove bag methods used in the fourth facility may have been more effective in containing the asbestos material. (Note that the analysis of PCM data in Table 5-7, comparing pre- and post-removal counts, indicated a similar possibility concerning the decrease in asbestos after removal.)

The present study does not provide enough replicates to specify whether particular work practices will reliably allow effective glove bag containment. The study does show that asbestos emissions can occur when glove bags are used during asbestos abatement and it is prudent to assume that emissions will occur, unless it is proven otherwise.

As noted previously, analysis by TEM methods specify that the dimensions and speciation of all structures be recorded. Using the post-removal aggressive sampling results, EPA researchers analyzed and prepared a graphical representation of the size distribution of the asbestos fibers. This distribution is shown in Figure 5-4. As seen, the large majority of fibers were less than 5 μm in length.

OTHER OBSERVATIONS

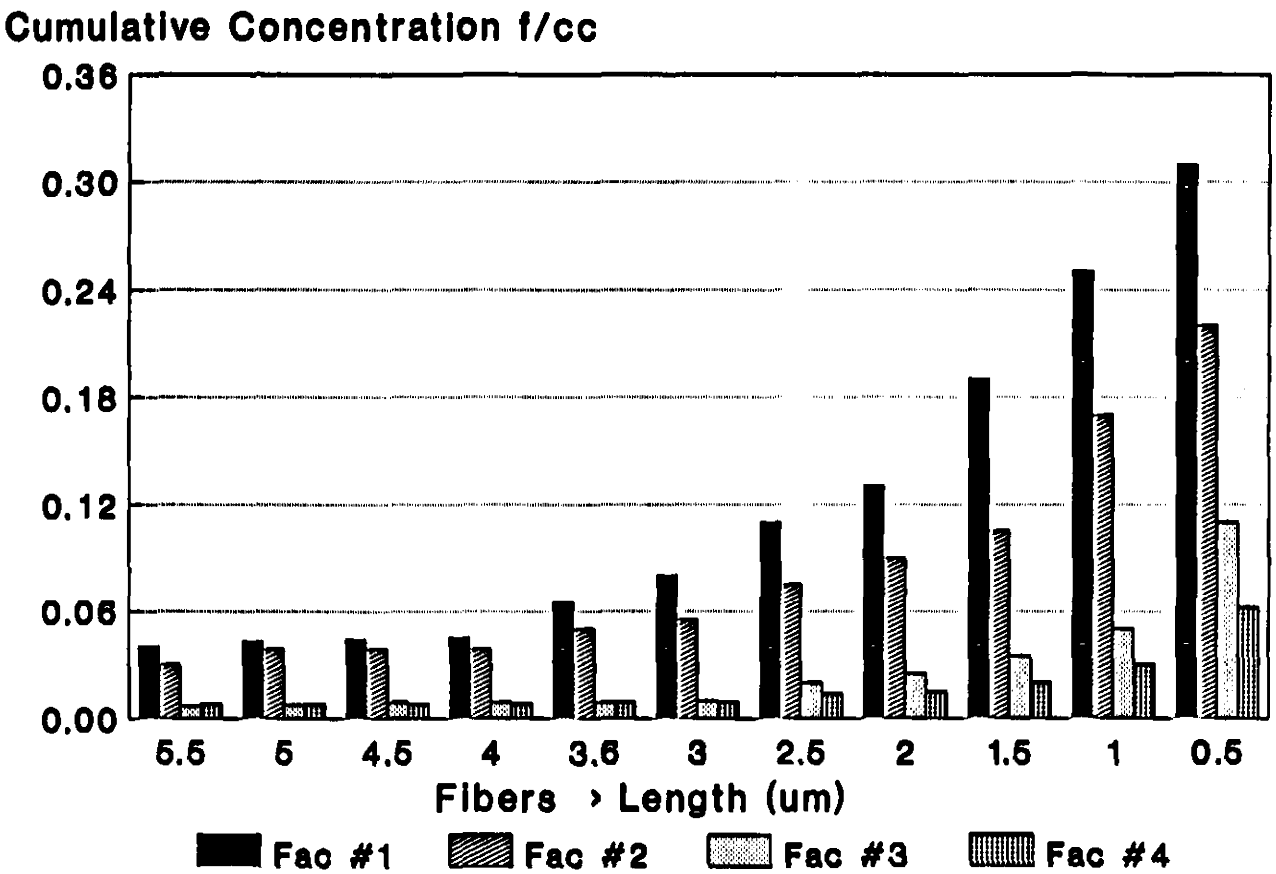
5.4.1. Magiscan II

A number of samples collected from the first facility surveyed were analyzed using the Magiscan II® (M-II) system, Version 2.0, and compared with results obtained from the manual use of PCM. For samples obtained during removal operations, the mean concentration was 0.42 f/cc for M-II and 0.46 f/cc for PCM. The correlation coefficient of 43 duplicate samples was 0.91. For fiber concentrations in this range (0.1 to 1.0 f/cc), the M-II could be

TABLE 5-9. AVERAGE PER CENT OF ASBESTOS IN STRUCTURES AND FIBERS

ROOM	Sampling Conditions	Non-Aggressive Sampling: Asbestos Structures in Total Structures (per cent)	Non-Aggressive Sampling: Asbestos Fibers in Total Fibers (per cent)	Aggressive Sampling: Asbestos Structures in Total Structures (per cent)	Aggressive Sampling: Asbestos Fibers in Total Fibers (per cent)
A	Pre-Removal	41.2	41.1	18.0	16.7
	Post-Removal	27.5	31.4	41.6	40.3
B	Pre-Removal	87.8	88.0	50.8	46.8
	Post-Removal	64.5	63.3	65.8	67.0
D	Pre-Removal	53.6	49.7	42.7	42.7
	Post-Removal	36.5	35.9	22.9	22.1
E	Pre-Removal	63.0	61.8	22.8	24.0
	Post-Removal	53.6	50.1	15.5	12.6
F	Pre-Removal			34.7	32.2
	Post-Removal			46.5	42.2
G	Pre-Removal			54.4	49.1
	Post-Removal			70.7	68.6
H	Pre-Removal			37.1	36.2
	Post-Removal			27.2	25.7
I	Pre-Removal			53.5	48.6
	Post-Removal			21.3	17.3
FACILITY					
1	Pre-Removal	64.5	64.5	34.4	31.8
	Post-Removal	46.0	47.3	52.0	51.8
2	Pre-Removal	58.3	55.7	32.7	33.3
	Post-Removal	45.1	43.0	19.2	17.3
3	Pre-Removal			44.5	40.6
	Post-Removal			58.6	55.4
4	Pre-Removal			45.3	42.4
	Post-Removal			24.3	21.5

Figure 5-5. Cumulative Size Distribution of Asbestos Fibers Aggressive Sampling, TEM Analysis



considered as an alternate analytical procedure that would provide results comparable to the manual PCM counting method, but in less time and with less operator fatigue.

However, it was found that when fiber concentrations were in the range of 0.001 to 0.1 f/cc, as with the asbestos abatement preparation operations and clearance procedures, the duplication of results was very poor. The ratio of of M-II to PCM fiber concentrations of duplicate samples were quite variable, ranging from 2:1 to 30:1. The correlation coefficients between the results obtained by the two methods ranged from 0.11 to 0.25. Therefore, the M-II system, as used in this study, was not suitable for measuring these low airborne asbestos fiber concentrations. A subsequent Magiscan software release (Version 4.0) reportedly has improved capability to measure low fiber counts.

5.4.2. Engineering Controls

Disposalene®, Profo®, and Safe-T-Strip® glove bags were used during this study. Although the majority of the work was done with Disposalene bags, the study was not designed to measure differences in the fiber concentrations emitted from the glove bags of the various manufacturers. It should be noted that glove bag design and construction has evolved since the time of this study and many conveniences and refinements are incorporated in many glove bags currently available.

5.4.3. Work Practices

The survey team observed and intermittently videotaped the work practices of the removal crew. The distributor for Safe-T-Strip® glove bags, who is also a National Asbestos Council instructor, provided on-site training which was very helpful in reinforcing good work practices and techniques. The training was well received by the workers and they were observed to make use of the demonstrated techniques for the duration of the study.

A subjective evaluation of work practices was improvised, and these ratings are summarized in Appendix A, Tables A7-1 through A7-4. Although the work practices appeared to improve as the workers received training and gained experience, it was not possible to identify work practices which would clearly explain the improved containment achieved in the final study site.

Attempts to analyze FAM measurements and compare observed real-time fiber concentrations with specific work conditions and activities were also unsuccessful. The removal work is composed of many short-duration, repetitive tasks; however, the cycle of repetition is inconsistent. In addition, two or more workers performing different tasks simultaneously at different locations in the same room further confounded the situation by the possibility of increasing the background levels from multiple, unrelated sources.

5.4.4. Contractor and School Board Monitoring

The removal contractor's program for monitoring airborne exposure to asbestos during the removal operation consisted of supplying the shift foreman with one personal sampling pump. During the present study, no personal sampling was conducted by the foreman because the survey team monitored each of the workers.

The school board also hired an independent consultant to monitor the asbestos abatement activities by observation and by air sampling. However, because abatement work was simultaneously in progress at four diverse sites, the monitoring consultant was unable to provide a level of observation sufficient to ensure full compliance with the work specifications at any one site.

5.4.5. Personal Protection

The removal workers wore disposable coveralls in the work area during removal activities. In addition, each worker was fit-tested for a half-face cartridge respirator equipped with high efficiency particulate air filters. These respirators were worn during all removal activities.

5.4.6. Safety Considerations

Work was performed over or around obstructions such as sinks, commodes, light fixtures, and other nonremovable structures. Safety hazards were typical of those associated with insecure footing while working on elevated platforms, ledges, and ladders, i.e., slips, falls, awkward working postures, etc. The use of razor knives and stapling guns also presented hazards to workers. Staples driven through the poly into the asbestos lagging presented a special risk of injury to the hands. Care was required when removing the poly from the lagging to avoid skin punctures and lacerations. The poly gloves in the bags provided no protection against this hazard and were not large enough to allow workers to wear additional hand protection.

6. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are based on the fiber exposure data collected and on the observation of the work practices used in this study.

6.1. Efficacy of Glove Bag Containment

- As used in this study, glove bags did not completely contain airborne asbestos when pipe lagging was being removed.

  Glove bags can be a useful engineering control to reduce worker exposure to asbestos during the removal of ACM. In the present investigation, however, workers' exposures to airborne asbestos were consistently below the OSHA PEL in only one of the four facilities surveyed. The study was not designed to demonstrate the effect of training on glove bag containment efficacy and it did not provide a basis to specify conditions under which adequate containment can be assured.

  Based on these results, it is prudent to assume that glove bags will afford varying degrees of containment, depending on the specific configuration of the structure from which asbestos is to be removed and the manner in which the glove bags are used by the workers.

- Because of the uncertainty in controlling exposures during the use of glove bags, it is essential to provide a backup containment system (e.g., isolation, barriers, negative air) and respiratory protection for workers.

  Worker training and experience are important components of a reliable system of control measures; however, even work performed by well-experienced crews is subject to accidental releases. Emissions of this sort must be prevented from entering other portions of the building.

  As discussed in Section 3, the lack of expertise demonstrated by the workers at the first survey is probably typical of other workers who use glove bags infrequently. Plant maintenance personnel, asbestos operations and maintenance personnel, and many asbestos removal contractors who use glove bags only occasionally could very likely encounter asbestos exposures similar to those observed in these surveys, due to incomplete containment.

  It is also necessary to use personal protective equipment (e.g., disposable coveralls) and respiratory protection during <u>any</u> glove bag operation, because of the potential for undetected leakage of the glove bag and accidental rupture of the bag or seals. OSHA permits the use of high efficiency, air purifying respirators for work with asbestos;[13] however, NIOSH recommends that type C positive pressure, supplied air respiratory protection be used when occupational exposure may occur.[41] Only NIOSH/MSHA-approved respirators should be used. When respirators are used, a written respirator program including a quantitative respirator fit testing program must also be instituted.

- In this study, exposures to asbestos exceeding the NIOSH REL did not occur when the rooms were being prepared for asbestos lagging removal.

  The maximum exposure observed during the preparation of the rooms and covering of the pipes before actual removal was 54,000 f/m^3. Preexisting contamination by ACM, i.e., asbestos contamination present in areas to be abated before the abatement operations are started, is an important factor to consider in evaluating the potential for exposure. Both the amount and the state of the preexisting contamination and the magnitude of the disturbance created by the workers activities can influence the contribution of preexisting contamination to airborne asbestos concentrations.

  The rooms evaluated in this study were selected because of the good condition of the pipe lagging and the absence of visible debris. The workers used respirators during removal operations, but did not use them during the preparation stage. It is more usual for abatement work to be performed in areas where damaged lagging and debris are present; under such conditions respiratory protection should always be used in preparing the work site.

6.2. Clearance Methodology

- For clearance testing, the aggressive sampling technique is more sensitive for detecting asbestos contamination than nonaggressive sampling techniques. Asbestos was found in all of the clearance samples that were collected using aggressive sampling techniques and analysis by TEM.

  Where aggressive sampling and TEM analysis techniques were used, preexisting contamination was found in all of the rooms in which this study was conducted, even though these rooms were selected because of the absence of any visual contamination. Using these same sampling and analytical techniques, asbestos concentrations observed following the abatement activities but prior to final inspection were greater than the preexisting contamination levels in five of the eight rooms.

- PCM analysis is not reliable for clearance testing.

  The AHERA regulation permits the use of PCM only until October 7, 1990.[11] The PCM analysis of samples collected using nonaggressive sampling techniques indicated that over 50% of the samples had nondetectable fiber concentrations. Even when aggressive sampling techniques were used, PCM analysis could not always detect the presence of asbestos, even though fibers were observed on all samples analyzed by TEM. Based on these findings, PCM should not be considered as a reliable method for determining the absence of residual asbestos. Furthermore, the results obtained by PCM are very close to the limit of detection for this method, and therefore, the confidence limits are very broad. This makes comparison with a clearance standard difficult.

TEM analysis presents several advantages for the measurement of low concentrations of asbestos fibers. It has the ability to detect short and narrow fibers, identify the type of fiber, and is less affected by overloading of particulates which may obscure fibers when using PCM.

The interlaboratory variability observed for the TEM analysis and the fiber contamination found on the polycarbonate filter media indicate that additional standardization and quality assurance are required. Laboratory accreditation is needed to assure that uniform sample preparation techniques and counting methods are used. Inter and intralaboratory quality control tests are needed to determine coefficients of variability and a measure of the accuracy and ability to replicate results. This need was recognized by both the April 1986 EPA peer review[35] and the Asbestos-Containing Materials in Schools regulation (October 1987).[32] This regulation charged the National Institute of Standards and Technology (NIST) (formerly the National Bureau of Standards) with the responsibility for establishing a laboratory accreditation program. NIST projects that such a program will require 2 to 3 years for implementation to occur. Until such time as TEM laboratory accreditation is accomplished, meaningful quantitative comparisons between laboratories or with EPA standards are possible only with extensive interlaboratory replicate analysis and quality assurance programs. It is recommended that laboratories performing TEM analyses initiate with other laboratories an interim program for quantitative comparisons of samples.

- Magiscan II is suitable for fiber analysis when airborne asbestos concentrations are compared to occupational standards, i.e., concentrations in the 0.2 f/cc (200,000 f/m^3) range.

From the limited observations in this study, it appears that the use of PCM with the automatic counting and sizing of particles, e.g., Magiscan II®, Version 2.0, is useful for the analysis of fibers when the concentration is above the present OSHA PEL of 0.2 f/cc (200,000 f/m^3). This system can provide results comparable to manual PCM, but in less time and with less operator fatigue. The Magiscan II (Version 2.0) did not correlate well with the PCM analyses for fiber concentrations in the 0.01 f/cc (10,000 f/m^3) range. Therefore, it is not appropriate for analysis of low fiber concentrations normally associated with ambient background or abatement clearance fiber concentrations. A modification of this system, Magiscan, Version 4.0, may have utility at these lower concentrations, but it was not evaluated in this study.

6.3. Monitoring and Recommended Work Practices for Glove Bag Use

Monitoring of airborne asbestos concentrations by the removal contractor and the building owner is necessary to verify the effective use of glove bags;

frequent observation and supervision by an experienced overseer is necessary to assure that proper work practices are being used. Although conventional workplace sampling for airborne concentrations can provide only after-the-fact exposure information, it may indicate the need for better control on future jobs. A direct-reading instrument (FAM) may be useful to indicate large, accidental releases of fibers and help to minimize contamination by timely corrective actions.

In the absence of other reputed studies that quantify the effectiveness of specific work practices, the following recommendations are given based on good industrial hygiene practice:

- Pre-mist all lagging with amended water.
- Wrap all pipe with poly prior to the start of removal work.
- Use a bag properly designed for the task (i.e., specially designed bags for working around large valves or fittings).
- Start with a clean, empty bag where the pipe interfaces with walls or ceiling. Special care must be used to avoid breaking the tape or adhesive seal; an empty or nearly empty bag is easier to manipulate.
- Cut preformed lagging blocks at the joints to minimize fiber generation.
- Use hoses on the amended water sprayers of sufficient length to facilitate wetting practices; spray frequently during the removal task to assure that freshly exposed materials are wetted.
- Use a HEPA-filtered vacuum device to contain fibers and to assist in collapsing the glove bag and tying it off prior to removal.
- Remove contaminated tools in an inverted glove for transfer to the next glove bag.
- Require documentation of specific training and experience for workers using glove bags.
- Use enclosures with decontamination showers and negative air on large jobs. On smaller jobs, at least seal off vents and wall or ceiling openings with poly and provide double-hung poly curtains at the doors.
- Clean up accumulated debris prior to removal; this will reduce the potential to disturb and resuspend accumulations of loose fibers.
- Stable elevated platforms and scaffolding must be provided where needed. Improvised platforms utilizing existing structures should be discouraged; worker safety should not be jeopardized by expediency.
- If the lagging is not fully wrapped with poly prior to removal, band the lagging with tape at the places where the glove bag is to be attached. This will provide a clean surface for affixing the tape that seals the glove bag, and prevent damage to the lagging when the sealing tape is removed.

- Test the effectiveness of the seals by pressure testing each bag installation (e.g., gently squeeze the bag to assure that the seal is tight).

- Periodically, use a smoke test to assure that correct installation procedures have been followed. Use a smoke tube inside the bag to fill the bag with smoke, then apply gentle pressure to the bag to observe that the seals are secure. The pressure applied should be consistent with the forces exerted on the bag during the removal of the pipe lagging.

- Care should be taken when metal bands, wires, or metal jacketing are encountered to avoid lacerations to the hands or to the glove bag; whenever possible, the sharp edges should be folded in and these items placed gently in the bottom of the bag.

- The accumulation of debris and water in the glove bag should not exceed the ability of the workers to safely manipulate the bag as needed. Bag loading practices should reflect good judgment and experience; heavily loaded bags create awkward and unsafe conditions. Where applicable, the bag may be supported by the use of a platform and/or slings.

- Use a HEPA filter vacuum to contain fibers during all bag opening procedures such as removal or moving.

- Seal the ends of the lagging with "wettable cloth" (plaster-impregnated fiberglass webbing) or equivalent encapsulant, when partial removal creates exposed ends.

- Use a direct-reading aerosol monitor, such as a FAM, to detect failures in control or containment so that on-the-spot corrections can be made.

- Decontaminate the work area thoroughly after the completion of the job. All contamination should be removed, whether it was caused by the removal task or has accumulated over time.

- Place barricades around working areas when outdoor work is performed. Removal of pipe lagging from salvaged or reclaimed pipe should be done in an enclosure or room with suitable controls to prevent the release of asbestos fibers to the environment.

- Crew size should be proper for the task; a minimum of two workers is recommended where heavily loaded bags are anticipated or elevated work is required. Where two or more removal operations are conducted in the same area, an auxiliary worker may be utilized to refill and pressurize the amended water sprayers, to assist in moving or adjusting the glove bags, and to perform other miscellaneous tasks.

6.4. Research Needs

There are several research efforts that may help to improve the containment of asbestos while using glove bags: evaluation of work practices for both reduction of emissions and ergonomic considerations; improvements for wetting the lagging before removal, such as using an injection technique to saturate the lagging; and use of glove bags in conjunction with local exhaust applied to the glove bag (negative pressure).

Several removal contractors use high volume HEPA-filtered vacuum systems that are truck-mounted and are connected to the containment area by means of flexible duct work. They are used to produce a negative or reduced pressure and frequent air changes within the sealed area, and/or local exhaust ventilation to the source of asbestos emissions when ACBM are being removed. They are also designed to remove airborne contamination and debris from the removal site or building and provide disposal techniques remote from abatement operation. These systems could offer better containment than conventional removal methods. A study of the efficacy of these systems, as compared to the use of conventional removal techniques, is recommended.

A further recommendation is an evaluation of exposures associated with the effects of age, use, and maintenance procedures on the efficiency of HEPA-filtered vacuum devices, because degradation in these devices could result in significant emissions of asbestos fibers.

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APPENDIX A

SUMMARY TABLES FROM REPORTS OF INDIVIDUAL FACILITIES

TABLE A1-1 PERSONAL EXPOSURE MEASUREMENTS DURING PREPARATION AND REMOVAL OF PIPE LAGGING AT FACILITY 1

Exposure is reported as f/cc using NIOSH 7400-B Method

WORKER	TYPE*	ACTIVITY	JUNE 18	JUNE 19	JUNE 20	JUNE 21
# A	TWA		0.25	0.30	0.47	0.17
	ST	REMOVAL			0.38	
	ST	REMOVAL			0.77	
	ST	REMOVAL			1.10	
# B	TWA		**	0.10	0.33	0.12
	ST	PREPARATION		0.03		
	ST	REMOVAL		1.00	0.52	0.34
	ST	REMOVAL			0.14	
# C	TWA		**	0.25	0.49	0.12
	ST	REMOVAL				0.43
	ST	REMOVAL				0.07
# D	TWA		0.21	0.32	0.31	0.15
	ST	PREPARATION		0.03		
	ST	REMOVAL		0.71	1.10	0.25
	ST	REMOVAL		0.92	1.20	
	ST	REMOVAL		0.95		

* TWA - Sequential, full-shift Time-Weighted-Average
ST - 15 Minute Short-Term

** In the report for this facility, values of 0.014 and 0.015 for workers B and C respectively are shown. However, subsequent investigation has indicated that values of "below detectable limit" reported by the analytical service should have stated that samples were obscured by too many particulates to be counted.

TABLE A1-2 PERSONAL EXPOSURE MEASUREMENTS DURING PREPARATION AND REMOVAL OF PIPE LAGGING AT FACILITY 2

Exposure is reported as f/cc using NIOSH 7400-B Method (PCM)

WORKER	TYPE*	ACTIVITY	JUNE 25	JUNE 26	JUNE 27	JUNE 28
# A	TWA		0.025	**	**	0.254
	ST	PREPARATION	0.017		0.045	
	ST	REMOVAL		0.188	0.956	0.178
	ST	REMOVAL	1.33	0.667		0.333
# B	TWA		0.339	0.348	**	0.198
	ST	PREPARATION	0.017		0.044	
	ST	REMOVAL	1.38	0.286	***	0.233
	ST	REMOVAL	0.91	0.756		0.400
# C	TWA		0.224	**	0.312	0.350
	ST	PREPARATION	0.025		0.033	
	ST	REMOVAL	0.711	0.457	0.867	0.233
	ST	REMOVAL		0.222		0.688
# D	TWA		**	0.290	**	**
	ST	PREPARATION			0.033	
	ST	REMOVAL	2.91	0.244	0.521	1.93
		REMOVAL		0.250		

* TWA = Time-Weighted-Averages for Preparation and Removal Work
ST = 15 Minute Short-Term

** The TWA not reported. One of the sequential samples was overloaded with particulates.

***Not counted - sample overloaded with particulates.

TABLE A1-3 PERSONAL EXPOSURE MEASUREMENTS DURING PREPARATION AND REMOVAL OF PIPE LAGGING AT FACILITY 3

Exposure is reported as f/cc using NIOSH 7400-B Method

WORKER	TYPE*	ACTIVITY	JULY 01	JULY 02	JULY 03
# A	TWA		0.345	0.554	0.799
	ST	PREPARATION	0.016		
	ST	REMOVAL	1.0	0.156	0.167
	ST	REMOVAL		2.0	
# B	TWA		0.295	0.560	0.412
	ST	REMOVAL	0.711	0.756	
# C	TWA		0.343	0.663	0.475
	ST	PREPARATION	0.017		
	ST	REMOVAL	0.467	3.18	0.711
	ST	REMOVAL	1.27	0.911	
# D	TWA		0.161	0.639	0.611
	ST	REMOVAL	0.933	2.44	0.622
	ST	REMOVAL		2.78	1.02
	ST	REMOVAL		9.29**	

* TWA = Sequential, full-shift Time-Weighted-Average
ST = 15 Minute Short-Term

** The Short-Term sample reported was during an episode of high release. A 10-ft. section of lagging separated from the pipe inside the poly.

TABLE A1-4 PERSONAL EXPOSURE MEASUREMENTS DURING PREPARATION AND REMOVAL OF PIPE LAGGING AT FACILITY 4

Exposure is reported as f/cc using NIOSH 7400-B Method

WORKER	TYPE*	ACTIVITY	JULY 15	JULY 16	JULY 17
# A	TWA		0.011	0.015	0.009
	ST	PREPARATION	0.015		
	ST	REMOVAL	0.022	0.016	0.016
	ST	REMOVAL			0.017
# B	TWA		0.010	0.013	0.005
	ST	PREPARATION	0.006		
	ST	REMOVAL	0.032	0.065	0.034
# C	TWA		0.003	**	0.008
	ST	PREPARATION	0.002		
	ST	REMOVAL	0.035	0.086	0.017
	ST	REMOVAL		0.20	0.016
# D	TWA		0.013	**	0.010
	ST	PREPARATION	0.016		
	ST	REMOVAL	0.036		0.044

* TWA - Sequential, full-shift Time-Weighted-Average
ST - 15 Minute Short-Term
** One of the filters was overloaded with particulates.

TABLE A2-1 PERSONAL SAMPLING RESULTS BY ACTIVITY AT FACILITY 1

PCM Analysis: f/cc using NIOSH 7400-B Method

WORKER	JUNE 18 ROOM B	JUNE 19 ROOM A	JUNE 20 ROOM B/ROOM C	JUNE 21	MEAN	MIN	MAX	ST D*	n*
---------- PREPARATION FOR PIPE LAGGING REMOVAL ----------									
A	0.032	0.026			0.029				
B	0.029	0.037			0.033				
C	0.032	0.029			0.030				
D	0.054	0.034			0.044				
PREP AVERAGE	0.037	0.032			0.034	0.026	0.054	0.009	8
-------------- PIPE LAGGING REMOVAL --------------									
A	0.40				0.40				1
		0.55	0.42		0.48				2
			0.53	0.17	0.35				2
AVG					0.414	0.17	0.55	0.135	5
B	**				0.003				1
		0.12	0.36		0.240				2
			0.30	0.12	0.210				2
AVG					0.225	0.012	0.36	0.107	4
C	**				0.003				1
		0.45	0.55		0.500				2
			0.43	0.12	0.280				2
AVG					0.388	0.012	0.55	0.161	4
D	0.32				0.320				1
		0.64	0.32		0.480				2
			0.29	0.15	0.220				2
AVG					0.344	0.15	0.64	0.161	5
REMOVAL AVERAGE	0.36	0.44	0.40	0.14	0.347	0.012	0.64	0.160	18
AMBIENT	0.002	0.002	0.003	0.002	0.002	0.001	0.003	0.001	8

* ST D - Standard Deviation   n - number of samples

** In the report for this facility, values of 0.003 are shown. However, subsequent investigation has indicated that values of "below detectable limit" reported by the analytical service should have stated that the samples were obscured by too many particulates to be counted.

TABLE A2-2 PERSONAL SAMPLING RESULTS BY ACTIVITY AT FACILITY 2

PCM Analysis: f/cc using NIOSH 7400-B Method

WORKER	JUNE 25 ROOM D	JUNE 26 ROOM D	JUNE 27 ROOM E	JUNE 28 ROOM E	MEAN	MIN	MAX	ST D*	n*
---------- PREPARATION FOR PIPE LAGGING REMOVAL ----------									
A	0.010		0.022		0.016				
B	0.016		0.054		0.035				
C	0.005		0.022		0.013				
D	0.010		0.022		0.016				
PREP AVERAGE	0.010		0.030		0.020	0.005	0.054	0.015	8
-------------- PIPE LAGGING REMOVAL --------------									
A	0.043	0.161	**		0.102				2
		**							
				0.278	0.223				2
				0.169					
AVG				0.223	0.163	0.043	0.278	0.083	4
B	0.606	0.362	**		0.511				3
		0.315							
				0.060	0.145				2
				0.231					
AVG		0.339		0.145	0.315	0.060	0.606	0.178	5
C	0.522	0.216	0.475		0.404				3
		**							
				0.323	0.388				2
				0.454					
AVG				0.389	0.398	0.216	0.522	0.112	5
D	**	0.287	**		0.292				2
		0.298							
			0.354	0.354				1	
				**					
AVG		0.292			0.313	0.287	0.354	0.029	3
REMOVAL AVERAGE	0.390	0.284	0.475	0.267	0.303	0.043	0.606	0.153	17
AMBIENT	0.001	0.001	0.001	0.001	0.001				8

* ST D = Standard Deviation n = number of samples

** Filter Overloaded with Particulate - unable to count.

TABLE A2-3 PERSONAL SAMPLING RESULTS BY ACTIVITY AT FACILITY 3

PCM Analysis: f/cc using NIOSH 7400-B Method

WORKER	JULY 01 ROOM F	JULY 02 ROOM G	JULY 03 ROOM G	MEAN	MIN	MAX	ST D*	n*
---------- PREPARATION FOR PIPE LAGGING REMOVAL ----------								
A	0.011							
B	0.008							
C	0.004							
D	0.007							
PREP AVERAGE	0.008			0.008	0.004	0.011	0.003	4
---------- PIPE LAGGING REMOVAL ----------								
A	0.165	0.260	0.799					
	1.03	1.07						
AVG	0.563	0.554	0.799	0.665	0.165	1.07	0.382	5
B	0.40	0.263	0.412					
	0.50	1.410						
AVG	0.446	0.837	0.412	0.597	0.263	1.41	0.414	
C	0.505	0.457	0.475					
	0.619	1.10						
AVG	0.566	0.663	0.475	0.631	0.457	1.10	0.240	5
D	0.241	0.452	0.611					
	0.287	0.951						
AVG	0.265	0.639	0.611	0.508	0.241	0.951	0.257	5
REMOVAL AVERAGE	0.468	0.745	0.574	0.600	0.165	1.41	0.337	20
AMBIENT	0.001	0.001	0.001	0.001				6

* ST D = Standard Deviation n = number of samples

TABLE A2-4 PERSONAL SAMPLING RESULTS BY ACTIVITY AT FACILITY 4

PCM Analysis: f/cc using NIOSH 7400-B Method

WORKER	JULY 15	JULY 16	JULY 17	MEAN	MIN	MAX	ST D*	n*
	ROOM H	ROOM I	ROOM J					
- - - - - - - - - - - PREPARATION FOR PIPE LAGGING REMOVAL - - - - - - - - - - -								
A	0.005							
B	0.006							
C	0.002							
D	0.010							
PREP AVERAGE	0.006			0.006	0.002	0.010	0.003	4
- - - - - - - - - - - - - - PIPE LAGGING REMOVAL - - - - - - - - - - - - - -								
A	0.018	0.015	0.002					
			0.023					
AVG	0.018	0.015	0.012	0.015	0.002	0.023	0.008	4
B	0.015	0.013	0.005****					
AVG	0.015	0.013	0.005	0.011	0.005	0.015	0.004	3
C	0.005	**	0.004					
			0.017					
AVG	0.005		0.010	0.009	0.004	0.017	0.006	3
D	0.017	***	0.010****	0.014				
AVG	0.017		0.010	0.014	0.010	0.017	0.003	2
REMOVAL AVERAGE	0.014	0.014	0.010	0.012	0.002	0.023	0.012	12
AMBIENT	0.001	0.001	0.001	0.001				

* ST D - Standard Deviation n - number of samples
** Filter overloaded with particulate; unable to count.
*** Worker not on job today.
**** Only half shift sample; worker on another job first half of day.

TABLE A3-1 AREA SAMPLING RESULTS PREPARATION FOR PIPE LAGGING REMOVAL AT FACILITY 1

Analysis: PCM using NIOSH 7400-B Method (f/cc)*
TEM using EPA Provisional Method (as/cc)*

	JUNE 18		JUNE 19						
	ROOM B		ROOM A						
	PCM	TEM	PCM	TEM					
SAMPLING SITE	f/cc	as/cc	f/cc	as/cc	MEAN	MIN	MAX	ST D*	n*
PCM ANALYSIS									
NEAR WORKERS	0.030				0.030	0.023	0.040	0.007	4
			0.019		0.019	0.009	0.029	0.014	2
AVERAGE					0.026	0.009	0.040	0.010	6
TEM ANALYSIS		(No Data)							
				0.590	0.590	0.540	0.640	0.069	2
AVERAGE				0.590	0.590	0.540	0.640	0.069	2
ROOM (BACKGROUND)									
PCM ANALYSIS	0.019				0.019	0.018	0.019	0.001	2
			0.013		0.013	0.009	0.017	0.005	2
AVERAGE					0.016	0.009	0.019	0.005	4
TEM ANALYSIS		0.870			0.870	0.574	1.200	0.410	2
				0.670	0.670	0.390	0.960	0.400	2
AVERAGE					0.780	0.390	1.200	0.370	4
HALL (BACKGROUND)									
PCM ANALYSIS	0.048				0.048	0.044	0.053	0.007	2
			0.070		0.070	0.043	0.096	0.037	2
AVERAGE					0.059	0.043	0.096	0.025	4
TEM ANALYSIS		0.499			0.499	0.450	0.550	0.073	2
				0.650	0.650	0.645	0.655	0.006	2
AVERAGE					0.575	0.450	0.655	0.096	4
OUTDOOR AMBIENT									
PCM ANALYSIS	0.002								2
			0.002						2

* f/cc - fibers/cc as/cc - asbestos structures/cc
ST D - Standard Deviation n - number of samples

TABLE A3-2 AREA SAMPLING RESULTS PREPARATION FOR PIPE LAGGING REMOVAL AT FACILITY 2

Analysis: PCM using NIOSH 7400-B Method (f/cc)*
TEM using EPA Provisional Method (as/cc)*

	JUNE 25 ROOM D		JUNE 27 ROOM E						
SAMPLING SITE	PCM f/cc	TEM as/cc	PCM f/cc	TEM as/cc	MEAN	MIN	MAX	ST D*	n*
NEAR WORKERS									
PCM ANALYSIS	0.013				0.012	0.011	0.014	0.002	2
			0.023		0.023	0.023	0.023	0.000	2
AVERAGE					0.018	0.011	0.023	0.005	4
TEM ANALYSIS				1.633	1.633	1.215	2.051	0.418	2
AVERAGE					1.633	1.215	2.051	0.418	2
ROOM (BACKGROUND)									
PCM ANALYSIS	0.015				0.014	0.013	0.016	0.002	2
			0.016		0.015	0.012	0.019	0.005	2
AVERAGE					0.015	0.012	0.019	0.003	4
TEM ANALYSIS		0.370			0.370	0.350	0.390	0.020	2
				1.269	1.269	1.210	1.328	0.059	2
AVERAGE					0.820	0.350	1.328	0.451	4
HALL (BACKGROUND)									
PCM ANALYSIS	0.007				0.007	0.006	0.008	0.001	2
			0.045		0.045	0.024	0.065	0.029	2
AVERAGE					0.026	0.006	0.065	0.024	4
TEM ANALYSIS									
		0.585			0.085	0.575	0.594	0.009	2
				2.061	2.061	1.598	2.525	0.463	2
AVERAGE					1.323	0.575	2.525	0.807	4
OUTDOOR AMBIENT									
PCM ANALYSIS	0.001				0.001	0.001	0.001	0.000	2
			0.001		0.001	0.001	0.001	0.000	2

* f/cc = fibers/cc   as/cc = asbestos structures/cc
ST D = Standard Deviation   n = number of samples

TABLE A3-3 AREA SAMPLING RESULTS PREPARATION FOR PIPE LAGGING REMOVAL AT FACILITY 3

Analysis: PCM using NIOSH 7400-B Method (f/cc)*
TEM using EPA Provisional Method (as/cc)*

SAMPLING SITE	JULY 1 ROOM F PCM f/cc	JULY 1 ROOM F TEM as/cc	MEAN	MIN	MAX	ST D*	n*
NEAR WORKERS							
PCM ANALYSIS	0.004		0.003	0.003	0.004	0.000	2
(TEM ANALYSIS NOT COMPLETED)							
ROOM (BACKGROUND)							
PCM ANALYSIS	0.006		0.007	0.004	0.009	0.003	2
(TEM ANALYSIS NOT COMPLETED)							
HALL (BACKGROUND)							
PCM ANALYSIS	0.005		0.005	0.002	0.009	0.003	2
(TEM ANALYSIS NOT COMPLETED)							
OUTDOOR AMBIENT							
PCM ANALYSIS	0.001						2

* f/cc - fibers/cc   as/cc - asbestos structures/cc
ST D - Standard Deviation   n - number of samples

TABLE A3-4 AREA SAMPLING RESULTS PREPARATION FOR PIPE LAGGING REMOVAL AT FACILITY 4

Analysis: PCM using NIOSH 7400-B Method (f/cc)*
TEM using EPA Provisional Method (as/cc)*

SAMPLING SITE	JULY 15 ROOM H PCM f/cc	JULY 15 ROOM H TEM as/cc	MEAN	MIN	MAX	ST D*	n*
NEAR WORKERS							
PCM ANALYSIS	0.008						
	0.006						
AVERAGE	0.007		0.006				2
(TEM ANALYSIS NOT COMPLETED)							
ROOM (BACKGROUND)							
PCM ANALYSIS	0.003						
	0.013						
AVERAGE	0.008		0.008	0.003	0.013		2
(TEM ANALYSIS NOT COMPLETED)							
HALL (BACKGROUND)							
PCM ANALYSIS	0.001						
	0.001						
AVERAGE	0.001		0.001				2
(TEM ANALYSIS NOT COMPLETED)							
OUTDOOR AMBIENT							
PCM ANALYSIS	0.001		0.001				2

* f/cc = fibers/cc as/cc = asbestos structures/cc
ST D = Standard Deviation n = number of samples

TABLE A4-1 AREA SAMPLING RESULTS PIPE LAGGING REMOVAL AT FACILITY 1

Analysis: PCM using NIOSH 7400-B Method (f/cc)*
TEM using EPA Provisional Method (as/cc)*

	JUNE 18 ROOM B				JUNE 19 ROOM A				JUNE 20 ROOM A/ROOM C				JUNE 21 ROOM C							
SAMPLING SITE	PCM		TEM		PCM		TEM		PCM		TEM		PCM		TEM					
	f/cc	n*	as/cc	n	f/cc	n	as/cc	n	f/cc	n	as/cc	n	f/cc	n	as/cc	n	MEAN	MIN	MAX	ST D*
NEAR WORKERS																				
PCM ANALYSIS	0.36	2															0.36	0.31	0.41	0.074
					0.47	2			0.35	2							0.41	0.29	0.49	0.086
									0.19	2			0.11	2			0.15	0.10	0.20	0.048
AVERAGE																	0.30	0.10	0.49	0.140
TEM ANALYSIS			3.1	2													3.1	1.7	4.5	2.0
							2.4	2			3.5	2					2.9	1.9	4.5	1.1
											1.1	2			1.4	2	1.3	0.78	1.8	0.45
AVERAGE																	1.500	0.780	4.500	1.600
ROOM (BACKGROUND)																				
PCM ANALYSIS	0.41	2															0.41	0.38	0.44	0.040
					0.47	2											0.47	0.34	0.59	0.140
									0.21	2										
									0.31	2			0.11	2			0.16	0.09	0.23	0.062
AVERAGE																	0.30	0.09	0.59	0.140
TEM ANALYSIS			2.1	2													2.1	2.0	2.1	0.06
							1.7	2			2.7	2					1.5	0.16	3.0	1.50
											1.1	2			0.94	2	1.0	0.84	1.1	0.11
AVERAGE																	1.7	0.16	3.0	0.71
AREA AVERAGE	0.39	4	2.6	4	0.47	4	2.0	4	0.27	8	2.1	8	0.11	4	1.17	2				
HALL (BACKGROUND)																				
PCM ANALYSIS	0.05	2															0.048	0.044	0.053	0.007
					0.07	2			0.13	2							0.100	0.043	0.140	0.042
									0.006	2			0.008	2			0.007	0.006	0.009	0.001
AVERAGE																	0.052	0.043	0.096	0.049
TEM ANALYSIS			0.5	2													0.50	0.45	0.55	0.07
							0.65	2			1.3	2					0.98	0.65	1.5	0.41
											0.51	2			0.26	2	0.39	0.23	0.62	0.17
AVERAGE																	0.63	0.23	1.50	0.375
OUTDOOR AMBIENT																				
PCM ANALYSIS	0.002	2			0.002	2			0.003	2			0.002	2			0.002	0.001	0.003	0.001

*f/cc = fibers/cc as/cc = asbestos structures/cc ST D = Standard Deviation n = number of samples

TABLE A4-2 AREA SAMPLING RESULTS PIPE LAGGING REMOVAL AT FACILITY 2

Analysis: PCM using NIOSH 7400-B Method (f/cc)*
TEM using EPA Provisional Method (as/cc)*

	JUNE 25 ROOM D				JUNE 26 ROOM D				JUNE 27 ROOM D				JUNE 28 ROOM E								
MPLING SITE	PCM		TEM		PCM		TEM		PCM		TEM		PCM		TEM						
	f/cc	n*	as/cc	n	f/cc	n	as/cc	n	f/cc	n	as/cc	n	f/cc	n	as/cc	n	MEAN	MIN	MAX	ST D*	n
AR WORKERS																					
PCM ANALYSIS	0.52	2			0.15	4			0.38	2							0.30	0.09	0.58	0.17	8
													0.17	4			0.17	0.05	0.33	0.10	4
AVERAGE																	0.26	0.05	0.58	0.16	12
TEM ANALYSIS			2.53	2			1.17	2			2.37	2					2.02	0.83	3.76	1.00	6
															2.60	4	2.6	1.20	5.02	1.46	4
AVERAGE																	2.25	0.83	5.02	1.24	10
OM (BACKGROUND)																					
PCM ANALYSIS	0.61	2			0.17	4			0.03	1							0.30	0.03	0.77	0.22	8
													0.18	4			0.18	0.09	0.34	0.10	4
AVERAGE																	0.26	0.03	0.77	0.20	12
TEM ANALYSIS			3.24	2			2.17	4			1.55	2					2.28	1.33	3.22	0.77	8
															2.93	4	2.93	1.20	4.51	1.27	4
AVERAGE																	2.49	1.20	4.51	1.01	12
EA AVERAGE	0.57	4	2.88	4	0.16	8	1.83	6	0.27	3	1.96	4	0.18	8	2.76	8					
LL (BACKGROUND)																					
PCM ANALYSIS	0.35	2			0.13	4			0.01	2							0.16	0.01	0.43	0.16	8
													0.02	4			0.02	0.00	0.04	0.01	4
AVERAGE																	0.11	0.00	0.43	0.14	12
TEM ANALYSIS			1.56	2			2.27	4			1.03	2					1.78	0.60	2.51	0.65	8
															1.3	4	1.3	0.46	2.35	0.83	4
AVERAGE																	1.62	0.46	2.51	0.75	12
TDOOR AMBIENT																					
PCM ANALYSIS	0.001	2			0.001	2			0.001	2			0.001	2			0.001	0.001	0.001	0.000	8

f/cc = fibers/cc as/cc = asbestos structures/cc n = number of samples ST D = Standard Deviation

TABLE A4-3 AREA SAMPLING RESULTS PIPE LAGGING REMOVAL AT FACILITY 3

Analysis: PCM using NIOSH 7400-B Method (f/cc)*
TEM using EPA Provisional Method (as/cc)*

SAMPLING SITE	JULY 01 ROOM F PCM f/cc	n*	JULY 01 TEM as/cc	n	JULY 02 ROOM G PCM f/cc	n	JULY 02 TEM as/cc	n	JULY 03 ROOM G PCM f/cc	n	JULY 03 TEM as/cc	n	MEAN	MIN	MAX	ST D*	n
NEAR WORKERS																	
PCM ANALYSIS	0.434	2															
	0.473	2			0.445	2			0.616	2							
					0.800	2											
AVERAGE	0.453	4			0.623	4			0.616	2			0.583	0.002	0.956	0.31	8
(TEM ANALYSIS NOT COMPLETED)				2				4				2					8
ROOM (BACKGROUND)																	
PCM ANALYSIS	0.423	2															
	0.443	2			0.467	2			0.546	2							
					0.789	2											
AVERAGE	0.436	4			0.628	4			0.546	2			0.546	0.258	0.816	0.19	8
(TEM ANALYSIS NOT COMPLETED)				2				4				2					8
AREA AVERAGE	0.444	0			0.625	8			0.581	4			0.565	0.002	0.956	0.24	20
HALL (BACKGROUND)																	
PCM ANALYSIS	0.012	2			0.001	2			0.300	2							
					0.451	2											
AVERAGE	0.012	2			0.226	4			0.300	2			0.155	0.001	0.458	0.23	8
(TEM ANALYSIS NOT COMPLETED)				2				4				2					8
OUTDOOR AMBIENT																	
PCM ANALYSIS	0.001	2			0.001	2			0.001	2			0.001				6

* f/cc = fibers/cc as/cc = asbestos structures/cc n = number of samples ST D = Standard Deviation

TABLE A4-4 AREA SAMPLING RESULTS PIPE LAGGING REMOVAL AT FACILITY 4

Analysis: PCM using NIOSH 7400-B Method (f/cc)*
TEM using EPA Provisional Method (as/cc)*

SAMPLING SITE	JULY 15 ROOM H PCM f/cc	n*	TEM as/cc	n	JULY 16 ROOM I PCM f/cc	n	TEM as/cc	n	JULY 17 ROOM J PCM f/cc	n	TEM as/cc	n	MEAN	MIN	MAX	ST D*	n
NEAR WORKERS																	
PCM ANALYSIS	0.007	2			0.013	1**			0.003	2							
									0.006	2							
AVERAGE	0.007	2			0.013	1			0.004	4			0.006	0.001	0.013	0.004	7
(TEM ANALYSIS NOT COMPLETED)																	
ROOM (BACKGROUND)																	
PCM ANALYSIS	0.007	2			0.032	2***			0.004	2							
									0.013	2							
AVERAGE	0.007	2			0.032	2			0.009	4			0.012	0.002	0.051	0.016	8
(TEM ANALYSIS NOT COMPLETED)																	
AREA AVERAGE	0.007	4			0.026	3			0.006	6							
HALL (BACKGROUND)																	
PCM ANALYSIS	0.002	2			0.002	2			0.001	2							
									0.004	2							
AVERAGE	0.002	2			0.002	2			0.002	4			0.002	0.001	0.004	0.001	8
(TEM ANALYSIS NOT COMPLETED)																	
OUTDOOR AMBIENT																	
PCM ANALYSIS	0.001	2			0.001	2			0.001	2			0.001				6

* f/cc = fibers/cc as/cc = asbestos structures/cc n = number of samples ST D = Standard Deviation

** The other filter sample of this pair was overloaded with particulates; unable to count.

*** One of the paired samples was overloaded with particulates; unable to count. However, a 20 min short term area sample which measured 0.051 f/cc was included in this average .

TABLE A5-1 MEAN ASBESTOS STRUCTURE AND ASBESTOS FIBER CONCENTRATIONS AT FACILITY 1

Analysis by TEM using EPA Provisional Method

Sample	Structures/m^3	Fibers/m^3
Pre-Removal		
Nonaggressive	77,000	65,000
Aggressive	167,000	139,000
Post-Removal		
Nonaggressive	148,000	140,000
Aggressive	385,000	294,000

TABLE A5-2 MEAN ASBESTOS STRUCTURE AND ASBESTOS FIBER CONCENTRATIONS AT FACILITY 2

Analysis by TEM using EPA Provisional Method

Sample	Structures/m^3	Fibers/m^3
Pre-Removal		
Nonaggressive	85,700	73,800
Aggressive	119,000	113,000
Post-Removal		
Nonaggressive	260,000	232,000
Aggressive	283,000	217,000

TABLE A5-3 MEAN ASBESTOS STRUCTURE AND ASBESTOS FIBER CONCENTRATIONS AT FACILITY 3

Analysis by TEM using EPA Provisional Method

Sample	Structures/m^3	Fibers/m^3
Pre Removal		
Nonaggressive	N/C	N/C
Aggressive	130,000	80,000
Post Removal		
Nonaggressive	N/C	N/C
Aggressive	130,000	110,000

N/C - Analysis not completed.

TABLE A5-4 MEAN ASBESTOS STRUCTURE AND ASBESTOS FIBER CONCENTRATIONS AT FACILITY 4

Analysis by TEM using EPA Provisional Method

Sample	Structures/m^3	Fibers/m^3
Pre Removal		
Nonaggressive	N/C	N/C
Aggressive	270,000	200,000
Post Removal		
Nonaggressive	N/C	N/C
Aggressive	80,000	62,000

N/C - Analysis not completed.

TABLE A6-1 COMPARISON OF MEAN PRE- AND POST-REMOVAL AREA SAMPLING AT FACILITY 1

Analysis: PCM using NIOSH 7400-B Method (f/cc)*
TEM using EPA Provisional Method (as/cc)*

LOCATION	JUNE 14 PRE-REMOVAL SAMPLES: NIOSH PCM AND TEM f/cc	n	as/cc	n	EPA TEM ANALYSIS** as/cc Total	>5 um long	n	JULY 9 POST-REMOVAL SAMPLES: NIOSH PCM AND TEM f/cc	n	as/cc	n	EPA TEM ANALYSIS** as/cc Total	>5 um long	n
NONAGGRESSIVE SAMPLING METHOD														
ROOM A	0.002	6	0.001	1	0.089	0.009	3	0.003	6	0.003	1	0.065	0.005	3
ROOM B	0.006	6	0.000	1	0.065	0.005	3	0.007	6	0.028	1	0.230	0.005	3
OUTSIDE ROOM A	None Taken							0.003	1	0.065	1			
OUTDOOR AMBIENT	0.001	2	0.003	2				0.001	2***	0.006	2***			
AGGRESSIVE SAMPLING METHOD														
ROOM A	0.015	6	0.028	1	0.140	0.009	3	0.017	6	0.110	1	0.260	0.013	3
ROOM B	0.021	6	0.160	1	0.190	0.027	3	0.035	6	1.400	1	0.558	0.071	3
OUTSIDE ROOM A	None Taken							0.005	1	0.220	1			
OUTDOOR AMBIENT	None Taken							0.001	2***	0.006	2***			

* f/cc = fibers/cc as/cc = asbestos structures/cc n = number of samples
** Sample volumes are approximately 1,500 liters. The lower limit of detection (LOD) is 0.010 as/cc. Analyses reported "below the LOD" are entered at half of the LOD = 0.005 as/cc.
*** These two samples were collected for a double shift; therefore, volumes = 3,000 liters.

TABLE A6-2 COMPARISON OF MEAN PRE- AND POST-REMOVAL AREA SAMPLING AT FACILITY 2

Analysis: PCM using NIOSH 7400-B Method (f/cc)*
TEM using EPA Provisional Method (as/cc)*

LOCATION	JUNE 12 PRE-REMOVAL SAMPLES: NIOSH PCM AND TEM f/cc	n*	as/cc	n	EPA TEM ANALYSIS** as/cc Total	>5 um long	n	JULY 11 POST-REMOVAL SAMPLES: NIOSH PCM AND TEM f/cc	n	as/cc	n	EPA TEM ANALYSIS** as/cc Total	>5 um long	n
NONAGGRESSIVE SAMPLING METHOD														
ROOM D	0.001	6			0.114	0.005	3	0.001	6			0.353	0.005	3
ROOM E	0.002	6			0.056	0.005	3	0.002	6			0.166	0.005	3
OUTSIDE HALL								0.002	2					
OUTDOOR AMBIENT			0.002	2***						0.002	2***			
AGGRESSIVE SAMPLING METHOD														
ROOM D	0.002	6			0.054	0.005	3	0.008	6			0.356	0.038	3
ROOM E	0.016	6			0.184	0.005	3	0.037	6			0.209	0.008	3
OUTSIDE HALL								0.005	2					
OUTDOOR AMBIENT	0.001	2	0.002	2***				0.001	4	0.01	2***			

* f/cc = fibers/cc as/cc = asbestos structures/cc n = number of samples
** These sample volumes are approximately 1,500 liters. The lower limit of detection (LOD) is 0.010 as/cc. Analyses reported below the LOD are entered at half of the LOD = 0.005 as/cc.
*** These are 25-mm cellulose ester filter samples analyzed by NIOSH 7402 method, March, 1987 revision. The Lower Limit of Detection for a 2500 l sample is about 0.002 as/cc.

TABLE A6-3 COMPARISON OF MEAN PRE- AND POST-REMOVAL AREA SAMPLING AT FACILITY 3

Analysis: PCM using NIOSH 7400-B Method (f/cc)*
TEM using EPA Provisional Method (as/cc)*

LOCATION	JUNE 13 PRE-REMOVAL SAMPLES							JULY 10 POST-REMOVAL SAMPLES						
	NIOSH PCM AND TEM				EPA TEM ANALYSIS** as/cc			NIOSH PCM AND TEM				EPA TEM ANALYSIS** as/cc		
	f/cc	n*	as/cc	n	Total	>5 um long	n	f/cc	n	as/cc	n	Total	>5 um long	n
					NONAGGRESSIVE SAMPLING METHOD									
ROOM F	0.002	6	N/C		N/C	N/C	3	0.001	6	N/C		N/C	N/C	3
ROOM G	0.003	6	N/C		N/C*	N/C	3	0.001	6	N/C		N/C	N/C	3
HALL ROOM F								0.001	2	N/C				
HALL ROOM G								0.001	2	N/C				
					AGGRESSIVE SAMPLING METHOD									
ROOM F	0.008	5	N/C		0.06	0.012	3	0.020	6	N/C		0.10	0.006	3
ROOM G	0.075	6	N/C		0.20	0.037	3	0.002	6	N/C		0.15	0.007	3
HALL ROOM F								0.003	1	N/C				
HALL ROOM G								0.000	1	N/C				
OUTDOOR AMBIENT	0.002	2	0.002	2***				0.000	2	0.002	2***			

* f/cc = fibers/cc as/cc = asbestos structures/cc n = number of samples
N/C - Analysis not completed
** These sample volumes are approximately 1,500 liters. The lower limit of detection (LOD) is 0.010 as/cc. Analyses reported below the LOD are entered at half of the LOD (0.005 as/cc).
*** These samples were collected on 25mm cellulose ester filters and analyzed by NIOSH Method 7402, March 1987 revision.

TABLE A6-4 COMPARISON OF MEAN PRE- AND POST-REMOVAL AREA SAMPLING AT FACILITY 4

Analysis: PCM using NIOSH 7400-B Method (f/cc)*;
TEM using EPA Provisional Method (as/cc)*

LOCATION	JULY 12 PRE REMOVAL SAMPLES							JULY 18 POST REMOVAL SAMPLES						
	NIOSH PCM AND TEM				EPA TEM ANALYSIS** as/cc			NIOSH PCM AND TEM				EPA TEM ANALYSIS** as/cc		
	f/cc	n*	as/cc	n	Total	>5 um long	n	f/cc	n	as/cc	n	Total	>5 um long	n
					NONAGGRESSIVE SAMPLING METHOD									
ROOM H	0.001	6	N/C		N/C	N/C	3	0.001	6	N/C		N/C	N/C	3
ROOM I	0.002	6	N/C*		N/C	N/C	3	0.001	6	N/C		N/C	N/C	3
HALL ROOM H	0.001	1	N/C					0.001	1	N/C				
HALL ROOM I	0.001	1	N/C					0.003	1	N/C				
					AGGRESSIVE SAMPLING METHOD									
ROOM H	0.004	6	N/C		0.24	0.012	3	0.002	6	N/C		0.07	0.007	3
ROOM I	0.010	6	N/C		0.30	0.014	3	0.003	6	N/C		0.09	0.021	3
HALL ROOM H	0.001	1	N/C					0.001	1	N/C				
HALL ROOM I	0.026	1	N/C					0.000	1	N/C				
OUTDOOR AMBIENT	0.001	2	0.001	2***				0.001	2	0.001	2***			

* f/cc = fibers/cc as/cc = asbestos structures/cc n = number of samples
N/C - Analysis not completed for these samples
** These sample volumes are approximately 1,500 liters. The TEM lower limit of detection (LOD) is 0.010 as/cc. Analyses reported below the LOD are entered at half of the LOD (0.005 as/cc).
*** These ambient samples were collected on 25mm cellulose ester filters and analyzed by NIOSH method 7402 March 1987 revision. The lower limit of detection for a 3000 l sample is about 0.002 as/cc. None detected values are reported here at half the LOD.

TABLE A7-1 EVALUATION OF WORK PRACTICES AT FACILITY 1

TASK	6/18/85 AM / PM ROOM B	6/19/85 AM / PM ROOM A	6/20/85 AM / PM <-----ROOM C	-----> 6/21/85 AM / PM
	WORK PRACTICE RATING#			
Prepare Pipe	A / -	A / -	- / -	- / -
Install Bag	P / -	P / -	- / -	A / -
Wet Pipe Lagging	P / P	- / P	A / A	A / P
Remove Lagging (use of bag)	P / P	- / P	P / A	A / A
Move Bag	- / P	- / P	P / A	G / A
Remove Bag	- / A	- / A	A / A	G / P
Clean Pipe	- / A	- / A	A / A	A / A
Decontaminate Room	- / A	- / -	A / A	A / A
Number of Bags Used	(5)	(12)	(13)	

\# SUBJECTIVE RATING VALUES: P - POOR A - AVERAGE G - GOOD

TABLE A7-2 EVALUATION OF WORK PRACTICES AT FACILITY 2

TASK	6/25/85 AM / PM <-----ROOM D	-----> 6/26/85 AM / PM	6/27/85 AM / PM <-----ROOM E	-----> 6/28/85 AM / PM
	WORK PRACTICE RATING#			
Prepare Pipe	G / -	- / -	- / A	- / -
Install Bag	A / -	A / -	- / G	G / -
Wet Pipe Lagging	- / A	A / A	A / -	A / A
Remove Lagging (use of bag)	- / A	A / A	A / -	A / G
Move Bag	- / A	A / A	A / -	A / G
Remove Bag	- / A	G / G	G / -	A / G
Clean Pipe	- / A	A / A	A / -	A / A
Decontaminate Room	- / G	- / G	- / -	- / G
Number of Bags Removed	0 / 3	4 / 2	7 / 0	4 / 0

\# SUBJECTIVE RATING VALUES: P - POOR A - AVERAGE G - GOOD

TABLE A7-3 EVALUATION OF WORK PRACTICES AT FACILITY 3

	7/1/85	7/2/85	7/3/85
Date	7/1/85	7/2/85	7/3/85
Time	AM / PM	AM / PM	AM / PM
Site	<----ROOM F--->/		<---ROOM G--->
TASK	**WORK PRACTICE RATING#**		
Prepare Pipe	A / -	- / -	- / -
Install Bag	G / -	A / -	A / G
Wet Pipe Lagging	- / A	A / A	A / -
Remove Lagging (use of bag)	- / A	A / A	G / -
Move Bag	- / G	- / G	G / A
Remove Bag	- / A	G / A	A / -
Clean Pipe	- / A	G / G	A / -
Decontaminate Room	- / A	G / G	G / -
Number of Bags Removed	0 / 3	6 / 3	3 / 0

\# SUBJECTIVE RATING VALUES: P = POOR A = AVERAGE G = GOOD

TABLE A7-4 EVALUATION OF WORK PRACTICES AT FACILITY 4

Date	7/15/85	7/16/85	7/17/85
Time	AM / PM	AM / PM	AM / PM
Site	ROOM H	ROOM I	ROOM J
TASK	**WORK PRACTICE RATING#**		
Prepare Pipe	A / -	- / -	- / -
Install Bag	G / -	- / -	- / -
Wet Pipe Lagging	A / A	A / -	G / G
Remove Lagging (use of bag)	G / A	A / -	A / A
Move Bag	G / G	A / -	G / A
Remove Bag	G / G	G / -	A / A
Clean Pipe	G / G	A / -	G / G
Decontaminate Room	- / G	A / -	- / G
Number of Bags Removed	(6)	(6)	(8)

\# SUBJECTIVE RATING VALUES: P = POOR A = AVERAGE G = GOOD

APPENDIX B

TABULATION OF DATA OBTAINED USING

PHASE CONTRAST MICROSCOPY (PCM)

AND MAGISCAN II

TABLE B1-1

LEGEND FOR FACILITY 1 PCM DATA

LOC	(Facility and room location of sampled activity)	
1xxx		Facility 1
RMA		Room A
RMB		Room B
RMC		Room C
RM9		Room 109
TLG		Teachers Lounge
FB		Field Blank no sample taken
SAMPLE CLASS		(Sample type and location, activity, and ID)
Location		
FB		Field Blank
IA		Interior Area (Background in the work room)
OA		Outside Area (in the hall)
AM		Ambient (Outside the building)
BZ		Personal Breathing Zone
CT		Mobile Sampling Cart (proximate to the work activity)
Activity		
PRE		Pre-removal activity - Full term sample
PST		Post-removal activity - Full term sample
REM		Removal work - Full term sequential sample
COV		Preparation - Full term sequential
RMS		Removal work - 15 minute short term PBZ sample
COS		Preparation - 15 minute short term PBZ
SEQ		Sample period covers sequential work activities
ID		
AGGR		Aggressive sampling mode
NAGR		Nonaggressive sampling mode
WK#X		Worker #X PBZ sample
mm/dd		Actual date of blank source
SAMPLE No.		Sample media Identification code and number
AAxxx		25-mm Cellulose Ester Filter Sample Number xxx (using a foil wrapped 2-inch cowl)
Mxxx		37-mm Cellulose Ester Filter Sample Number xxx
Nxxx		37-mm Polycarbonate Filter Sample Number xxx
RATE		Sample flow rate in liters per minute (lpm)
VOL		Sample volume in liters (l)
MAGISCAN II		Magiscan II is a computerized image analysis system for PCM; results are in total fibers per cubic centimeter

Phase Contrast Microscopy using NIOSH Method 7400B counting rules

UBTL	PCM analysis performed by Utah Biological Testing Labs
NIOSH	PCM analysis performed in the NIOSH Laboratory
Fibers	Total fibers
f/cc	Fibers per cubic centimeter

TABLE B1-2

PHASE CONTRAST MICROSCOPY ANALYTICAL RESULTS
FOR AIRBORNE ASBESTOS ANALYSIS
FACILITY 1
CINCINNATI, OHIO
June 14, 18 - 21 & July 9, 1985

NOTE: For samples reported less than detectable, one half of the limit of detection is used as follows:

LAB	25-mm Filter	37-mm Filter
UBTL	750	1750
NIOSH	1347	2992

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II Fibers	MAGISCAN II f/cc	UBTL Fibers	UBTL f/cc	NIOSH Fibers	NIOSH f/cc
1RMB	IA-PRE-AGGR	AA79	6/14	1611	0211	480	3.25	1560.0	70070	0.045		0.000		
1RMB	IA-PRE-AGGR	AA80	6/14	1811	0211	480	3.20	1536.0	66990	0.044	23000	0.015		
1RMB	IA-PRE-AGGR	AA90	6/14	1811	0211	480	3.25	1560.0	74690	0.048	26000	0.017	25795	0.017
1RMB	IA-PRE-AGGR	M332	6/14	1811	0211	480	3.25	1560.0	101745	0.065	30000	0.019	88065	0.056
1RMB	IA-PRE-AGGR	M334	6/14	1811	0211	480	3.25	1560.0	71820	0.046	35000	0.022		
1RMB	IA-PRE-AGGR	M340	6/14	1811	0211	480	3.20	1536.0	112005	0.073	30000	0.020	58995	0.038
1RMB	IA-PRE-NAGR	AA61	6/14	0938	1738	480	3.25	1560.0	24255	0.016	6000	0.004		
1RMB	IA-PRE-NAGR	AA75	6/14	0938	1738	480	3.00	1440.0	41195	0.029	2000	0.001		
1RMB	IA-PRE-NAGR	AA99	6/14	0938	1738	480	3.25	1560.0	54285	0.035	3000	0.002		
1RMB	IA-PRE-NAGR	M327	6/14	0938	1738	480	3.00	1440.0	30780	0.021	1750	0.001		
1RMB	IA-PRE-NAGR	M331	6/14	0938	1738	480	3.25	1560.0	30780	0.020	4000	0.003		
1RMB	IA-PRE-NAGR	M335	6/14	0938	1738	480	3.25	1560.0	47025	0.030	4000	0.003		
1RMA	IA-PRE-AGGR	AA63	6/14	1923	0330	487	3.25	1582.8	29645	0.019	21000	0.013	33495	0.021
1RMA	IA-PRE-AGGR	AA72	6/14	1923	0330	487	3.25	1582.8	46200	0.029	35000	0.022	37730	0.024
1RMA	IA-PRE-AGGR	AA87	6/14	1923	0330	487	3.00	1461.0	35420	0.024	30000	0.021		
1RMA	IA-PRE-AGGR	M324	6/14	1923	0330	487	3.25	1582.8	73530	0.046	30000	0.019		
1RMA	IA-PRE-AGGR	M325	6/14	1923	0330	487	3.25	1582.8	83790	0.053	44000	0.028	57285	0.036
1RMA	IA-PRE-AGGR	M329	6/14	1923	0330	487	3.00	1461.0	87210	0.060	30000	0.021	56430	0.039
1RMA	IA-PRE-NAGR	AA70	6/14	1037	1840	483	3.30	1593.9	34265	0.021	6000	0.004	16170	0.010
1RMA	IA-PRE-NAGR	AA74	6/14	1037	1840	483	3.25	1569.8	81620	0.052	10000	0.006	16555	0.011
1RMA	IA-PRE-NAGR	AA98	6/14	1037	1840	483	3.25	1569.8	74690	0.048	10000	0.006	26565	0.017
1RMA	IA-PRE-NAGR	M321	6/14	1037	1840	483	3.25	1569.8	47025	0.030	9000	0.006		
1RMA	IA-PRE-NAGR	M338	6/14	1037	1840	483	3.20	1545.6	34200	0.022	10000	0.006		
1RMA	IA-PRE-NAGR	M339	6/14	1037	1840	483	3.25	1569.8	54720	0.035	10000	0.006		
1RM9	AM-PRE-NAGR	AA68	6/14	1026	1830	484	2.90	1403.6	11165	0.008	750	0.001		
1RM9	AM-PRE-NAGR	AA89	6/14	1026	1830	484	3.00	1452.0	8855	0.006	750	0.001		
1FB	FB-PRE-AGGR	AA62	6/14						1347		750			
1FB	FB-PRE-AGGR	AA95	6/14						1347		750		1347	
1FB	FB-PRE-NAGR	AA59	6/14						1347		750		1347	
1FB	FB-PRE-NAGR	AA60	6/14						1347		750		1347	
1FB	FB-PRE-NAGR	AA71	6/14						1347		750		1347	
1FB	FB-PRE-NAGR	AA92	6/14						1347		750		1347	
1FB	FB-PRE-NAGR	M322	6/14								1750			
1FB	FB-PRE-NAGR	M330	6/14						2992		1750		2992	
1FB	FB-PRE-NAGR	M337	6/14						2992		1750		2992	

TABLE B1-2 (Continued - page 2)

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II Fibers	MAGISCAN II f/cc	UBTL Fibers	UBTL f/cc	NIOSH Fibers	NIOSH f/cc
1RMB	BZ-COV-WK#1	AA148	6/18	0930	1126	116	3.10	359.6	87010	0.242			11550	0.032
1RMB	BZ-COV-WK#2	AA111	6/18	0930	1126	116	2.96	343.4	8855	0.026			10010	0.029
1RMB	BZ-COV-WK#3	AA150	6/18	0930	1126	116	3.12	361.9	17325	0.048			11550	0.032
1RMB	BZ-COV-WK#4	AA91	6/18	0930	1126	116	3.06	355.0	20405	0.057			19250	0.054
1RMB	BZ-REM-WK#1	AA51	6/18	1235	1515	160	3.16	505.6	77385	0.153			202895	0.401
1RMB	BZ-REM-WK#2	AA142	6/18	1235	1520	165	2.96	488.4	169015	0.346			1347	0.003
1RMB	BZ-REM-WK#3	AA143	6/18	1235	1515	160	3.12	499.2	219065	0.439			1347	0.003
1RMB	BZ-REM-WK#4	AA138	6/18	1235	1520	165	3.06	504.9	96635	0.191			163625	0.324
1RMB	CT-COV	AA64	6/18	0932	1126	114	3.16	360.2	12705	0.035			10010	0.028
1RMB	CT-COV	AA139	6/18	0932	1126	114	3.02	344.3	8085	0.023			13860	0.040
1RMB	CT-COV	AA140	6/18	0940	1126	106	3.00	318.0	12320	0.039			7315	0.023
1RMB	CT-COV	AA141	6/18	0932	1126	114	3.06	348.6	6930	0.020			9625	0.028
1RMB	CT-REM	AA22	6/18	1240	1520	160	3.00	480.0	72380	0.151			147070	0.306
1RMB	CT-REM	AA52	6/18	1240	1520	160	3.16	505.6	113190	0.224			207515	0.410
1RMB	IA-COV	AA66	6/18	0932	1126	114	3.11	354.5	12705	0.036			6545	0.018
1RMB	IA-COV	AA69	6/18	0932	1126	114	3.14	358.0	9240	0.026			6930	0.019
1RMB	IA-REM	AA24	6/18	1239	1520	161	3.10	499.1	92785	0.186			191730	0.384
1RMB	IA-REM	AA50	6/18	1239	1520	161	3.10	499.1	108185	0.217			219835	0.440
1RMB	OA-SEQ	AA67	6/18	0934	1413	279	3.00	837.0	33495	0.040			44275	0.053
1RMB	OA-SEQ	AA137	6/18	0934	1413	279	3.00	837.0	34265	0.041			36575	0.044
1TLG	AM-SEQ	AA65	6/18	0740	1530	470	3.00	1410.0	31955	0.023			1347	0.001
1TLG	AM-SEQ	AA93	6/18	0740	1530	470	2.80	1316.0	31570	0.024			4235	0.003
1FB	FB-COV-6/14	AA55	6/18						1347				1347	
1FB	FB-REM-6/14	AA56	6/18						1347				1347	
1RMA	BZ-COS-WK#2	AA5	6/19	1043	1058	15	3.00	45.0	2695	0.060			1347	
1RMA	BZ-COS-WK#4	AA48	6/19	1111	1126	15	3.00	45.0	1347	0.030			1347	0.030
1RMA	BZ-COV-WK#1	AA44	6/19	0939	1129	110	3.06	336.6	36190	0.108			8816	0.026
1RMA	BZ-COV-WK#2	AA45	6/19	1038	1129	51	3.12	159.1	15015	0.094			5852	0.037
1RMA	BZ-COV-WK#3	AA43	6/19	0935	1129	114	2.96	337.4	40040	0.119			9779	0.029
1RMA	BZ-COV-WK#4	AA42	6/19	0938	1129	111	3.09	343.0	39270	0.114			11742	0.034
1RMA	BZ-REM-WK#1	AA3	6/19	1249	1448	119	3.06	364.1	197120	0.541			199045	0.547
1RMA	BZ-REM-WK#2	AA47	6/19	1250	1459	129	3.12	402.5	147070	0.365			50050	0.124
1RMA	BZ-REM-WK#3	AA1	6/19	1247	1459	132	3.09	411.0	189035	0.460			184030	0.448
1RMA	BZ-REM-WK#4	AA35	6/19	1248	1429	101	3.00	303.0	108185	0.357			193270	0.638
1RMA	BZ-RMS-WK#2	AA126	6/19	1440	1455	15	3.00	45.0	46585	1.035			47355	1.052
1RMA	BZ-RMS-WK#4	AA7	6/19	1333	1348	15	3.00	45.0	45045	1.001			31955	0.710
1RMA	BZ-RMS-WK#4	AA127	6/19	1448	1503	15	3.00	45.0	35035	0.779			41195	0.915
1RMA	BZ-RMS-WK#4	AA128	6/19	1300	1315	15	3.00	45.0	33880	0.753			42735	0.950
1RMA	CT-COV	AA40	6/19	0933	1130	117	3.05	356.9	22330	0.063			3187	0.009
1RMA	CT-COV	AA41	6/19	0933	1130	117	3.12	365.0	22330	0.061			10510	0.029
1RMA	CT-REM	AA25	6/19	1245	1518	153	3.12	477.4	172865	0.362			211750	0.444
1RMA	CT-REM	AA53	6/19	1245	1518	153	3.00	459.0	194425	0.424			225995	0.492
1RMA	IA-COV	AA37	6/19	0933	1130	117	3.06	358.0	17325	0.048			3207	0.009
1RMA	IA-COV	AA39	6/19	0933	1130	117	3.14	367.4	25025	0.068			6121	0.017
1RMA	IA-REM	AA23	6/19	1245	1518	153	3.06	468.2	176715	0.377			276045	0.590
1RMA	IA-REM	AA28	6/19	1245	1518	153	3.14	480.4	142835	0.297			163240	0.340
1RMA	OA-FIM	AA31	6/19	0933	1406	273	3.16	862.7	48510	0.056			82778	0.096
1RMA	OA-FIM	AA38	6/19	0933	1406	273	3.00	819.0	58135	0.071			35535	0.043
1TLG	AM-SEQ	AA21	6/19	0804	1540	456	3.00	1368.0	19250	0.014			1347	0.001
1TLG	AM-SEQ	AA54	6/19	0804	1540	456	2.70	1231.2	43505	0.035			3888	0.003
1FB	FB-COV	AA4	6/19	0933	0934	1	3.00	3.0	1347				1347	
1FB	FB-COV-6/14	AA57	6/19	0933	0934	1	3.00	3.0	1347				1347	
1FB	FB-REM-6/14	AA58	6/19	1245	1246	1	3.00	3.0	1347				1347	

TABLE B1-2 (Continued - page 3)

		SAMPLE		PERIOD		TIME	RATE	VOL.	MAGISCAN II		UBTL		NIOSH	
LOC.	SAMPLE CLASS	No.	Date	Start	Stop	(min)	(lpm)	(l)	Fibers	f/cc	Fibers	f/cc	Fibers	f/cc
1RMC	BZ-REM-WK#1	AA13	6/20	1242	1447	125	3.12	390.0	215215	0.528			205975	0.528
1RMC	BZ-REM-WK#2	AA26	6/20	1241	1510	149	3.00	447.0	108570	0.243			133595	0.299
1RMC	BZ-REM-WK#3	AA125	6/20	1240	1510	150	3.02	453.0	100870	0.223			196350	0.433
1RMC	BZ-REM-WK#4	AA12	6/20	1240	1510	150	3.06	459.0	109340	0.238			132440	0.289
1RMC	BZ-RMS-WK#1	AA11	6/20	1408	1423	15	2.50	37.5	18095	0.483			14360	0.383
1RMC	BZ-RMS-WK#2	AA121	6/20	1259	1314	15	2.50	37.5	12320	0.329			5390	0.144
1RMC	BZ-RMS-WK#4	AA20	6/20	1330	1345	15	2.50	37.5	31570	0.842			41965	1.119
1RMC	CT-REM	AA6	6/20	1236	1519	163	3.14	511.8	98945	0.193			104335	0.204
1RMC	CT-REM	AA9	6/20	1236	1519	163	3.00	489.0	83160	0.170			88935	0.182
1RMC	IA-REM	AA2	6/20	1241	1519	158	3.00	474.0	103950	0.219			108955	0.230
1RMC	IA-REM	AA32	6/20	1241	1519	158	3.12	493.0	100670	0.205			94710	0.192
1RMC	OA-SEQ	AA33	6/20	1239	1520	161	3.00	483.0	11165	0.023			2695	0.006
1RMC	OA-SEQ	AA124	6/20	1239	1520	161	3.16	508.6	6160	0.012			3465	0.007
1RM3	BZ-REM-WK#1	AA19	6/20	0751	0957	126	3.17	399.4	162470	0.407			165935	0.415
1RM3	BZ-REM-WK#2	AA14	6/20	0752	0957	125	3.00	375.0	109725	0.293			134365	0.358
1RM3	BZ-REM-WK#3	AA122	6/20	0752	0957	125	3.02	377.5	119735	0.317			209055	0.554
1RM3	BZ-REM-WK#4	AA27	6/20	0754	1008	134	3.06	410.0	99715	0.243			132440	0.323
1RM3	BZ-RMS-WK#1	AA29	6/20	0812	0827	15	2.50	37.5	24640	0.657			28875	0.770
1RM3	BZ-RMS-WK#1	AA123	6/20	1007	1022	15	2.40	36.0	43120	1.198			39655	1.102
1RM3	BZ-RMS-WK#2	AA10	6/20	0947	1002	15	2.40	36.0	26180	0.727			18865	0.524
1RM3	BZ-RMS-WK#4	AA17	6/20	0904	0915	11	2.50	27.5	26180	0.952			32725	1.190
1RM3	CT-REM	AA147	6/20	0755	1054	179	3.00	537.0	108185	0.201			155540	0.290
1RM3	CT-REM	AA149	6/20	0755	1054	179	3.05	546.0	75075	0.138			224840	0.412
1RM3	IA-REM	AA16	6/20	0755	1053	178	3.00	534.0	128975	0.242			177485	0.332
1RM3	IA-REM	AA18	6/20	0755	1053	178	3.00	534.0	130130	0.244			155925	0.292
1RM3	OA-SEQ	AA8	6/20	0754	1104	190	3.11	590.9	91245	0.154			70840	0.120
1RM3	OA-SEQ	AA15	6/20	0754	1104	190	3.00	570.0	72765	0.128			82005	0.144
1TLG	AM-FTM	AA129	6/20	0720	1540	500	2.70	1350.0	75845	0.056			3465	0.003
1TLG	AM-FTM	AA130	6/20	0720	1540	500	2.90	1450.0	65835	0.045			3850	0.003
1FB	FB-REM-6/14	AA97	6/20	0720	0721	1	3.00	3.0	1347				1347	
1FB	FB-REM-6/14	AA146	6/20	0720	0721	1	3.00	3.0	1347				1347	
1RMC	BZ-REM-WK#4	AA152	6/21	0834	1203	209	3.12	652.1	81620	0.125			95865	0.147
1RMC	BZ-REM-WK#2	AA153	6/21	0842	1203	201	3.00	603.0	63140	0.105			70840	0.117
1RMC	BZ-REM-WK#1	AA157	6/21	0836	1203	207	3.06	633.4	168630	0.266			109340	0.173
1RMC	BZ-REM-WK#3	AA158	6/21	0835	1203	208	3.02	628.2	80465	0.128			78155	0.124
1RMC	CT-REM	AA151	6/21	0836	1206	210	3.00	630.0	73920	0.117			62755	0.100
1RMC	CT-REM	AA154	6/21	0836	1206	210	3.14	659.4	88550	0.134			83930	0.127
1RMC	OA-FTM	AA155	6/21	0832	1209	217	3.00	651.0	48125	0.074			4620	0.007
1RMC	OA-FTM	AA156	6/21	0832	1209	217	3.11	674.9	41195	0.061			5775	0.009
1RMC	IA-REM	AA171	6/21	0838	1206	208	3.10	644.8	74305	0.115			58520	0.091
1RMC	IA-REM	AA175	6/21	0838	1206	208	3.00	624.0	85470	0.137			82390	0.132
1RMC	BZ-RMS-WK#3	AA176	6/21	0918	0933	15	3.00	45.0	34650	0.770			29645	0.659
1RMC	BZ-RMS-WK#2	AA177	6/21	0943	0959	16	3.00	48.0	20790	0.433			16170	0.337
1RMC	BZ-RMS-WK#3	AA178	6/21	0906	0923	17	3.00	51.0	21945	0.430			21945	0.430
1RMC	BZ-RMS-WK#4	AA170	6/21	1027	1042	15	3.00	45.0	16555	0.368			11165	0.248
1TLG	AM-FTM	AA159	6/21	0720	1220	300	3.00	900.0	2356	0.003			1347	0.001
1TLG	AM-FTM	AA160	6/21	0720	1220	300	2.70	810.0	26180	0.032			1347	0.002

TABLE B1-2 (Continued - page 4)

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II Fibers	MAGISCAN II f/cc	UBTL Fibers	UBTL f/cc	NIOSH Fibers	NIOSH f/cc
1RMB	IA-PST-AGGR	AA447	7/09	1801	0207	486	3.00	1458.0	31955	0.022			16901	0.012
1RMB	IA-PST-AGGR	AA454	7/09	1801	0207	486	3.00	1458.0	29529	0.020			27951	0.019
1RMB	IA-PST-AGGR	AA459	7/09	1850	0207	437	3.00	1311.0	38731	0.030			14976	0.011
1RMB	IA-PST-AGGR	M827	7/09	1801	0207	486	3.50	1701.0	37021	0.022			29412	0.017
1RMB	IA-PST-AGGR	M829	7/09	1801	0207	486	3.00	1458.0	67032	0.046			38133	0.026
1RMB	IA-PST-AGGR	M831	7/09	1801	0207	486	3.40	1652.4	64296	0.039			29825	0.018
1RMB	OA-PST-AGGR	AA457	7/09	1801	0207	486	3.20	1555.2	14514	0.009			11627	0.007
1RMB	IA-PST-NAGR	AA389	7/09	0900	1700	480	3.05	1464.0	26026	0.018	750	0.001		
1RMB	IA-PST-NAGR	AA417	7/09	0900	1700	480	3.00	1440.0	25025	0.017	2000	0.001		
1RMB	IA-PST-NAGR	AA432	7/09	0900	1700	480	3.00	1440.0	12588	0.009			13744	0.010
1RMB	IA-PST-NAGR	M832	7/09	0900	1700	480	3.20	1536.0	89347	0.058			10944	0.007
1RMB	IA-PST-NAGR	M835	7/09	0900	1700	480	3.15	1512.0	76266	0.050	1750	0.001		
1RMB	IA-PST-NAGR	M837	7/09	0900	1700	480	3.05	1464.0	37021	0.025	1750	0.001		
1RMB	OA-PST-NAGR	AA416	7/09	0903	1700	477	3.00	1431.0	28952	0.020			9779	0.007
1RMA	IA-PST-AGGR	AA440	7/09	1814	0215	481	3.50	1683.5	52745	0.031			62216	0.037
1RMA	IA-PST-AGGR	AA448	7/09	1814	0215	481	3.00	1443.0	51243	0.036			72649	0.050
1RMA	IA-PST-AGGR	AA453	7/09	1814	0215	481	3.25	1563.3	49742	0.032			62293	0.040
1RMA	IA-PST-AGGR	M833	7/09	1814	0215	481	3.50	1683.5	82849	0.049			76180	0.045
1RMA	IA-PST-AGGR	M834	7/09	1814	0215	481	3.50	1683.5	106789	0.063			51471	0.031
1RMA	IA-PST-AGGR	M836	7/09	1814	0215	481	3.50	1683.5	136287	0.081	8000	0.005		
1RMA	OA-PST-AGGR	AA445	7/09	1814	0215	481	3.20	1539.2	42119	0.027			7584	0.005
1RMA	IA-PST-NAGR	AA381	7/09	0900	1700	480	3.00	1440.0	82351	0.057			5852	0.004
1RMA	IA-PST-NAGR	AA383	7/09	0900	1700	480	3.00	1440.0	85932	0.060	750	0.001		
1RMA	IA-PST-NAGR	AA458	7/09	0900	1700	480	2.95	1416.0	80195	0.057			7584	0.005
1RMA	IA-PST-NAGR	M826	7/09	0900	1700	480	3.10	1488.0	122607	0.082			20178	0.014
1RMA	IA-PST-NAGR	M828	7/09	0900	1700	480	3.20	1536.0	129278	0.084			13081	0.009
1RMA	IA-PST-NAGR	M830	7/09	0900	1700	480	3.05	1464.0	70281	0.048			14193	0.010
1RMA	OA-PST-NAGR	AA374	7/09	0903	1700	477	2.95	1407.2	35343	0.025	4000	0.003		
1TLG	AM-PST-NAGR	AA379	7/09	0853	0320	1107	2.85	3154.9	93247	0.026	750	0.000		
1TLG	AM-PST-NAGR	AA424	7/09	0853	1826	1107	3.00	3321.0	62793	0.018			5121	0.002
1FB	FB-PST-6/21	AA172	7/09	1814	1815				1347		750			
1FB	FB-PST-6/21	AA173	7/09	1814	1815		1.0		1347		750			
1FB	FB-PST-7/18	M950	7/09	1814	1815		1.0		2982		1750			
1FB	FB-PST-7/18	M951	7/09	1814	1815		1.0		10858		1750			

TABLE B2-1

LEGEND FOR FACILITY 2 PCM DATA

LOC	(Facility and room location of sampled activity)
2xxx	Facility 2
RMD	Room D
RME	Room E
EW	Outside the Executive Washroom window
FB	Field Blank no sample taken
SAMPLE CLASS	(Sample type and location, activity, and ID)
Location	
FB	Field Blank
IA	Interior Area (Background in the work room)
OA	Outside Area (in the hall)
AM	Ambient (Outside the building)
BZ	Personal Breathing Zone
CT	Mobile Sampling Cart (proximate to work activity)
Activity	
PRE	Pre-removal activity - Full-term sample
PST	Post-removal activity - Full-term sample
REM	Removal work - Full-term sequential sample
COV	Preparation - Full-term sequential
RMS	Removal work - 15-minute short-term PBZ sample
COS	Preparation - 15-minute short-term BZ
SEQ	Sample period covers sequential work activities
ID	
AGGR	Aggressive sampling mode
NAGR	Nonaggressive sampling mode
WK#X	Worker #X BZ sample
mm/dd	Actual date of blank source
SAMPLE No.	Sample media Identification code and number
AAxxx	25-mm Cellulose Ester Filter Sample Number xxx (using a foil wrapped 2-inch cowl)
Mxxx	37-mm Cellulose Ester Filter Sample Number xxx
Nxxx	37-mm Polycarbonate Filter Sample Number xxx
RATE	Sample flow rate in liters per minute (lpm)
VOL	Sample volume in liters (l)
MAGISCAN II	Magiscan II is a computerized image analysis system for PCM; results are in total fibers per cubic centimeter

Phase Contrast Microscopy using NIOSH Method 7400B counting rules

UBTL	PCM analysis performed by Utah Biological Testing Labs
NIOSH	PCM analysis performed in the NIOSH Laboratory
Fibers	Total fibers
f/cc	Fibers per cubic centimeter
POL	Particulate Overload - Unable to count.

TABLE B2-2

PHASE CONTRAST MICROSCOPY ANALYTICAL RESULTS
FOR AIRBORNE ASBESTOS ANALYSIS
FACILITY 2
CINCINNATI, OHIO
June 12, 25 - 28 & July 11, 1985

NOTE: For samples reported less than detectable, one half of the limit of detection is used as follows:

LAB	25-mm Filter	37-mm Filter
UBTL	750	1750
NIOSH	1347	2992

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II Fibers	MAGISCAN II f/cc	UBTL Fibers	UBTL f/cc	NIOSH Fibers	NIOSH f/cc
2RMD	IA-PRE-AGGR	AA106	6/12	2316	0723	487	3.25	1582.8	45045	0.028	3000	0.002		
2RMD	IA-PRE-AGGR	AA107	6/12	2316	0723	487	3.25	1582.8	21945	0.014	750	0.000		
2RMD	IA-PRE-AGGR	AA120	6/12	2316	0723	487	3.14	1529.2	39655	0.026			5621	0.004
2RMD	IA-PRE-AGGR	M268	6/12	2316	0723	487	3.25	1582.8	29070	0.018	1750	0.001		
2RMD	IA-PRE-AGGR	M274	6/12	2316	0723	487	3.25	1582.8	65322	0.041	1750	0.001		
2RMD	IA-PRE-AGGR	M270	6/12	2316	0723	487	3.06	1490.2	33601	0.023			2992	0.002
2RMD	IA-PRE-NAGR	AA116	6/12	1320	2134	494	3.12	1541.3	39270	0.025	750	0.000		
2RMD	IA-PRE-NAGR	AA117	6/12	1320	2134	494	3.25	1605.5	76230	0.047			1347	0.001
2RMD	IA-PRE-NAGR	AA118	6/12	1320	2134	494	3.25	1605.5	60445	0.038	2000	0.001		
2RMD	IA-PRE-NAGR	M262	6/12	1320	2134	494	3.12	1541.3	29925	0.019	1750	0.001		
2RMD	IA-PRE-NAGR	M272	6/12	1320	2134	494	3.25	1605.5	10780	0.007	1750	0.001		
2RMD	IA-PRE-NAGR	M278	6/12	1320	2134	494	3.25	1605.5	33687	0.021			2992	0.002
2RME	IA-PRE-AGGR	AA106	6/12	2358	0802	484	3.11	1505.2	43505	0.029			27335	0.018
2RME	IA-PRE-AGGR	AA109	6/12	2358	0802	484	3.25	1573.0	50820	0.032	15000	0.010		
2RME	IA-PRE-AGGR	AA119	6/12	2358	0802	484	3.25	1573.0	69685	0.044	10000	0.006		
2RME	IA-PRE-AGGR	M256	6/12	2358	0802	484	3.25	1573.0	90630	0.058	30000	0.019		
2RME	IA-PRE-AGGR	M260	6/12	2358	0802	484	3.25	1573.0	90630	0.058			51300	0.033
2RME	IA-PRE-AGGR	M264	6/12	2358	0802	484	3.16	1529.4	66690	0.044	20000	0.013		
2RME	IA-PRE-NAGR	AA134	6/12	1334	2153	499	3.00	1497.0	33706	0.023			7084	0.005
2RME	IA-PRE-NAGR	AA135	6/12	1334	2153	499	2.96	1477.0	35343	0.024	750	0.001		
2RME	IA-PRE-NAGR	AA136	6/12	1334	2153	499	3.25	1621.8	15207	0.009	750	0.000		
2RME	IA-PRE-NAGR	M252	6/12	1334	2153	499	3.25	1621.8	21375	0.013	1750	0.001		
2RME	IA-PRE-NAGR	M254	6/12	1334	2153	499	3.16	1576.8	33345	0.021	1750	0.001		
2RME	IA-PRE-NAGR	M258	6/12	1334	2153	499	3.25	1621.8	28215	0.017	3500	0.002		
2EW	AM-PRE-FTER	AA104	6/12	1700	0700	840	3.00	2520.0	85085	0.034			1347	
2EW	AM-PRE-FTER	AA105	6/12	1700	0700	840	2.75	2310.0	88165	0.038			1347	
2FB	FB-PRE-FTRM	AA102	6/12								750			
2FB	FB-PRE-FTRM	AA103	6/12								750			
2FB	FB-PRE-FTRM	AA131	6/12						1463		750			
2FB	FB-PRE-FTRM	M266	6/12						2992					
2FB	FB-PRE-NAGR	AA132	6/12						34265		750			
2FB	FB-PRE-NAGR	M276	6/12						4360		1750			
2FB	FB-PRE-6/14	M298	6/12						3249					
2FB	FB-PRE-6/14	M323	6/12						28129				2992	
2FB	FB-PRE-6/14	M326	6/12						3249					

TABLE B2-2: (Continued - page 2)

		SAMPLE		PERIOD		TIME	RATE	VOL.	MAGISCAN II		UBTL		NIOSH	
LOC.	SAMPLE CLASS	No.	Date	Start	Stop	(min)	(lpm)	(l)	Fibers	f/cc	Fibers	f/cc	Fibers	f/cc
2RMD	BZ-COS-WK#1	AA186	6/25	1020	1035	15	3.00	45.0			750	0.017		
2RMD	BZ-COS-WK#2	AA190	6/25	1000	1015	15	3.00	45.0			750	0.017		
2RMD	BZ-COS-WK#3	AA179	6/25	0930	0950	20	3.00	60.0			1500	0.025		
2RMD	BZ-COV-WK#1	AA184	6/25	0807	1126	199	3.14	624.9			6000	0.010		
2RMD	BZ-COV-WK#2	AA198	6/25	0932	1133	121	3.05	369.1			6000	0.016		
2RMD	BZ-COV-WK#3	AA187	6/25	0807	1126	199	3.02	601.0			3000	0.005		
2RMD	BZ-COV-WK#4	AA205	6/25	0929	1114	105	3.00	315.0			3000	0.010		
2RMD	BZ-REM-WK#1	AA194	6/25	1245	1507	142	2.96	420.3			18000	0.043		
2RMD	BZ-REM-WK#2	AA195	6/25	1241	1507	146	3.05	445.3			270000	0.606		
2RMD	BZ-REM-WK#3	AA201	6/25	1241	1507	146	3.02	440.9			230000	0.522		
2RMD	BZ-REM-WK#4	AA207	6/25	1240	1507	147	3.00	441.0			POL			
2RMD	BZ-RMS-WK#1	AA197	6/25	1430	1445	15	3.00	45.0			60000	1.333		
2RMD	BZ-RMS-WK#2	AA200	6/25	1450	1505	15	3.00	45.0			62000	1.378		
2RMD	BZ-RMS-WK#2	AA202	6/25	1300	1315	15	3.00	45.0			41000	0.911		
2RMD	BZ-RMS-WK#3	AA185	6/25	1319	1334	15	3.00	45.0			32000	0.711		
2RMD	BZ-RMS-WK#4	AA203	6/25	1403	1419	16	3.00	48.0			140000	2.917		
2RMD	CT-COV	AA180	6/25	0757	1127	210	3.00	630.0			7000	0.011		
2RMD	CT-COV	AA193	6/25	0757	1127	210	3.11	653.1			9000	0.014		
2RMD	CT-REM	AA182	6/25	1242	1506	144	3.11	447.6			210000	0.469		
2RMD	CT-REM	AA196	6/25	1242	1506	144	3.00	432.0			250000	0.579		
2RMD	IA-COV	AA183	6/25	0757	1127	210	3.00	630.0			8000	0.013		
2RMD	IA-COV	AA191	6/25	0757	1127	210	3.00	630.0			10000	0.016		
2RMD	IA-REM	AA192	6/25	1243	1506	143	3.00	429.0			330000	0.769		
2RMD	IA-REM	AA199	6/25	1243	1506	143	3.00	429.0			190000	0.443		
2RMD	OA-COV	AA189	6/25	0757	1127	210	3.09	648.9			5000	0.008		
2RMD	OA-COV	AA206	6/25	0757	1127	210	3.12	655.2			4000	0.006		
2RMD	OA-REM	AA181	6/25	1244	1506	142	3.12	443.0			190000	0.429		
2RMD	OA-REM	AA208	6/25	1244	1506	142	3.09	438.8			120000	0.273		
2EW	AM-REM	AA188	6/25	0736	1515	459	2.60	1285.2			750	0.001		
2EW	AM-REM	AA204	6/25	0736	1515	459	2.70	1239.3			750	0.001		
2FB	FB-COV-6/18	AA030	6/25								750			

TABLE B2-2: (Continued - page 3)

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II Fibers	MAGISCAN II f/cc	UBTL Fibers	UBTL f/cc	NIOSH Fibers	NIOSH f/cc
2RMD	BZ-REM-WK#1	AA219	6/26	0745	1115	210	2.96	621.6			100000	0.161		
2RMD	BZ-REM-WK#1	AA285	6/26	1330	1446	76	2.96	225.0			FOL			
2RMD	BZ-REM-WK#2	AA210	6/26	0814	1115	181	3.05	552.1			200000	0.362		
2RMD	BZ-REM-WK#2	AA296	6/26	1330	1448	78	3.05	237.9			75000	0.315		
2RMD	BZ-REM-WK#3	AA220	6/26	0743	1115	212	3.02	640.2			FOL			
2RMD	BZ-REM-WK#3	AA311	6/26	1331	1446	75	3.02	226.5			49000	0.216		
2RMD	BZ-REM-WK#4	AA211	6/26	0746	1115	209	3.00	627.0			180000	0.287		
2RMD	BZ-REM-WK#4	AA291	6/26	1333	1448	75	3.00	225.0			67000	0.298		
2RMD	BZ-RMS-WK#1	AA284	6/26	0944	1000	16	3.00	48.0			9000	0.188		
2RMD	BZ-RMS-WK#1	AA295	6/26	1345	1400	15	3.00	45.0			30000	0.667		
2RMD	BZ-RMS-WK#2	AA297	6/26	1406	1421	15	3.50	52.5			15000	0.286		
2RMD	BZ-RMS-WK#2	AA301	6/26	0836	0851	15	3.00	45.0			34000	0.756		
2RMD	BZ-RMS-WK#3	AA303	6/26	1020	1035	15	3.00	45.0			10000	0.222		
2RMD	BZ-RMS-WK#3	AA308	6/26	1422	1437	15	3.50	52.5			24000	0.457		
2RMD	BZ-RMS-WK#4	AA294	6/26	1001	1016	15	3.00	45.0			11000	0.244		
2RMD	BZ-RMS-WK#4	AA322	6/26	1440	1448	8	3.50	28.0			7000	0.250		
2RMD	CT-REM	AA214	6/26	0737	1117	220	3.00	660.0			110000	0.167		
2RMD	CT-REM	AA218	6/26	0737	1117	220	3.00	660.0			110000	0.167		
2RMD	CT-REM	AA286	6/26	1330	1450	80	3.00	240.0			35000	0.146		
2RMD	CT-REM	AA326	6/26	1330	1450	80	3.00	240.0			21000	0.088		
2RMD	IA-REM	AA215	6/26	0737	1117	220	3.00	660.0			160000	0.242		
2RMD	IA-REM	AA217	6/26	0737	1117	220	3.06	673.2			110000	0.163		
2RMD	IA-REM	AA279	6/26	1330	1450	80	3.06	244.8			26000	0.106		
2RMD	IA-REM	AA325	6/26	1330	1450	80	3.00	240.0			42000	0.175		
2RMD	OA-REM	AA221	6/26	0737	1117	220	3.09	679.8			10000	0.015		
2RMD	OA-REM	AA222	6/26	0737	1117	220	3.12	686.4			10000	0.015		
2RMD	OA-REM	AA292	6/26	1330	1450	80	3.12	249.6			51000	0.204		
2RMD	OA-REM	AA300	6/26	1330	1450	80	3.09	247.2			75000	0.303		
2EW	AM-REM	AA209	6/26	0717	1515	478	2.60	1242.8			750	0.001		
2EW	AM-REM	AA216	6/26	0717	1515	478	2.90	1386.2			750	0.001		
2FB	FB-REM-6/19	AA034	6/26								750			
2FB	FB-REM-6/21	AA161	6/26								750			

TABLE B2-2: (Continued - page 4)

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II Fibers	MAGISCAN II f/cc	UBTL Fibers	UBTL f/cc	NIOSH Fibers	NIOSH f/cc
2RMD	BZ-REM-WK#1	AA281	6/27	0740	1117	217	2.96	642.3			FOL			
2RMD	BZ-REM-WK#2	AA283	6/27	0740	1116	216	3.05	658.6			FOL			
2RMD	BZ-REM-WK#3	AA282	6/27	0741	1117	216	3.02	652.3			310000	0.475		
2RMD	BZ-REM-WK#4	AA293	6/27	0736	1119	221	3.00	663.0			FOL			
2RMD	BZ-RMS-WK#1	AA312	6/27	1020	1035	15	3.00	45.0			43000	0.956		
2RMD	BZ-RMS-WK#2	AA298	6/27	0809	0824	15	3.00	45.0			FOL			
2RMD	BZ-RMS-WK#3	AA306	6/27	0826	0841	15	3.00	45.0			39000	0.867		
2RMD	BZ-RMS-WK#4	AA290	6/27	0945	1001	16	3.00	48.0			25000	0.521		
2RMD	CT-REM	AA272	6/27	0736	1122	226	3.00	676.0			310000	0.457		
2RMD	CT-REM	AA287	6/27	0736	1122	226	3.00	676.0			210000	0.310		
2RMD	IA-REM	AA320	6/27	0736	1122	226	3.00	676.0			20000	0.029		
2RMD	IA-REM	AA324	6/27	0736	1122	226	3.06	691.6			FOL			
2RMD	OA-REM	AA299	6/27	0736	1123	227	3.00	681.0			6000	0.012		
2RMD	OA-REM	AA323	6/27	0736	1123	227	3.06	694.6			8000	0.012		
2RME	BZ-COV-WK#1	AA305	6/27	1316	1519	121	2.96	358.2			8000	0.022		
2RME	BZ-COV-WK#2	AA307	6/27	1318	1519	121	3.05	369.1			20000	0.054		
2RME	BZ-COV-WK#3	AA316	6/27	1317	1519	122	3.02	368.4			8000	0.022		
2RME	BZ-COV-WK#4	AA304	6/27	1316	1519	121	3.00	363.0			8000	0.022		
2RME	BZ-COS-WK#1	AA250	6/27	1427	1442	15	2.96	44.4			2000	0.045		
2RME	BZ-COS-WK#2	AA228	6/27	1404	1419	15	3.00	45.0			2000	0.044		
2RME	BZ-COS-WK#3	AA255	6/27	1326	1341	15	3.00	45.0			1500	0.033		
2RME	BZ-COS-WK#4	AA213	6/27	1447	1502	15	3.00	45.0			1500	0.033		
2RME	CT-COV	AA243	6/27	1301	1523	142	3.00	426.0			10000	0.023		
2RME	CT-COV	AA247	6/27	1301	1523	142	3.00	426.0			10000	0.023		
2RME	IA-COV	AA234	6/27	1302	1523	141	3.06	431.5			5000	0.012		
2RME	IA-COV	AA253	6/27	1302	1523	141	3.00	423.0			8000	0.019		
2RME	OA-COV	AA227	6/27	1302	1520	138	3.12	430.6			28000	0.065		
2RME	OA-COV	AA289	6/27	1302	1520	138	3.00	414.0			10000	0.024		
2EW	AM-FTM	AA309	6/27	0721	1525	484	3.00	1452.0			750	0.001		
2EW	AM-FTM	AA310	6/27	0721	1525	484	3.00	1452.0			750	0.001		
2FB	FB-COV-6/19	AA036	6/27								750			
2FB	FB-COV-6/21	AA162	6/27								750			

TABLE B2-2: (Continued - page 5)

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II Fibers	MAGISCAN II f/cc	UBTL Fibers	UBTL f/cc	NIOSH Fibers	NIOSH f/cc
2RME	BZ-REM-WK#1	AA271	6/28	0744	1135	231	2.96	683.8			190000	0.278		
2RME	BZ-REM-WK#1	AA327	6/28	1244	1348	64	2.00	188.4			32000	0.169		
2RME	BZ-REM-WK#2	AA248	6/28	0744	1135	231	3.00	693.0			160000	0.231		
2RME	BZ-REM-WK#2	AA278	6/28	1243	1338	55	3.00	167.8			10000	0.060		
2RME	BZ-REM-WK#3	AA252	6/28	0742	1139	237	3.00	711.0			230000	0.323		
2RME	BZ-REM-WK#3	AA275	6/28	1243	1345	62	3.02	187.2			85000	0.454		
2RME	BZ-REM-WK#4	AA212	6/28	0743	1135	232	3.00	696.0			FOL			
2RME	BZ-REM-WK#4	AA314	6/28	1243	1348	65	3.00	195.0			69000	0.354		
2RME	BZ-RMS-WK#1	AA231	6/28	1303	1318	15	3.00	45.0			8000	0.178		
2RME	BZ-RMS-WK#1	AA260	6/28	0945	1001	16	3.00	48.0			16000	0.333		
2RME	BZ-RMS-WK#2	AA230	6/28	1320	1335	15	3.00	45.0			8000	0.067		
2RME	BZ-RMS-WK#2	AA235	6/28	0825	0840	15	3.00	45.0			18000	0.400		
2RME	BZ-RMS-WK#3	AA233	6/28	1008	1023	15	3.00	45.0			31000	0.882		
2RME	BZ-RMS-WK#3	AA258	6/28	1336	1347	11	3.00	33.0			7000	0.212		
2RME	BZ-RMS-WK#4	AA265	6/28	0803	0822	19	3.00	57.0			110000	1.930		
2RME	CT-REM	AA224	6/28	0740	1142	242	3.00	726.0			240000	0.331		
2RME	CT-REM	AA263	6/28	0740	1142	242	3.00	726.0			130000	0.179		
2RME	CT-REM	AA273	6/28	1240	1344	64	3.00	192.0			23000	0.128		
2RME	CT-REM	AA328	6/28	1240	1344	64	3.00	192.0			10000	0.052		
2RME	IA-REM	AA249	6/28	0740	1142	242	3.00	726.0			250000	0.344		
2RME	IA-REM	AA261	6/28	0740	1142	242	3.00	726.0			65000	0.090		
2RME	IA-REM	AA288	6/28	1240	1344	64	3.00	192.0			33000	0.172		
2RME	IA-REM	AA302	6/28	1240	1344	64	3.00	195.8			21000	0.107		
2RME	OA-REM	AA274	6/28	1240	1345	65	3.09	200.9			750	0.004		
2RME	OA-REM	AA259	6/28	0740	1142	242	3.09	747.8			10000	0.013		
2RME	OA-REM	AA262	6/28	0740	1142	242	3.00	747.8			6000	0.008		
2RME	OA-REM	AA317	6/28	1240	1345	65	3.12	202.8			9000	0.044		
2EW	AM-FTM	AA223	6/28	0715	1355	400	3.00	1200.0			750	0.001		
2EW	AM-FTM	AA264	6/28	0715	1355	400	2.80	1120.0			750	0.001		
2FB	FB-REM-6/21	AA163	6/28								750			
2FB	FB-REM-6/28	AA315	6/28								750			
2FB	FB-REM-FTER	AA316	6/28								LOST			

TABLE B2-2: (Continued - page 6)

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II Fibers	MAGISCAN II f/cc	UBTL Fibers	UBTL f/cc	NIOSH Fibers	NIOSH f/cc
2RMD	IA-PST-AGGR	AA395	7/11	0013	0715	422	3.00	1266.0	13398	0.011	7000	0.006	24986	0.020
2RMD	IA-PST-AGGR	AA412	7/11	0013	0715	422	3.25	1371.5	189035	0.138	8000	0.006		
2RMD	IA-PST-AGGR	AA414	7/11	0013	0715	422	3.00	1266.0	164395	0.130	10000	0.008	19366	0.015
2RMD	IA-PST-AGGR	MB60	7/11	0013	0715	422	3.00	1266.0	68400	0.054	10000	0.008	33345	0.026
2RMD	IA-PST-AGGR	MB61	7/11	0013	0715	422	3.00	1266.0	173565	0.137	20000	0.016	42750	0.034
2RMD	IA-PST-AGGR	MB62	7/11	0013	0715	422	3.00	1266.0	116280	0.092	10000	0.008	26505	0.021
2RMD	OA-PST-AGGR	AA413	7/11	0013	0715	422	3.00	1266.0	198660	0.157	4000	0.003		
2RMD	IA-PST-NAGR	AA410	7/11	0827	1630	483	3.00	1449.0	82775	0.057	2000	0.001	5621	0.004
2RMD	IA-PST-NAGR	AA418	7/11	0827	1630	483	3.15	1521.5	38885	0.026	2000	0.001		
2RMD	IA-PST-NAGR	AA419	7/11	0827	1630	483	2.90	1400.7	48125	0.034	2000	0.001		
2RMD	IA-PST-NAGR	MB40	7/11	0827	1630	483	3.00	1449.0	123120	0.085	3500	0.002		
2RMD	IA-PST-NAGR	MB47	7/11	0827	1630	483	3.05	1473.2	127315	0.086	1750	0.001		
2RMD	IA-PST-NAGR	MB55	7/11	0827	1630	483	3.15	1521.5	70965	0.047	1750	0.001		
2RMD	OA-PST-NAGR	AA431	7/11	0827	1630	483	2.95	1424.9	43120	0.030	2000	0.001		
2RME	IA-PST-AGGR	AA392	7/11	2300	0715	495	3.10	1534.5	123585	0.081	42000	0.027		
2RME	IA-PST-AGGR	AA398	7/11	2300	0715	495	3.50	1732.5	92015	0.053	36000	0.021		
2RME	IA-PST-AGGR	AA420	7/11	2300	0715	495	3.50	1732.5	58135	0.034	32000	0.018		
2RME	IA-PST-AGGR	MB58	7/11	2300	0715	495	3.50	1732.5	169290	0.098	97000	0.056	78404	0.045
2RME	IA-PST-AGGR	MB59	7/11	2300	0715	495	3.00	1485.0	94905	0.064	93000	0.063	91485	0.062
2RME	IA-PST-AGGR	MB68	7/11	2300	0715	495	3.50	1732.5	106875	0.062	59000	0.034	102600	0.059
2RME	OA-PST-AGGR	AA403	7/11	2300	0715	495	3.25	1608.8	103565	0.064	9000	0.006		
2RME	IA-PST-NAGR	AA415	7/11	0827	1630	483	3.05	1473.2	52745	0.036	3000	0.002		
2RME	IA-PST-NAGR	AA421	7/11	0827	1630	483	3.00	1449.0	51590	0.036	4000	0.003		
2RME	IA-PST-NAGR	AA450	7/11	0827	1630	483	3.10	1497.3	77000	0.051	3000	0.002	7700	0.005
2RME	IA-PST-NAGR	MB38	7/11	0827	1630	483	3.20	1545.6	106875	0.069	1750	0.001	13595	0.009
2RME	IA-PST-NAGR	MB39	7/11	0827	1630	483	3.15	1521.5	90630	0.060	1750	0.001		
2RME	IA-PST-NAGR	MB46	7/11	0827	1630	483	3.25	1569.6	129960	0.083	5000	0.003	9747	0.006
2RME	OA-PST-NAGR	AA435	7/11	0827	1630	483	3.00	1449.0	20405	0.014	3000	0.002		
2EW	AM-PST-FTER	AA434	7/11	0850	1630	460	3.00	1380.0	41580	0.030	750	0.001		
2EW	AM-PST-FTER	AA441	7/11	1024	0707	1243	3.00	3729.0	182490	0.049	750	0.000	1347	0.000
2EW	AM-PST-FTER	AA449	7/11	0850	1630	460	2.90	1334.0	20790	0.016	750	0.001		
2EW	AM-PST-FTER	AA408	7/11	1024	0707	1243	3.00	3729.0	162470	0.044	2000	0.001		
2FB	FB-PST-6/21	AA174	7/11						6314		750		9770	
2FB	FB-PST-7/18	MB53	7/11						2992		1750			
2FB	FB-PST-7/18	MB54	7/11						2992		1750			

TABLE B3-1

LEGEND FOR FACILITY 3 PCM DATA

LOC	(Facility and room location of sampled activity)
3xxx	Facility 3
RMF	Room F
RMG	Room G
TLG	Teachers Lounge outside window
SAMPLE CLASS	(Sample type and location, activity, and ID)
Location	
FB	Field Blank
IA	Interior Area (Background in the work room)
OA	Outside Area (in the hall)
AM	Ambient (Outside the building)
BZ	Personal Breathing Zone
CT	Mobile Sampling Cart (proximate to work activity)
Activity	
PRE	Pre-removal activity - Full-term sample
PST	Post-removal activity - Full-term sample
REM	Removal work - Full-term sequential sample
COV	Preparation - Full-term sequential
RMS	Removal work - 15-minute short-term PBZ sample
COS	Preparation - 15-minute short-term BZ
SEQ	Sample period covers sequential work activities
ID	
AGGR	Aggressive sampling mode
NAGR	Nonaggressive sampling mode
WK#X	Worker #X BZ sample
mm/dd	Actual date of blank source
SAMPLE No.	Sample media Identification code and number
AAxxx	25-mm Cellulose Ester Filter Sample Number xxx (using a foil wrapped 2-inch cowl)
Mxxx	37-mm Cellulose Ester Filter Sample Number xxx
Nxxx	37-mm Polycarbonate Filter Sample Number xxx
RATE	Sample flow rate in liters per minute (lpm)
VOL	Sample volume in liters (l)
MAGISCAN II	Magiscan II is a computerized image analysis system for PCM; results are in total fibers per cubic centimeter

Phase Contrast Microscopy using NIOSH Method 7400B counting rules

UBTL	PCM analysis performed by Utah Biological Testing Labs
NIOSH	PCM analysis performed in the NIOSH Laboratory
Fibers	Total fibers
f/cc	Fibers per cubic centimeter

TABLE B3-2

PHASE CONTRAST MICROSCOPY ANALYTICAL RESULTS
FOR AIRBORNE ASBESTOS ANALYSIS
FACILITY 3
CINCINNATI, OHIO
June 13, July 1-3 & 10, 1985

NOTE: For samples reported less than detectable, one half of the limit of detection is used as follows:

LAB	25-mm Filter	37-mm Filter
UBTL	750	1750
NIOSH	1347	2992

		SAMPLE		PERIOD		TIME	RATE	VOL.	MAGISCAN II		UBTL		NIOSH	
LOC.	SAMPLE CLASS	No.	Date	Start	Stop	(min)	(lpm)	(l)	Fibers	f/cc	Fibers	f/cc	Fibers	f/cc
3RMG	IA-PRE-AGGR	AA073	6/13	2315	0715	480	3.14	1507.2	57365	0.038			87203	0.058
3RMG	IA-PRE-AGGR	AA094	6/13	2315	0715	480	3.3	1584.0	93940	0.059			86625	0.055
3RMG	IA-PRE-AGGR	AA133	6/13	2315	0715	480	3.3	1584.0	102410	0.065	62000	0.039		
3RMG	IA-PRE-AGGR	M293	6/13	2315	0715	480	3.1	1488.0	90630	0.061			134235	0.090
3RMG	IA-PRE-AGGR	M294	6/13	2315	0715	480	3.3	1584.0	102600	0.065			159885	0.101
3RMG	IA-PRE-AGGR	M297	6/13	2315	0715	480	3.2	1536.0	83790	0.055			168435	0.110
3RMG	IA-PRE-NAGR	AA084	6/13	1344	2145	481	3.0	1443.0	130515	0.090			1347	0.001
3RMG	IA-PRE-NAGR	AA100	6/13	1344	2145	481	3.0	1443.0	73535	0.051			1347	0.001
3RMG	IA-PRE-NAGR	AA101	6/13	1344	2145	481	3.1	1491.1	96250	0.065			1347	0.001
3RMG	IA-PRE-NAGR	M296	6/13	1344	2145	481	3.0	1443.0	152190	0.105			10260	0.007
3RMG	IA-PRE-NAGR	M299	6/13	1344	2145	481	3.2	1539.2	135945	0.088			9405	0.006
3RMG	IA-PRE-NAGR	M305	6/13	1344	2145	481	3.2	1539.2	54976	0.036			2992	0.002
3RMF	IA-PRE-AGGR	AA077	6/13	2303	0703	480	3.3	1584.0	1347	0.001			6930	0.004
3RMF	IA-PRE-AGGR	AA112	6/13	2303	0703	480	3.1	1488.0	65065	0.044			1347	0.001
3RMF	IA-PRE-AGGR	AA114	6/13	2303	0703	480	3.3	1584.0	93940	0.059				
3RMF	IA-PRE-AGGR	M292	6/13	2303	0703	480	3.3	1584.0	61560	0.039			23085	0.015
3RMF	IA-PRE-AGGR	M303	6/13	2303	0703	480	3.2	1536.0	103455	0.067			2992	0.002
3RMF	IA-PRE-AGGR	M304	6/13	2303	0703	480	3.2	1536.0	142785	0.093	30000	0.020		
3RMF	IA-PRE-AGGR	M320	6/13	2303	0703	480	3.2	1536.0						
3RMF	IA-PRE-NAGR	AA081	6/13	1337	2137	480	3.0	1440.0	36768	0.026			1347	0.001
3RMF	IA-PRE-NAGR	AA113	6/13	1337	2137	480	3.0	1440.0	24524	0.017	1500	0.001		
3RMF	IA-PRE-NAGR	AA115	6/13	1337	2137	480	3.0	1440.0	51975	0.036			1347	0.001
3RMF	IA-PRE-NAGR	M291	6/13	1337	2137	480	3.1	1488.0	20520	0.014			2992	0.002
3RMF	IA-PRE-NAGR	M301	6/13	1337	2137	480	3.0	1440.0	10858	0.008			2992	0.002
3RMF	IA-PRE-NAGR	M302	6/13	1337	2137	480	3.1	1488.0	15219	0.010	4000	0.003		
3FB	FB-PRE-FTER	AA076	6/13						1347		750			
3FB	FB-PRE-FTER	AA078	6/13						1347		750			
3FB	FB-PRE-FTER	AA085	6/13						1347		750			
3FB	FB-PRE-FTER	AA086	6/13						1347		750			
3FB	FB-PRE-FTER	AA088	6/13						3426		750			
3FB	FB-PRE-FTER	AA096	6/13						962		750			
3FB	FB-PRE-FTER	M295	6/13						2992		1750			
3FB	FB-PRE-FTER	M300	6/13						11371				2992	
3FB	FB-PRE-6/14	M328	6/13						7609				2992	
3FB	FB-PRE-6/14	M333	6/13						5472		1750			
3FB	FB-PRE-6/14	M336	6/13						1111		1750			
3LNG	AM-FTER	AA082	6/13	1050	0637	1187	2.8	3323.6	242550	0.073			1347	0.000
3LNG	AM-FTER	AA083	6/13	1050	0637	1187	2.8	3323.6	190960	0.057			1347	0.000

TABLE B3-2 (Continued - page 2)

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II Fibers	MAGISCAN II f/cc	UBTL Fibers	UBTL f/cc	NIOSH Fibers	NIOSH f/cc
3RMF	BZ-COS-WK#1	AA321	7/01	0836	0852	16	3.0	48.0			750	0.016		
3RMF	BZ-COS-WK#3	AA239	7/01	0817	0832	15	3.0	45.0			750	0.017		
3RMF	BZ-COS-WK#4	AA254	7/01	0942	1009	37	3.0	111.0			2000	0.018		
3RMF	BZ-COV-WK#1	AA269	7/01	0801	1030	149	2.96	441.0			5000	0.011		
3RMF	BZ-COV-WK#2	AA238	7/01	0820	1020	120	3.05	366.0			3000	0.008		
3RMF	BZ-COV-WK#3	AA240	7/01	0800	1030	150	3.02	453.0			2000	0.004		
3RMF	BZ-COV-WK#4	AA318	7/01	0800	1030	150	3.00	450.9			3000	0.007		
3RMF	BZ-REM-WK#1	AA226	7/01	1330	1515	105	2.96	310.8			320000	1.030		
3RMF	BZ-REM-WK#1	AA244	7/01	1030	1233	123	2.96	364.1			60000	0.165		
3RMF	BZ-REM-WK#2	AA242	7/01	1030	1233	123	3.05	375.2			150000	0.400		
3RMF	BZ-REM-WK#2	AA386	7/01	1330	1515	105	3.05	320.3			160000	0.500		
3RMF	BZ-REM-WK#3	AA319	7/01	1030	1233	120	3.02	375.5			230000	0.613		
3RMF	BZ-REM-WK#3	AA390	7/01	1330	1515	105	3.02	317.1			160000	0.505		
3RMF	BZ-REM-WK#4	AA245	7/01	1030	1233	120	3.08	348.0			100000	0.287		
3RMF	BZ-REM-WK#4	AA385	7/01	1330	1515	105	3.00	315.0			76000	0.241		
3RMF	BZ-RMS-WK#1	AA333	7/01	1404	1413	9	3.0	27.0			27000	1.000		
3RMF	BZ-RMS-WK#2	AA349	7/01	1437	1452	15	3.0	45.0			32000	0.711		
3RMF	BZ-RMS-WK#3	AA313	7/01	1047	1102	15	3.0	45.0			21000	0.467		
3RMF	BZ-RMS-WK#3	AA341	7/01	1337	1352	15	3.0	45.0			57000	1.267		
3RMF	BZ-RMS-WK#4	AA334	7/01	1314	1329	15	3.0	45.0			42000	0.933		
3RMF	CT-COV	AA277	7/01	0759	1028	149	3.00	447.0			1500	0.003		
3RMF	CT-COV	AA280	7/01	0759	1028	149	2.82	420.2			1500	0.004		
3RMF	CT-REM	AA232	7/01	1033	1233	120	2.82	338.4			240000	0.709		
3RMF	CT-REM	AA276	7/01	1033	1233	120	3.00	360.0			57000	0.158		
3RMF	CT-REM	AA335	7/01	1330	1530	120	2.82	338.4			750	0.002		
3RMF	CT-REM	AA342	7/01	1330	1530	120	3.00	360.0			340000	0.944		
3RMF	IA-COV	AA246	7/01	0803	1028	149	3.00	435.0			4000	0.009		
3RMF	IA-COV	AA251	7/01	0759	1028	149	3.12	464.9			2000	0.004		
3RMF	IA-REM	AA225	7/01	1033	1233	120	3.12	374.4			220000	0.588		
3RMF	IA-REM	AA237	7/01	1330	1530	120	3.00	360.0			93000	0.258		
3RMF	IA-REM	AA266	7/01	1033	1233	120	3.00	360.0			140000	0.389		
3RMF	IA-REM	AA387	7/01	1330	1530	120	3.12	374.4			190000	0.507		
3RMF	OA-COV	AA229	7/01	0759	1028	149	3.12	464.9			4000	0.009		
3RMF	OA-COV	AA270	7/01	0759	1028	149	3.06	455.9			700	0.009		
3RMF	OA-REM	AA236	7/01	1330	1530	120	3.12	374.4			4000	0.011		
3RMF	OA-REM	AA241	7/01	1247	1330	43	3.12	134.2			3000	0.022		
3RMF	OA-REM	AA256	7/01	1035	1233	118	3.06	361.1			7000	0.019		
3RMF	OA-REM	AA257	7/01	1035	1150	75	3.12	234.0			2000	0.009		
3RMF	OA-REM	AA388	7/01	1330	1530	120	3.06	367.2			5000	0.014		
3FB	FB-COV-6/21	AA164	7/01								750			
3FB	FB-REM-6/21	AA165	7/01								750			
3LBG	AM-FIM	AA267	7/01	0750	1545	475	3.0	1425.0			750	0.001		
3LBG	AM-FIM	AA268	7/01	0750	1545	475	2.8	1330.0			750	0.001		

TABLE B3-2 (Continued - page 3)

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II Fibers	MAGISCAN II f/cc	UBTL Fibers	UBTL f/cc	NIOSH Fibers	NIOSH f/cc
3RMG	BZ-REM-WK#1	AA332	7/02	1259	1512	133	2.82	375.1			400000	1.066		
3RMG	BZ-REM-WK#2	AA345	7/02	1255	1413	78	3.00	234.0			330000	1.410		
3RMG	BZ-REM-WK#3	AA355	7/02	1323	1512	109	3.00	327.0			360000	1.101		
3RMG	BZ-REM-WK#4	AA348	7/02	1258	1512	134	3.06	410.0			390000	0.951		
3RMG	BZ-RMS-WK#1	AA368	7/02	1341	1356	15	3.00	45.0			90000	2.000		
3RMG	BZ-RMS-WK#3	AA353	7/02	1430	1452	22	3.00	66.0			210000	3.182		
3RMG	BZ-RMS-WK#4	AA359	7/02	1457	1511	14	3.00	42.0			390000	9.286		
3RMG	BZ-RMS-WK#4	AA369	7/02	1313	1331	18	3.00	54.0			150000	2.778		
3RMG	CT-REM	AA344	7/02	1257	1520	143	2.82	403.3			260000	0.645		
3RMG	CT-REM	AA358	7/02	1257	1520	143	3.00	429.0			410000	0.956		
3RMG	IA-REM	AA338	7/02	1257	1520	143	3.00	429.0			350000	0.816		
3RMG	IA-REM	AA352	7/02	1257	1520	143	3.12	446.2			340000	0.762		
3RMG	OA-REM	AA329	7/02	1257	1520	143	2.90	414.7			190000	0.458		
3RMG	OA-REM	AA337	7/02	1257	1520	143	3.00	429.0			190000	0.443		
3RMF	BZ-REM-WK#1	AA362	7/02	0735	1127	232	2.82	654.2			170000	0.260		
3RMF	BZ-REM-WK#2	AA361	7/02	0735	1119	224	3.05	683.2			180000	0.263		
3RMF	BZ-REM-WK#3	AA376	7/02	0735	1127	232	3.02	700.6			320000	0.457		
3RMF	BZ-REM-WK#4	AA375	7/02	0735	1119	224	3.00	685.4			310000	0.452		
3RMF	BZ-RMS-WK#1	AA347	7/02	0812	0827	15	3.00	45.0			7000	0.156		
3RMF	BZ-RMS-WK#2	AA346	7/02	0832	0847	15	3.00	45.0			34000	0.756		
3RMF	BZ-RMS-WK#3	AA354	7/02	0942	0957	15	3.00	45.0			41000	0.911		
3RMF	BZ-RMS-WK#4	AA360	7/02	1005	1020	15	3.00	45.0			110000	2.444		
3RMF	CT-REM	AA356	7/02	0735	1127	232	3.00	696.0			300000	0.431		
3RMF	CT-REM	AA370	7/02	0735	1127	232	2.82	654.2			300000	0.459		
3RMF	IA-REM	AA363	7/02	0735	1127	232	3.00	696.0			390000	0.560		
3RMF	IA-REM	AA377	7/02	0735	1127	232	3.12	723.8			270000	0.373		

3RMF	OA-REM	AA330	7/02	0735	1128	233	3.12	727.0	750	0.001
3RMF	OA-REM	AA340	7/02	0735	1128	233	3.06	713.0	750	0.001
3FB	FB-REM-6/21	AA166	7/02						750	
3FB	FB-REM-6/21	AA167	7/02						750	
3LNG	AM-FTM	AA331	7/02	0727	1525	478	3.0	1434.0	1500	0.001
3LNG	AM-FTM	AA339	7/02	0727	1525	478	2.8	1338.4	750	0.001
3RMG	BZ-REM-WK#1	AA366	7/03	0742	1115	213	2.82	600.7	480000	0.799
3RMG	BZ-REM-WK#2	AA336	7/03	0740	1115	215	3.05	655.8	270000	0.412
3RMG	BZ-REM-WK#3	AA343	7/03	0739	1115	216	3.02	652.3	310000	0.475
3RMG	BZ-REM-WK#4	AA357	7/03	0741	1115	214	3.06	654.8	400000	0.611
3RMG	BZ-RMS-WK#1	AA373	7/03	1010	1030	20	3.00	60.0	100000	1.667
3RMG	BZ-RMS-WK#3	AA371	7/03	0816	0831	15	3.00	45.0	32000	0.711
3RMG	BZ-RMS-WK#4	AA378	7/03	0755	0810	15	3.00	45.0	28000	0.622
3RMG	BZ-RMS-WK#4	AA380	7/03	0948	1003	15	3.00	45.0	46000	1.022
3RMG	CT-REM	AA351	7/03	0737	1115	218	2.82	614.8	410000	0.667
3RMG	CT-REM	AA364	7/03	0737	1115	218	3.00	654.0	370000	0.566
3RMG	IA-REM	AA350	7/03	0737	1115	218	3.00	654.0	310000	0.474
3RMG	IA-REM	AA372	7/00	0737	1115	218	3.12	680.2	420000	0.617
3RMG	OA-REM	AA382	7/03	0737	1115	218	3.00	654.0	240000	0.367
3RMG	OA-REM	AA391	7/03	0737	1115	218	2.96	645.3	150000	0.232
3FB	FB-REM-6/21	AA168	7/03						750	
3FB	FB-REM-6/21	AA169	7/03						750	
3LNG	AM-FTM	AA365	7/03	0720	1150	270	2.8	756.0	750	0.001
3LNG	AM-FTM	AA367	7/03	0720	1150	270	3.0	810.0	750	0.001

TABLE B3-2 (Continued - page 4)

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II Fibers	MAGISCAN II f/cc	UBTLPCM 7400-B Fibers	UBTLPCM 7400-B f/cc	NIOSHPCM 7400-B Fibers	NIOSHPCM 7400-B f/cc
3RMG	IA-PST-AGGR	AA422	7/10	1750	0218	508	3.0	1524.0	26565	0.017	2000	0.001		
3RMG	IA-PST-AGGR	AA425	7/10	1750	0218	508	3.0	1524.0	28490	0.019	2000	0.001		
3RMG	IA-PST-AGGR	AA428	7/10	1750	0218	508	3.0	1524.0	31955	0.021	2000	0.001		
3RMG	IA-PST-AGGR	M852	7/10	1750	0218	508	3.5	1778.0	74641	0.042			2992	0.002
3RMG	IA-PST-AGGR	M853	7/10	1750	0218	508	3.5	1778.0	92340	0.052	1750	0.001		
3RMG	IA-PST-AGGR	M854	7/10	1750	0218	508	3.5	1778.0	82849	0.047			12996	0.007
3RMG	OA-PST-AGGR	AA443	7/10	1750	0218	508	3.0	1524.0	86240	0.057	750	0.000		
3RMG	IA-PST-HAGR	AA433	7/10	0842	1655	493	3.0	1479.0	24640	0.017	750	0.001		
3RMG	IA-PST-HAGR	AA438	7/10	0902	1655	473	3.0	1419.0	111650	0.079			1347	0.001
3RMG	IA-PST-HAGR	AA439	7/10	0842	1655	493	3.0	1479.0	108570	0.073	750	0.001		
3RMG	IA-PST-HAGR	M841	7/10	0842	1655	493	3.3	1626.9	35910	0.022	1750	0.001		
3RMG	IA-PST-HAGR	M842	7/10	0842	1655	493	3.2	1577.6	22230	0.014	1750	0.001		
3RMG	IA-PST-HAGR	M843	7/10	0902	1655	473	3.1	1466.3	25650	0.017	1750	0.001		
3RMG	OA-PST-HAGR	AA437	7/10	0843	1655	492	3.1	1525.2	45045	0.030	1500	0.001		
3RMF	IA-PST-AGGR	AA384	7/10	1603	0208	605	3.3	1996.5	31185	0.016	25000	0.013		
3RMF	IA-PST-AGGR	AA442	7/10	1603	0208	605	3.0	1815.0	72765	0.040			40040	0.022
3RMF	IA-PST-AGGR	AA451	7/10	1603	0208	605	3.5	2117.5	60445	0.029	23000	0.011		
3RMF	IA-PST-AGGR	M845	7/10	1603	0208	605	3.5	2117.5	64125	0.030			63270	0.030
3RMF	IA-PST-AGGR	M848	7/10	1603	0208	605	3.0	1815.0	45315	0.025	46000	0.025		
3RMF	IA-PST-AGGR	M849	7/10	1603	0208	605	3.5	2117.5	94050	0.044			43520	0.021
3RMF	OA-PST-AGGR	AA455	7/10	1603	0208	605	3.5	2117.5	32147	0.015			5390	0.003
3RMF	IA-PST-HAGR	AA429	7/10	0845	1655	490	3.0	1470.0	94710	0.064			3465	0.002
3RMF	IA-PST-HAGR	AA430	7/10	0845	1655	490	3.1	1519.0	55825	0.037	750	0.000		
3RMF	IA-PST-HAGR	AA436	7/10	0845	1655	490	3.1	1519.0	33880	0.022	750	0.000		
3RMF	IA-PST-HAGR	M844	7/10	0845	1655	490	3.4	1666.0	79515	0.048			2992	0.002
3RMF	IA-PST-HAGR	M850	7/10	0845	1655	490	3.5	1715.0	87210	0.051	1750	0.001		
3RMF	IA-PST-HAGR	M851	7/10	0845	1655	490	3.4	1666.0	84645	0.051	1750	0.001		
3RMF	OA-PST-HAGR	AA423	7/10	0843	1655	492	3.0	1476.0	46585	0.032			1347	0.001
3FB	FB-PST-7/18	AA479	7/10						10549				1347	
3FB	FB-PST-7/18	M955	7/10						2992				2992	
3FB	FB-PST-7/18	M956	7/10						2992				2992	
3FB	FB-PST-7/18	M960	7/10						17955				2992	
3LMG	AM-PST-FIM	AA452	7/10	0854	0325	1111	3.0	3333.0	227150	0.068	750	0.000		
3LMG	AM-PST-FIM	AA460	7/10	0854	0325	1111	2.9	3221.9	217910	0.068	750	0.000		

TABLE B4-1

LEGEND FOR FACILITY 4 PCM DATA

<u>LOC</u>	(Facility and room location of sampled activity)
4xxx	Facility 4
RMH	Room H
RMI	Room I
RMJ	Room J
CE	Combined Exposure Areas Room H and Room I
PO	Principle's Office
<u>SAMPLE CLASS</u>	(Sample type and location, activity, and ID)
<u>Location</u>	
FB	Field Blank
IA	Interior Area (Background in the work room)
OA	Outside Area (in the hall)
AM	Ambient (Outside the building)
BZ	Personal Breathing Zone
CT	Mobile Sampling Cart (proximate to work activity)
<u>Activity</u>	
PRE	Pre-removal activity - Full term sample
PST	Post-removal activity - Full term sample
REM	Removal work - Full term sequential sample
COV	Preperation - Full term sequential
RMS	Removal work - 15 minute short term PBZ sample
COS	Preperation - 15 minute short term BZ
SEQ	Sample period covers sequential work activities
FTM	Ambient Sample - Full Term Monitoring; 8 to 16 hours
<u>ID</u>	
AGGR	Aggressive sampling mode
NAGR	Nonaggressive sampling mode
WK#<u>X</u>	Worker #X BZ sample
<u>mm</u>/<u>dd</u>	Date of blank
<u>SAMPLE No.</u>	Sample media Identification code and number
AA<u>xxx</u>	25mm Cellulose Ester Filter Sample Number xxx (using a foil wrapped 2-inch cowl)
M<u>xxx</u>	37mm Cellulose Ester Filter Sample Number xxx
N<u>xxx</u>	37mm Polycarbonate Filter Sample Number xxx
RATE	Sample flow rate in liters per minute (lpm)
VOL	Sample volume in liters (l)
MAGISCAN II	Magiscan II is a computerized image analysis system for PCM; results are in total fibers per cubic centimeter.

<u>Phase Contrast Microscopy using NIOSH Method 7400B counting rules</u>

UBTL	PCM analysis performed by Utah Biological Testing Labs
NIOSH	PCM analysis performed in the NIOSH Laboratory
Fibers	Total fibers
f/cc	Fibers/cubic centimeter

TABLE B4-2

PHASE CONTRAST MICROSCOPY ANALYTICAL RESULTS
FOR AIRBORNE ASBESTOS ANALYSIS
FACILITY 4
CINCINNATI, OHIO
July 12 & July 15-18, 1985

NOTE: For samples reported less than detectable, one half of the limit of detection is used as follows:

LAB	25 mm Filter	37 mm Filter
UBTL	750	1750
NIOSH	1347	2992

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II Fibers	MAGISCAN II f/cc	UBTL Fibers	UBTL f/cc	NIOSH Fibers	NIOSH f/cc
4RMI	IA-PRE-AGGR	AA393	7/12	1800	0201	481	2.50	1202.5	43505	0.036	12000	0.010		
4RMI	IA-PRE-AGGR	AA401	7/12	1800	0201	481	2.75	1322.8	57750	0.044			1347	0.001
4RMI	IA-PRE-AGGR	AA448	7/12	1800	0201	481	2.50	1202.5	46970	0.039	10000	0.008		
4RMI	IA-PRE-AGGR	M864	7/12	1800	0201	481	2.75	1322.8	53950	0.041			24966	0.019
4RMI	IA-PRE-AGGR	M871	7/12	1800	0201	481	3.00	1443.0	47965	0.033	20000	0.014		
4RMI	IA-PRE-AGGR	M872	7/12	1800	0201	481	2.75	1322.8	85760	0.072				
4RMI	OA-PRE-AGGR	AA427	7/12	1800	0201	481	3.00	1443.0	17671	0.012	2000	0.001		
4RMI	IA-PRE-NAGR	AA405	7/12	0906	1700	474	2.60	1232.4	31993	0.026	2000	0.002		
4RMI	IA-PRE-NAGR	AA406	7/12	0906	1700	474	2.70	1279.8	33841	0.026			1347	0.001
4RMI	IA-PRE-NAGR	AA444	7/12	0906	1700	474	3.15	1493.1	32147	0.022			4158	0.003
4RMI	IA-PRE-NAGR	M857	7/12	0906	1700	474	3.00	1422.0	49077	0.035	3500	0.002		
4RMI	IA-PRE-NAGR	M865	7/12	0906	1700	474	3.15	1493.1	16208	0.011	1750	0.001		
4RMI	IA-PRE-NAGR	M869	7/12	0906	1700	474	2.95	1398.3	47965	0.034	1750	0.001		
4RMI	OA-PRE-NAGR	AA397	7/12	0905	1700	475	3.05	1448.8	27989	0.019	750	0.001		
4RMH	IA-PRE-AGGR	AA394	7/12	1752	0152	480	2.50	1190.0	43890	0.037	6000	0.005		
4RMH	IA-PRE-AGGR	AA399	7/12	1752	0152	480	3.00	1428.0	50435	0.035			1347	0.001
4RMH	IA-PRE-AGGR	AA407	7/12	1752	0152	480	2.75	1309.0	40040	0.031	4000	0.003		
4RMH	IA-PRE-AGGR	M867	7/12	1752	0152	480	3.00	1428.0	55062	0.039			2992	0.002
4RMH	IA-PRE-AGGR	M870	7/12	1752	0152	480	2.75	1309.0	53950	0.041			17357	0.013
4RMH	IA-PRE-AGGR	M873	7/12	1752	0152	480	3.00	1428.0	39244	0.027			2992	0.002
4RMH	OA-PRE-AGGR	AA404	7/12	1752	0152	480	3.00	1428.0	15939	0.011			1347	0.001
4RMH	IA-PRE-NAGR	AA402	7/12	0904	1700	476	3.00	1428.0	21098	0.015	750	0.001		
4RMH	IA-PRE-NAGR	AA409	7/12	0904	1700	476	2.70	1285.2	16208	0.013	750	0.001		
4RMH	IA-PRE-NAGR	AA426	7/12	0904	1700	476	2.60	1237.6	23793	0.019			1347	0.001
4RMH	IA-PRE-NAGR	M856	7/12	0904	1700	476	2.95	1404.2	36508	0.026			2992	0.002
4RMH	IA-PRE-NAGR	M874	7/12	0904	1700	476	2.90	1380.4	38133	0.028	1750	0.001		
4RMH	IA-PRE-NAGR	M875	7/12	0904	1700	476	3.00	1428.0	47367	0.033			2992	0.002
4RMH	OA-PRE-NAGR	AA396	7/12	0904	1700	476	3.00	1428.0	64295	0.045			36575	0.026
4FB	FB-PRE-7/12	M863	7/12						53266		1750			
4FB	FB-PRE-7/12	M866	7/12						9832		1750			
4FB	FB-PRE-7/18	M962	7/12						47965		1750			
4FB	FB-PRE-7/18	M963	7/12						27018				2992	
4FB	FB-PRE-7/18	M964	7/12						7609		1750			
4FB	FB-PRE-7/18	M965	7/12						7609				2992	
4FO	AM-FTM	AA400	7/12	0915	0230	1035	2.90	3001.5	43120	0.014	750	0.000		
4FO	AM-FTM	AA456	7/12	0915	0230	1035	3.00	3105.0	38269	0.012			3889	0.001

TABLE B4-2 (Continued - page 2)

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II Fibers	MAGISCAN II f/cc	UBTL Fibers	UBTL f/cc	NIOSH Fibers	NIOSH f/cc
4RMI	BZ-COS-WK#1	AA471	7/15	0842	0902	20	2.50	50.0			750	0.015		
4RMI	BZ-COS-WK#2	AA503	7/15	0822	0837	15	3.70	55.5			750	0.014		
4RMH	BZ-COS-WK#4	AA500	7/15	0938	0953	15	3.20	48.0			750	0.016		
4RMS	BZ-REM-WK#1	AA465	7/15	1045	1245	120	2.75	330.0			6000	0.018		
4RME	BZ-REM-WK#2	AA464	7/15	1045	1252	127	3.20	406.4			6000	0.015		
4RME	BZ-REM-WK#3	AA494	7/15	1043	1245	122	3.00	366.0			2000	0.005		
4RMH	BZ-REM-WK#4	AA466	7/15	1044	1245	121	2.90	350.9			6000	0.017		
4RMH	BZ-RMS-WK#1	AA501	7/15	1326	1341	15	2.30	34.5			750	0.022		
4RME	BZ-RMS-WK#2	AA477	7/15	1306	1321	15	3.15	47.3			1500	0.032		
4RME	BZ-RMS-WK#3	AA470	7/15	1108	1123	15	3.10	46.5			2000	0.043		
4RME	BZ4RMS-WK#3	AA511	7/15	1345	1355	10	3.20	32.0			750	0.023		
4RMH	BZ-RMS-WK#4	AA461	7/15	1357	1410	13	3.20	41.6			1500	0.036		
4RME	CT-COV	AA473	7/15	0755	1045	170	3.10	527.0			3000	0.006		
4RME	CT-COV	AA510	7/15	0755	1045	170	3.10	527.0			3000	0.006		
4RME	CT-REM	AA474	7/15	1045	1243	118	3.10	365.8			3000	0.008		
4RME	CT-REM	AA490	7/15	1045	1243	118	3.00	354.0			2000	0.006		
4RME	IA-COV	AA495	7/15	0755	1045	170	3.20	544.0			7000	0.013		
4RMH	IA-COV	AA508	7/15	0755	1045	170	3.25	552.5			1500	0.003		
4RMH	IA-REM	AA497	7/15	1045	1241	116	3.30	382.8			2000	0.005		
4RMH	IA-REM	AA498	7/15	1045	1241	116	3.20	371.2			3000	0.008		
4RME	OA-REM	AA476	7/15	1048	1243	115	3.30	379.5			750	0.002		
4RMH	OA-REM	AA507	7/15	1048	1243	115	3.30	379.5			750	0.002		
4CE	BZ-COV-WK#1	AA506	7/15	0810	1045	155	2.80	434.0			2000	0.005		
4CE	BZ-COV-WK#2	AA514	7/15	0811	1045	154	3.20	492.8			3000	0.006		
4CE	BZ-COV-WK#3	AA468	7/15	0811	1030	139	2.80	389.2			750	0.002		
4CE	BZ-COV-WK#4	AA472	7/15	0811	1044	153	3.20	489.6			5000	0.010		
4CE	OA-COV	AA504	7/15	0755	1045	170	3.20	544.0			750	0.001		
4CE	OA-COV	AA509	7/15	0755	1045	170	3.20	544.0			750	0.001		
4FB	FB-COV-7/18	AA525	7/15								750			
4FB	FB-REM-7/18	AA545	7/15								750			
4PO	AM-FTM	AA467	7/15	0816	1420	364	3.00	1092.0			750	0.001		
4PO	AM-FTM	AA469	7/15	0816	1420	364	2.90	1055.6			750	0.001		
4RMI	BZ-REM-WK#1	AA411	7/16	0756	1130	214	3.20	684.8			10000	0.015		
4RMI	BZ-REM-WK#2	AA489	7/16	0756	1130	214	3.15	674.1			9000	0.013		
4RMI	BZ-REM-WK#3	AA491	7/16	0756	1130	214	3.00	642.0						
4RMI	BZ-RMS-WK#1	AA485	7/16	0959	1014	15	3.20	48.0			750	0.016		
4RMI	BZ-RMS-WK#2	AA483	7/16	0824	0839	15	3.10	46.5			3000	0.065		
4RMI	BZ-RMS-WK#3	AA484	7/16	0803	0818	15	3.00	45.0			9000	0.200		
4RMI	BZ-RMS-WK#3	AA486	7/16	0941	0956	15	3.10	46.5			4000	0.086		
4RMI	CT-REM	AA480	7/16	0745	1130	225	3.00	675.0						
4RMI	CT-REM	AA505	7/16	0745	1130	225	3.00	675.0			9000	0.013		
4RMI	IA-REM	AA475	7/16	0756	0822	26	3.00	78.0			4000	0.051		
4RMI	IA-REM	AA487	7/16	0745	1130	225	3.20	720.0						
4RMI	IA-REM	AA488	7/16	0745	1130	225	3.20	720.0			9000	0.013		
4RMI	OA-REM	AA462	7/16	0743	1130	227	3.20	726.4			2000	0.003		
4RMS	OA-REM	AA463	7/16	0743	1130	227	3.40	771.8			750	0.001		
4FB	FB-REM-7/18	AA554	7/16								750			
4FB	FB-REM-7/18	AA555	7/16								750			
4PO	AM-FTM	AA492	7/16	0737	1325	348	2.80	974.4			750	0.001		
4PO	AM-FTM	AA499	7/16	0737	1325	348	2.90	1009.2			750	0.001		

TABLE B4-2 (Continued - page 3)

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II Fibers	MAGISCAN II f/cc	UNTL Fibers	UNTL f/cc	NIOSH Fibers	NIOSH f/cc
4RMJ	BZ-REM-WK#1	AA502	7/17	0924	1133	129	2.95	380.6			750	0.002		
4RMJ	BZ-REM-WK#1	AA536	7/17	1243	1343	60	2.90	174.0			4000	0.023		
4RMJ	BZ-REM-WK#2	AA515	7/17	1040	1341	181	3.15	570.2			3000	0.005		
4RMJ	BZ-REM-WK#3	AA482	7/17	0922	1133	131	3.00	393.0			1500	0.004		
4RMJ	BZ-REM-WK#3	AA544	7/17	1243	1340	57	3.10	176.7			3000	0.017		
4RMJ	BZ-REM-WK#4	AA496	7/17	1238	1343	65	3.10	201.5			2000	0.010		
4RMJ	BZ-RMS-WK#1	AA528	7/17	1313	1328	15	3.00	45.0			750	0.017		
4RMJ	BZ-RMS-WK#1	AA535	7/17	0936	0951	15	3.05	45.8			750	0.016		
4RMJ	BZ-RMS-WK#2	AA543	7/17	1332	1340	8	2.75	22.0			750	0.034		
4RMJ	BZ-RMS-WK#3	AA527	7/17	1100	1115	15	3.00	45.0			750	0.017		
4RMJ	BZ-RMS-WK#3	AA532	7/17	0956	1011	15	3.20	48.0			750	0.016		
4RMJ	BZ-RMS-WK#4	AA542	7/17	1257	1312	15	3.05	45.8			2000	0.044		
4RMJ	CT-REM	AA478	7/17	0730	1134	244	3.10	756.4			4000	0.005		
4RMJ	CT-REM	AA481	7/17	0730	1134	244	3.00	732.0			750	0.001		
4RMJ	CT-REM	AA521	7/17	1240	1341	61	3.20	195.2			750	0.004		
4RMJ	CT-REM	AA537	7/17	1240	1341	61	3.30	201.3			1500	0.007		
4RMJ	IA-REM	AA512	7/17	0730	1134	244	3.15	768.6			5000	0.007		
4RMJ	IA-REM	AA516	7/17	0730	1134	244	3.10	756.4			1500	0.002		
4RMJ	IA-REM	AA517	7/17	1240	1341	61	3.10	189.1			2000	0.011		
4RMJ	IA-REM	AA519	7/17	1240	1341	61	3.40	207.4			750	0.004		
4RMJ	OA-REM	AA493	7/17	0730	1134	244	3.40	829.6			750	0.001		
4RMJ	OA-REM	AA513	7/17	0730	1134	244	3.30	805.2			750	0.001		
4RMJ	OA-REM	AA526	7/17	1240	1341	61	3.40	207.4			750	0.004		
4RMJ	OA-REM	AA534	7/17	1240	1341	61	3.30	201.3			750	0.004		
4FB	FB-REM-7/18	AA558	7/17								750			
4FB	FB-REM-7/18	AA562	7/17								750			
4PO	AM-FTM	AA529	7/17	0745	1411	386	3.00	1158.0			750	0.001		
4PO	AM-FTM	AA540	7/17	0745	1411	386	2.90	1119.4			750	0.001		

TABLE B4-2 (Continued - page 4)

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II Fibers	MAGISCAN II f/cc	UBTL Fibers	UBTL f/cc	NIOSH Fibers	NIOSH f/cc
4RMI	IA-PST-AGGR	AA538	7/18	1638	2440	482	3.50	1687.0	85085	0.050	7000	0.004		
4RMI	IA-PST-AGGR	AA552	7/18	1638	2440	482	3.25	1566.5	94710	0.060	5000	0.003		
4RMI	IA-PST-AGGR	AA553	7/18	1638	2440	482	3.25	1566.5	51590	0.033	3000	0.002	10395	0.007
4RMI	IA-PST-AGGR	M958	7/18	1638	2440	482	3.50	1687.0	41040	0.024	9000	0.005		
4RMI	IA-PST-AGGR	M968	7/18	1638	2440	482	3.00	1446.0	73102	0.051	1750	0.001	2992	0.002
4RMI	IA-PST-AGGR	M969	7/18	1638	2440	482	3.50	1687.0	129105	0.077	7000	0.004		
4RMI	OA-PST-AGGR	AA557	7/18	1645	2440	475	3.25	1543.8	54285	0.035	750	0.000		
4RMI	IA-PST-NAGR	AA549	7/18	0727	1530	483	3.20	1545.6	54285	0.035	1500	0.001	7315	0.005
4RMI	IA-PST-NAGR	AA559	7/18	0727	1530	483	3.10	1497.3	43120	0.029	750	0.001		
4RMI	IA-PST-NAGR	AA560	7/18	0727	1530	483	3.20	1545.6	31185	0.020	2000	0.001		
4RMI	IA-PST-NAGR	M957	7/18	0727	1530	483	3.15	1521.5	54720	0.036	1750	0.001	2992	0.002
4RMI	IA-PST-NAGR	M959	7/18	0727	1530	483	3.50	1690.5	50445	0.030	3500	0.002		
4RMI	IA-PST-NAGR	M973	7/18	0727	1530	483	3.50	1690.5	69939	0.041	3500	0.002	2992	0.002
4RMI	OA-PST-NAGR	AA548	7/18	0727	1530	483	3.05	1473.2	45045	0.031	4000	0.003	7893	0.005
4RMH	IA-PST-AGGR	AA523	7/18	1625	2435	490	3.50	1715.0	97405	0.057	3000	0.002	1347	0.001
4RMH	IA-PST-AGGR	AA551	7/18	1625	2435	490	3.00	1470.0	165550	0.113	4000	0.003		
4RMH	IA-PST-AGGR	AA566	7/18	1625	2435	490	3.25	1592.5	60060	0.038	2000	0.001		
4RMH	IA-PST-AGGR	M961	7/18	1625	2435	490	3.50	1715.0	29925	0.017	3500	0.002		
4RMH	IA-PST-AGGR	M966	7/18	1625	2435	490	3.00	1470.0	34200	0.023	5000	0.003		
4RMH	IA-PST-AGGR	M974	7/18	1625	2435	490	3.50	1715.0	50530	0.029	1750	0.001		
4RMH	OA-PST-AGGR	AA556	7/18	1625	2435	490	3.00	1470.0	99330	0.068	2000	0.001	6160	0.004
4RMH	IA-PST-NAGR	AA550	7/18	0726	1530	484	3.25	1573.0	8701	0.006	750	0.000	8701	0.006
4RMH	IA-PST-NAGR	AA563	7/18	0726	1530	484	3.15	1524.6	48895	0.032	750	0.000		
4RMH	IA-PST-NAGR	AA565	7/18	0728	1530	482	2.90	1397.8	77385	0.055	750	0.001		
4RMH	IA-PST-NAGR	M952	7/18	0728	1530	482	3.00	1446.0	29070	0.020	1750	0.001	11115	0.008
4RMH	IA-PST-NAGR	M967	7/18	0726	1530	484	3.20	1548.8	29925	0.019	1750	0.001		
4RMH	IA-PST-NAGR	M970	7/18	0726	1530	484	3.40	1645.6	73102	0.044	1750	0.001	2992	0.002
4RMH	OA-PST-NAGR	AA564	7/18	0728	1530	482	3.10	1494.2	78155	0.052	750	0.001		
4FB	FB-PST-7/18	AA520	7/18						16940		750			
4FB	FB-PST-7/18	AA524	7/18						5813					
4FB	FB-PST-7/18	M971	7/18						3249		1750			
4FB	FB-PST-7/18	M972	7/18						4275		1750			
4PO	AM-FTM	AA547	7/18	0729	2435	1026	3.00	3078.0	108185	0.035	750	0.000		
4PO	AM-FTM	AA561	7/18	0729	2435	1026	2.90	2975.4	45045	0.015	2000	0.001		

APPENDIX C

TABULATION OF DATA OBTAINED USING TRANSMISSION ELECTRON MICROSCOPY (TEM)

TABLE C-1. FACILITY 1 PRE- AND POST-REMOVAL SAMPLING -- ANALYZED BY TEM

Sample	Structures/cc					Asbestos structures/cc			Fibers/cc			
Number	Total	Nonasbestos	Asbestos	Chrysotile	Amphibole	Matrix	Cluster	Bundle	Total	Asbestos	Chrysotile	Amphibole
					PRE-REMOVAL - Nonaggressive							
+N-373	0.200	0.104	0.096	0.088	0.008	-	-	0.016	0.184	0.080	0.072	0.008
+N-375	0.095	0.043	0.052	0.026	0.026	-	-	-	0.087	0.052	0.026	0.026
+N-376	0.576	0.456	0.120	0.056	0.064	-	0.008	-	0.560	0.112	0.048	0.064
*N-363	0.048	0.006	0.040	0.032	0.008	-	-	0.016	0.032	0.024	0.018	0.008
*N-367	0.095	0.008	0.087	0.080	0.008	-	0.008	0.016	0.072	0.064	0.056	0.008
*N-371	0.078	0.009	0.069	0.034	0.034	-	-	0.009	0.060	0.060	0.026	0.034
Avg	0.182	0.105	0.077	0.053	0.025				0.166	0.065	0.041	0.025
					PRE-REMOVAL - Aggressive							
+N-360	0.936	0.780	0.156	0.078	0.078	0.009	-	0.009	0.867	0.139	0.061	0.078
+N-369	0.440	0.328	0.112	0.088	0.024	-	0.008	0.016	0.408	0.088	0.064	0.024
+N-374	1.333	1.174	0.160	0.120	0.040	-	-	-	1.280	0.160	0.120	0.040
*N-316	0.528	0.237	0.292	0.229	0.063	0.032	-	0.016	0.457	0.229	0.166	0.063
*N-359	0.386	0.158	0.229	0.173	0.055	0.024	-	-	0.315	0.166	0.110	0.055
*N-372	0.146	0.092	0.055	0.027	0.027	-	-	-	0.146	0.055	0.027	0.027
Avg	0.628	0.461	0.167	0.119	0.048				0.579	0.139	0.091	0.048
					POST-REMOVAL - Nonaggressive							
+N-664	0.141	0.111	0.030	0.007	0.022	0.007	-	-	0.119	0.022	0.007	0.015
+N-685	0.312	0.286	0.026	0.017	0.009	-	-	-	0.225	0.026	0.017	0.009
+N-686	0.264	0.124	0.140	0.107	0.033	-	0.008	-	0.206	0.132	0.099	0.033
*N-682	0.199	0.087	0.113	0.095	0.017	-	0.008	0.017	0.173	0.087	0.069	0.017
*N-687	0.545	0.294	0.252	0.168	0.084	-	-	-	0.512	0.252	0.168	0.084
*N-688	0.364	0.035	0.329	0.234	0.095	-	-	0.009	0.355	0.321	0.225	0.095
Avg	0.304	0.156	0.148	0.105	0.043				0.265	0.140	0.098	0.042
					POST REMOVAL - Aggressive							
+N-667	0.514	0.283	0.231	0.214	0.017	-	0.009	0.017	0.445	0.205	0.188	0.017
+N-872	0.521	0.308	0.213	0.205	0.007	-	0.007	0.044	0.396	0.161	0.154	0.007
+N-873	0.753	0.402	0.342	0.248	0.094	0.043	0.017	0.009	0.651	0.274	0.180	0.094
+N-873R	0.659	0.419	0.231	0.197	0.034	0.026	-	-	0.608	0.197	0.163	0.034
*N-668	0.927	0.287	0.639	0.639	0.000	0.139	0.019	0.009	0.695	0.463	0.463	0.000
*N-874	0.824	0.140	0.676	0.659	0.016	0.181	-	0.008	0.560	0.478	0.461	0.018
*N-683	0.711	0.351	0.359	0.319	0.040	0.056	-	0.016	0.567	0.279	0.240	0.040
Avg	0.701	0.313	0.385	0.355	0.029				0.560	0.294	0.264	0.030

+ = Room A   * = Room B   R = Recount using original grid preparation

TABLE C-2. FACILITY 2 PRE- AND POST-REMOVAL SAMPLING -- ANALYZED BY TEM

Sample Number	Structures/cc Total	Nonasbestos	Asbestos	Chrysotile	Amphibole	Asbestos structures/cc Matrix	Cluster	Bundle	Fibers/cc Total	Asbestos	Chrysotile	Amphibole
					PRE-REMOVAL - Nonaggressive							
+N-267	0.070	0.016	0.054	0.054	0.000	-	-	0.016	0.054	0.039	0.039	0.000
+N-277	0.638	0.482	0.155	0.062	0.093	-	-	0.019	0.622	0.140	0.047	0.093
+N-279	0.226	0.092	0.134	0.100	0.033	-	-	0.025	0.201	0.109	0.075	0.033
*N-257	0.100	0.038	0.062	0.054	0.008	-	-	-	0.100	0.062	0.054	0.006
*N-263	0.057	0.032	0.024	0.016	0.008	-	-	-	0.057	0.024	0.016	0.008
*N-273	0.100	0.015	0.085	0.046	0.038	-	-	0.015	0.085	0.069	0.031	0.038
Avg	0.198	0.113	0.086	0.056	0.030	-	-	-	0.186	0.074	0.044	0.030
					PRE-REMOVAL - Aggressive							
+N-253	0.152	0.093	0.059	0.017	0.042	-	-	-	0.152	0.059	0.017	0.042
+N-261	0.087	0.032	0.055	0.032	0.024	-	-	-	0.087	0.055	0.032	0.024
+N-275	0.181	0.134	0.047	0.016	0.032	-	-	-	0.181	0.047	0.016	0.032
*N-265	0.381	0.333	0.048	0.024	0.024	-	-	-	0.341	0.048	0.024	0.024
*N-269	0.321	0.186	0.135	0.068	0.068	-	-	-	0.287	0.127	0.068	0.059
*N-271	2.698	2.328	0.370	0.132	0.238	0.026	-	-	2.513	0.344	0.106	0.238
Avg	0.637	0.519	0.119	0.048	0.071	-	-	-	0.594	0.113	0.044	0.070
					POST-REMOVAL - Nonaggressive							
+N-792	1.511	0.876	0.635	0.272	0.363	-	0.030	0.015	1.421	0.589	0.227	0.363
+N-793	0.627	0.517	0.110	0.093	0.017	-	-	0.008	0.565	0.102	0.085	0.017
+N-675	0.634	0.317	0.317	0.183	0.133	0.008	-	0.017	0.600	0.292	0.167	0.125
*N-676	0.347	0.226	0.121	0.057	0.065	-	0.008	0.016	0.315	0.097	0.032	0.085
*N-680	0.331	0.121	0.210	0.186	0.024	-	-	0.024	0.291	0.170	0.153	0.016
*N-789	0.267	1.000	0.167	0.108	0.058	0.008	-	0.008	0.233	0.142	0.083	0.058
Avg	0.619	0.360	0.260	0.150	0.110	-	-	0.015	0.574	0.232	0.125	0.107
					POST-REMOVAL - Aggressive							
+N-671	0.986	0.826	0.158	0.099	0.059	-	-	0.010	0.897	0.148	0.089	0.059
+N-795	0.848	0.562	0.286	0.276	0.010	0.039	-	-	0.700	0.227	0.227	0.000
+N-799	3.286	2.662	0.624	0.526	0.099	0.033	-	-	3.024	0.526	0.427	0.099
*N-796	2.402	2.113	0.264	0.216	0.048	0.048	-	-	1.705	0.168	0.120	0.048
*N-797	2.426	2.233	0.192	0.096	0.096	0.024	-	-	2.113	0.120	0.072	0.048
*N-800	0.627	0.454	0.173	0.173	0.000	0.050	-	-	0.519	0.115	0.115	0.000
Avg	1.762	1.475	0.283	0.231	0.052	-	-	-	1.493	0.217	0.175	0.042

+ = Room D   * = Room E

TABLE C-3. FACILITY 3 PRE- AND POST-REMOVAL SAMPLING -- ANALYZED BY TEM

Sample Number	Structures/cc Total	Structures/cc Nonasbestos	Structures/cc Asbestos	Structures/cc Chrysotile	Structures/cc Amphibole	Asbestos structures/cc Matrix	Asbestos structures/cc Cluster	Asbestos structures/cc Bundle	Fibers/cc Total	Fibers/cc Asbestos	Fibers/cc Chrysotile	Fibers/cc Amphibole
					PRE-REMOVAL - Aggressive							
+N-307R	0.350	0.254	0.096	0.076	0.021	0.048	-	-	0.296	0.048	0.027	0.021
+N-316R	0.064	0.028	0.035	0.021	0.014	-	-	-	0.057	0.035	0.021	0.014
+N-320R	0.282	0.220	0.062	0.041	0.021	1.014	-	-	0.254	0.048	0.027	0.021
*N-306R	0.673	0.309	0.364	0.350	0.014	0.137	-	0.027	0.399	0.199	0.192	0.007
*N-309R	0.588	0.385	0.203	0.181	0.022	0.087	-	0.007	0.486	0.109	0.094	0.015
*N-311R	0.055	0.014	0.041	0.041	0.000	-	-	-	0.055	0.041	0.041	0.000
Avg	0.335	0.202	0.133	0.118	0.015	-	-	-	0.258	0.080	0.067	0.013
					POST-REMOVAL - Aggressive							
+N-665R	0.215	0.072	0.143	0.131	0.012	-	-	0.006	0.209	0.137	0.125	0.012
+N-666R	0.089	0.044	0.044	0.033	0.011	0.011	-	-	0.077	0.033	0.022	0.011
+N-790R	0.477	0.364	0.113	0.087	0.024	0.036	-	0.006	0.393	0.072	0.048	0.024
*N-670R	0.485	0.173	0.312	0.201	0.111	0.021	-	0.021	0.416	0.270	0.173	0.097
*N-679R	0.071	0.019	0.052	0.026	0.026	-	-	0.006	0.065	0.045	0.019	0.026
*N-788R	0.130	0.032	0.097	0.091	0.006	-	-	0.013	0.117	0.084	0.078	0.006
Avg	0.245	0.117	0.127	0.098	0.03	-	-	-	0.212	0.107	0.078	0.029

+ = Room F   * = Room G   R = Recount using original grid preparation.

TABLE C-4. FACILITY 4 PRE- AND POST-REMOVAL SAMPLING -- ANALYSIS BY TEM

Sample Number	Structures/cc Total	Structures/cc Nonasbestos	Structures/cc Asbestos	Structures/cc Chrysotile	Structures/cc Amphibole	Asbestos structures/cc Matrix	Asbestos structures/cc Cluster	Asbestos structures/cc Bundle	Fibers/cc Total	Fibers/cc Asbestos	Fibers/cc Chrysotile	Fibers/cc Amphibole
					PRE-REMOVAL - Aggressive							
+N-807D	1.331	1.102	0.228	0.108	0.121	-	-	0.027	1.277	0.202	0.081	0.121
+N-808D	0.444	0.052	0.392	0.318	0.074	-	-	0.059	0.377	0.333	0.259	0.074
+N-809D	1.645	1.548	0.097	0.081	0.016	-	-	0.032	1.435	0.065	0.048	0.016
*N-801R	0.388	0.149	0.237	0.193	0.044	0.044	-	0.018	0.325	0.176	0.141	0.035
*N-802R	0.363	0.257	0.106	0.083	0.023	0.015	-	0.008	0.302	0.083	0.060	0.023
*N-806D	0.817	0.246	0.517	0.518	0.053	0.132	-	0.079	0.562	0.360	0.307	0.053
Avg	0.831	0.509	0.272	0.217	0.055	-	-	0.037	0.711	0.203	0.140	0.054
					POST-REMOVAL - Aggressive							
+N-944R	0.201	0.108	0.093	0.036	0.057	0.014	-	0.007	0.172	0.072	0.014	0.057
+N-947R	0.239	0.206	0.033	0.020	0.013	0.007	-	-	0.206	0.027	0.013	0.013
+N-949R	0.398	0.312	0.086	0.060	0.027	-	-	0.013	0.332	0.073	0.046	0.027
*N-917R	0.150	0.069	0.081	0.069	0.013	0.025	-	0.006	0.119	0.050	0.038	0.013
*N-937D	2.107	1.940	0.167	0.167	0.000	0.021	-	0.021	1.710	0.125	0.125	0.000
*N-940D	1.123	1.101	0.022	0.011	0.011	-	-	-	0.887	0.022	0.011	0.011
Avg	0.703	0.622	0.080	0.061	0.020	-	-	-	0.571	0.062	0.041	0.020

+ = Room H   * = Room I   R = Recount using original grid preparation.

D = Duplicate count from grid prepared from the same filter; original grid preparation not suitable for recounting.

TABLE C-5. MIXED CELLULOSE ESTER FILTERS FROM FACILITY 1 ANALYZED BY TEM

Sample Number	Total Structures (s/cc)	Asbestos Structures (s/cc) Total	Fibers	Matrix	Cluster	Bundle	Unknown	Non-Asbestos Structures (s/cc) Total	Fibers	Matrix	Cluster	Bundle	Unknown	Total Fibers (f/cc)
A. Concentrations Measured During Removal Operations														
AA 3	6.854	1.828	0.718	1.044	-	-	0.065	5.026	3.394	1.110	-	-	0.522	4.112
AA 12	4.142	2.106	0.932	1.070	-	0.069	0.035	2.037	1.726	0.069	-	-	0.242	2.658
AA 14	3.359	1.838	0.887	0.729	-	0.032	0.190	1.521	1.426	0.032	-	0.032	0.032	2.313
AA 26	4.537	2.339	0.567	1.701	-	0.071	-	2.198	1.914	0.246	-	-	0.035	2.481
AA 27	4.251	2.589	0.657	1.778	-	0.155	-	1.662	1.391	0.193	-	-	0.077	2.048
AA 47	4.369	2.165	0.551	1.575	-	0.039	-	2.204	2.008	0.116	-	0.039	0.039	2.559
AA 122	6.547	2.896	1.322	1.196	0.189	-	0.189	3.651	3.211	0.252	-	-	0.189	4.533
AA 125	5.666	4.040	1.889	1.889	0.052	0.105	0.105	1.626	1.416	0.105	-	-	0.105	3.305
AA 138	5.084	2.871	1.224	1.600	-	0.047	-	2.212	2.118	0.094	-	-	-	3.342
AA 142	4.915	3.601	1.022	2.482	-	0.049	0.049	1.314	1.022	0.915	-	0.049	0.049	2.044
AA 157	3.752	1.914	0.563	1.351	-	-	-	1.839	1.538	0.263	-	-	0.038	2.101
AA 158	3.783	2.270	1.211	1.021	-	-	0.038	1.513	1.248	0.151	-	-	0.113	2.459
Avg	4.772	2.538	0.962	1.453	-	-	-	2.234	1.868	0.238	-	-	-	2.830
B. Concentrations Measured During Preparation Operations														
AA 44	0.014	0.014	0.014	-	-	-	-	-	-	-	-	-	-	0.014
AA 45	0.000	0.000	0.000	-	-	-	-	-	-	-	-	-	-	0.000
AA 91	1.272	0.054	0.013	0.040	-	-	-	1.218	1.125	-	-	0.094	-	1.138
AA 111	0.374	0.249	0.180	0.055	-	-	0.014	0.125	0.111	0.014	-	-	-	0.291
Avg	0.415	0.079	0.052	-	-	-	-	-	-	-	-	-	-	0.361

APPENDIX D

STATISTICAL ANALYSIS

APPENDIX D

STATISTICAL ANALYSIS

Goals of Analysis

Do asbestos levels increase because of the removal operations? We study this question by making a variety of comparisons:

a.) comparison of the pre- and post-removal nonaggressive structure and fiber counts.

b.) comparison of the pre- and post-removal aggressive structure and fiber counts.

These first two sets of comparisons are meant to answer the question directly -- is there more asbestos in the given room after removal than there was before removal?

Other comparisons that answer related questions are the following:

c.) comparison of the fraction of fibers that are asbestos, pre- vs. post-removal.

d.) comparison of the faction of structures that are asbestos, pre- vs. post-removal.

The two above comparisons, which could each be made for the aggressive and nonaggressive data separately, could give information on the nature of the removal process.

Other comparisons are as follows:

e.) comparison of the pre-aggressive and pre-nonaggressive data.

f.) comparison of the post-aggressive and post-nonaggressive data.

The above comparisons provide information on the value of the aggressive and nonaggressive data.

Remarks on Statistical Analysis

The comparisons (a), (b), (e), and (f) were carried out on the (natural) log scale, where the residuals seem to behave nicely. There is little indication of outliers. Since several samples were taken simultaneously, the residual mean square from each analysis of variance reflects the sampling and counting variability associated with the TEM method. The estimated relative standard deviation associated with this variability was no bigger than 80%, and as low as 60%. (The comparisons for (c) and (d) were carried out on the untransformed scale.)

Aggressive Sampling -- Changes in Fiber Counts Due to Removal

We begin by discussing comparisons (a) and (b). For the aggressive measurements, the differences among rooms within a facility are not significant at the 5% level. We must consider the asbestos measurements separately for the total (fiber and structure) measurements. See the table below for the ratios of post/pre measurements, for aggressive sampling.) In the first two facilities, the post removal measurements on asbestos fibers and structures are higher than the corresponding pre-removal figures by over 100% (ratio 2.69 and 2.23 from table below). This is not true in the Facilities 3 and 4. In Facility 3, there appears to be no statistically significant difference between the pre- and post-removal figures. In Facility 4, the post-removal asbestos measurements are lower -- by about 70% (ratios 0.293 and 0.308). It is not clear whether these differences have to do with the state of the asbestos or with the effectiveness of the glove control methods. Although one might expect that the figures on total structures and fibers would yield results similar to those for asbestos, there are some differences. Only for Facility 2 are the post-aggressive figures higher than the pre-removal figure -- by almost 400% (ratio = 4.831). This could indicate some differences in the material being removed from the various sites. One might presume that the change in asbestos material present after removal would be similar to the change in all material -- since the asbestos is presumably mixed in with other fibrous material. This, however, is not true for Facilities 1 and 4, the first and the last. Indeed, it is not true for Facility 2, either. Below is the table presenting post/pre ratios from the fitted models for total and asbestos fibers and structures, from the aggressive sampling:

Fitted Values (Post/Pre) -- Aggressive Sampling

Facility	Struc/Tot	Struc/Asb	Ratio	Fiber/Tot	Fiber/Asb	Ratio
1	1	2.69	2.69	1	2.23	2.23
2	4.831	2.69	0.557	4.267	2.23	0.523
3	1	1	1	1	1	1
4	1	0.293	0.293	1	0.308	0.308

For three facilities, there is no statistically significant difference between post- and pre-removal totals (of structures or fibers). However, the corresponding ratios for asbestos take on all three possible trends: increase (Facility 1), stay the same (Facility 3), or decrease (Facility 4). This suggests that any kind of change is possible, and makes it difficult to assign reasons for such change.

Nonaggressive Data -- Changes in Fiber Counts Due to Removal

For the nonaggressive data, Room A in Facility 1 is peculiar. For that room alone, there is no statistically significant difference between the pre- and post-removal data. For all other rooms (in Facilities 1 and 2), the post data are higher -- on average, by between 200% and 300%. We note that the nonaggressive measurements by TEM were not made in Rooms 3 and 4.

These observations can also be made by studying a table analogous to the one constructed above. Here we distinguish between Room A and the other rooms, in agreement with the statistical results discussed above.

Fitted Values (Post/Pre) -- Nonaggressive Sampling

Room	Struc/Tot	Struc/Asb	Ratio	Fiber/Tot	Fiber/Asb	Ratio
A	1.02	0.567	0.556	0.850	0.545	0.641
non-A	4.137	3.093	0.748	4.491	3.357	0.747

We recall that nonaggressive data are available only for Facilities 1 and 2. Thus, the non-A rooms above include both rooms from Facility 2 and one room from Facility 1. The fitted values for the non-A rooms agree fairly well with the aggressive sampling ratios for Facility 2 given in the previous table. The nonaggressive sampling ratios for Room A differ somewhat from the aggressive sampling ratios for Facility 1 from the previous table -- especially in the ratios for asbestos structures and asbestos fibers. The reason why these ratios should indicate an increase in asbestos (ratios 2.69 and 2.23) for the aggressive sampling and a decrease (ratios 0.567 and 0.545) for nonaggressive sampling are unclear.

How Much Higher Are Aggressive Than Nonaggressive Counts?

Rather than just compare the ratios, it might make some sense, as is stated in (e) and (f) at the beginning of these remarks, to compare the actual nonaggressive measurements with the corresponding aggressive measurements. Again, recall that such comparisons are limited to the first two facilities. For the pre-removal data, Room D has different results than the three other rooms, when the aggressive and nonaggressive data are compared. For all four measures, the Room D data yield results for the aggressive measurements that are lower than the nonaggressive -- on average between 30 and 50% lower. For the three other rooms, the aggressive results are over 100% higher. The reason for this discrepancy is not clear.

For the post-removal data, Facility 2 (which includes Room D) shows no statistically significant difference between the aggressive and nonaggressive measurements, for either asbestos fibers or structures. Facility 1 data indicates that the aggressive measurements for asbestos fibers and structures are about 150% higher than the nonaggressive. For the total structures and fibers, the facilities are consistent, and both total structures and fibers are about 250% higher when aggressive sampling is used.

Summary

In summary, a main question here is the effectiveness of glove bags in containing asbestos material during the removal process, the conclusion that the first two facilities shows signs of additional asbestos after removal, whereas the fourth facility show signs of decrease in such material allows the possibility that the removal crew did improve its removal techniques, so that the glove bag methods used in the fourth facility were more effective in containing the asbestos material. (Note that the analysis of PCM data in Table 5-7, comparing pre- and post-removal counts, led to a similar conclusion concerning the decrease in asbestos after removal.)

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