IN-DEPTH SURVEY REPORT

CONTROL TECHNOLOGY FOR ASBESTOS REMOVAL

AT

Bloom Middle School
Cincinnati, Ohio

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FACILITY SURVEYED:	Cincinnati Public School System Bloom Middle School 1941 Baymiller Street Cincinnati, Ohio 45214
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DISCLAIMER

I INTRODUCTION

The primary Federal agency engaged in occupational safety and health research is the National Institute for Occupational Safety and Health (NIOSH) It was established in the Department of Health and Human Services by the Occupational Safety and Health Act of 1970 This legislation mandated NIOSH to conduct a number of 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 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 of health hazard prevention and control In a number of cases, including the present research on asbestos removal, NIOSH control technology studies have been performed in collaboration with the Environmental Protection Agency (EPA)

Since 1976, ECTB has conducted assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques Examples of these completed studies include the foundry industry, various chemical manufacturing or processing operations; spray painting, and the recirculation of exhaust air The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures

These studies involve a number of steps or phases. When a perceived need for research is identified, a literature and/or pilot study is undertaken to assess the need for bench research and/or validation of existing techniques If it is determined that field studies are needed, a series of walk-through surveys is conducted to select facilities, plants, or processes with effective and potentially transferable control concepts or techniques Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures Ultimately, the information from these research activities increases the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury

The overall objective of the present study was to evaluate the efficacy of controls used by the asbestos abatement industry to constrain asbestos contamination at its source The purpose of this specific survey was to determine the effectiveness of the glove bag control method to prevent occupational exposure to asbestos dust during the removal of asbestos pipe lagging from a public school building

The EPA has interest in control methods that prevent emissions created by asbestos removal operations in order to protect the health of the general population and environment In cooperation with this Agency, two facets were added to the scope of work to determine if ambient atmospheric asbestos concentrations were affected by the removal activities, and to assist in the development of an improved analytical method for the measurement of airborne concentrations of asbestos To accomplish this, the EPA (Manufacturing and Service Industries Branch of the Industrial Wastes and Toxics Technology Division in the Office of Research and Development) provided financial and technical support for this project by means of an Interagency Agreement with NIOSH (ECTB)

BACKGROUND

Technical

A pilot study of asbestos abatement operations conducted by ECTB in 1984 revealed that many novel approaches have been and are being developed to control asbestos dust exposure to workers removing asbestos-containing materials. Two principles in general use are wetting and negative pressure Wetting involves the use of fluids to soak or saturate asbestos-containing materials before and during the removal of these materials to reduce the potential for the asbestos fibers to become airborne Negative pressure involves the use of fans or vacuum devices to exhaust contaminated air from enclosed or controlled areas and to draw clean air into these areas in order to contain and reduce airborne asbestos; exhausted air is filtered through high efficiency particulate air (HEPA) filters before being released to the atmosphere

Evaluation of controls applied at the source of contaminant emission, such as isolation or local ventilation, is of particular interest since these are generally most effective in controlling both occupational exposure and environmental releases. One important subset of asbestos abatement activities required the removal of pipe lagging, i e , asbestos-containing materials used to insulate pipes carrying heated or refrigerated liquids or vapors Glove bags were developed specifically as source controls for this use These are large plastic bags which can be sealed around the materials to be removed Workers manipulate tools inside the bag to remove the lagging by means of long gloves sealed into the body of the bag The debris then falls to the bottom of the bag and is contained by it for final disposal in a sanitary landfill Glove bags are widely used both in building abatement and in operation and maintenance of boilers, industrial plants, etc They are often used in such situations without secondary containment (such as plastic barriers and negative air) and thus their performance may be extremely important to assuring the safety of workers in many workplaces For this reason, they were selected for evaluation in this present study

Environmental Regulation

The EPA has been involved in activities to reduce asbestos emissions and contamination of the environment for many years A major concern of this Agency is the degradation or disturbance of in-place asbestos-containing materials in buildings which may result in airborne asbestos concentrations several orders of magnitude higher than ambient levels outside the building Although no new asbestos fireproofing is used in buildings today, the eventual removal of existing in-place asbestos is a major technical and economic dilemma A part of the Toxic Substances and Control Act known as the Asbestos-in-Schools rule requires all primary and secondary schools, both private and public, to inspect the buildings for asbestos-containing materials, document the findings, and inform the employees and the PTA or parents.

In the past, rather than promulgate specific regulations for asbestos abatement activities, the EPA preferred to provide "Guidance Documents" which represented the "best engineering judgment" approach at the time Based on these guidelines, asbestos-containing materials can be (1) left in place and an operation and maintenance program established, (2) encapsulated with a penetrating or bridging chemical; (3) enclosed to prevent access to public or to airflow; or (4) removed Any abatement technique other than removal should be viewed as a temporary measure since recent regulations require the removal of asbestos-containing materials prior to demolition of the building

Because the long-term efficacy of current control methods for asbestos removal is not well known, the EPA funded an addition to the present study to document the effectiveness of glove bags in reducing risk to the environment The specific issue is whether there is less free asbestos in the room after removal than before This required the measurement of the asbestos fiber concentrations in work areas before asbestos removal was started and after the activities were completed These measurements are described subsequently under the subheading, "Methodology "

Analytical

Another adjunct to this study was to use several analytical methods to determine airborne asbestos fiber concentrations Phase Contrast Microscopy (PCM) methods have historically been used for this purpose and are the basis for the Occupational Safety and Health Administration (OSHA) permissible exposure level (PEL) This method utilizes an optical microscope 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) supported on cellulose ester filter media Under NIOSH method 7400, a ratio of either 3 1 (A rules) or 5 1 (B rules) may be used [1] The B rules were used in the present study

The number of fibers which can be observed is limited by the resolving power of the microscope Very thin fibers (less than 0 2 μm wide) cannot be observed by PCM Transmission Electron Microscopy (TEM) is sometimes used for asbestos counting because of the greatly enhanced power of resolution; however, widespread use is hampered by the relative high cost, limited availability of equipment and trained technicians, and the lack of an adequately standardized method of analysis The EPA has developed a provisional method for TEM analysis of asbestos[2] which requires a sample collection medium (polycarbonate) different from that used for PCM NIOSH has also developed a TEM method, Number 7402,[3] using cellulose ester filters

Cincinnati Board of Eduction

In the summer of 1983, the Cincinnati Public School Board contracted with Gandee and Associates to survey asbestos conditions in 84 facilities Asbestos-containing pipe and/or boiler lagging was found in 76 of these facilities, seven had asbestos-containing acoustical plaster, two had asbestos-containing fireproofing; and one had asbestos-containing acoustical ceiling tile In addition, there were numerous occurrences of miscellaneous architectural (pressed asbestos-board, asbestos-cement sheeting, etc.) and nonarchitectural (asbestos gloves, leggings, pot holders, gaskets, etc) materials in the facilities The Gandee report[4] recommendations for controlling these asbestos hazards included the removal of acoustical plaster and fireproofing where there was significant deterioration, and the repainting and repairing of acoustical plaster in some areas Also recommended was the repair of damaged and/or exposed asbestos pipe and boiler insulation It also highly recommended the establishment of an asbestos hazard management program which would provide for employee training and the monitoring and management of all asbestos materials that remain in these facilities

At Bloom Middle School, Gandee reported damaged and exposed asbestos in many of the occupied areas, in the ventilation system, in the boiler room, and in the maintenance and storage areas Pipe lagging debris was found scattered throughout the two HVAC tunnels (the air handling system reportedly had not been in operation for 5 to 10 years) A sample of asbestos floor pad in one room was reported to contain 43% chrysotile An extensive cleanup and repair program was completed, including the replacement of easily accessible lagging at lower elevations with metal clad fiberglass insulation

In 1985, the School Board contracted the I & F Corporation to remove deteriorated pipe lagging and other asbestos materials The management and workers of this firm cooperated with the NIOSH survey team during the renovation of four facilities This report deals with observations and data taken at one of those four facilities: Bloom Middle School

II SITE AND PROCESS DESCRIPTION

SITE DESCRIPTION

During a walk-through visit on June 4, 1985, the NIOSH survey team noted that, in spite of the metal cladding, the new fiberglass lagging had been severely damaged in numerous locations The remaining asbestos lagging was generally in good repair, however, there were instances of torn or separated lagging above false ceilings and at pipe interfaces with walls and structural members None of this damage was observed in the rooms evaluated Bulk samples taken at the time of the removal activity were analyzed as follows. In room 3, lagging on the large pipe contained less than 1% chrysotile and that on the small diameter pipe contained 20-25% chrysotile; the lagging in the lunchroom contained 30-35% chrysotile No actinolite/tremolite, amosite, anthophyllite, or crocidolite asbestos forms were detected in these samples

The removal contract for the Bloom Middle School required approximately 1,800 linear feet of asbestos pipe lagging to be removed from 15 major rooms and areas During this survey, removal operations were observed in four rooms located on the basement level: the Music Room (Room 5), the Special Education (Room 3), the Lunchroom, and the Kitchen Rooms 3 and 5 had wood flooring and plastered walls which had deteriorated in spots Window curtains were hanging in the lunchroom Ceiling tile was present in Room 5 and in the lunchroom

Pre- and post-removal studies were conducted in Rooms 3 and 5 Although not required by the specifications of work for this glove bag removal contract, these "controlled areas" were isolated to minimize the interaction with areas and activities outside the study area, at the request of the survey team All air ducts, holes, and windows in these rooms were sealed with polyethylene sheeting (poly) and duct tape, doors were hung with a two sheet poly baffle

Room 5 (Figure A) measured approximately 35'x 33'x 12 5', enclosing 14,438 cubic feet Insulation from approximately 40' of 5-inch and 25' of 2-inch pipe was removed, including 5 T-joints, 13 elbows, 6 pipe hangers, and 5 pipe/structure intersections

Room 3 (Figure B) measured approximately 35'x 23'x 13 5', enclosing 10,868 cubic feet Insulation from approximately 45' of 3-inch and 53' of 2-inch pipe was removed, including 5 T-joints, 15 elbows, 7 pipe hangers, and 7 pipe/structure intersections

The Lunchroom (Figure C) measured approximately 116'x 35'x 12 5', enclosing 50,750 cubic feet Insulation from approximately 91' of 4-inch, 9' of 3-inch, and 25' of 2-inch pipe was removed, including 5 T-joints, 10 elbows, 7 pipe hangers, and 4 pipe/structure intersections

The Kitchen (Figure C) measured approximately 35'x 31'x 12 5', enclosing 13,563 cubic feet. Insulation from approximately 13' of 4-inch and 8' of 2-inch pipe was removed, including 2 T-joints, 4 elbows, 1 pipe hanger, and 1 pipe/structure intersection.

PROCESS DESCRIPTION

There are a variety of approaches to the asbestos removal process. For the purpose of completeness and comparison, a generic description of the process is included below, followed by a summary of the specific methods used in this study

Asbestos removal is a complex task which requires special knowledge and exceptional controls. There is a need for careful planning by an expert consultant to assure that the building owner, occupants, and removal workers are protected by a definitive and complete specification of work and that a competent asbestos removal contractor is selected On-site monitoring and control by the owner representative is very critical These prerequisites should be provided for prior to the start of the removal operations Typically, the removal work involves three phases preparation, removal, and decontamination A generic description of the activities is summarized below to provide a general overview of industry practices; however, each job will vary with the specific circumstances

Generic Overview

<u>Preparation</u> The site is cleaned, cleared of all movable materials, and isolated by sealing off all access with plastic sheeting taped to windows, air vents, doors, etc Surfaces not involved in the removal are covered and sealed with plastic sheeting (usually polyethylene, commonly called

FIGURE A

Schematic Piping Layout of Room 5

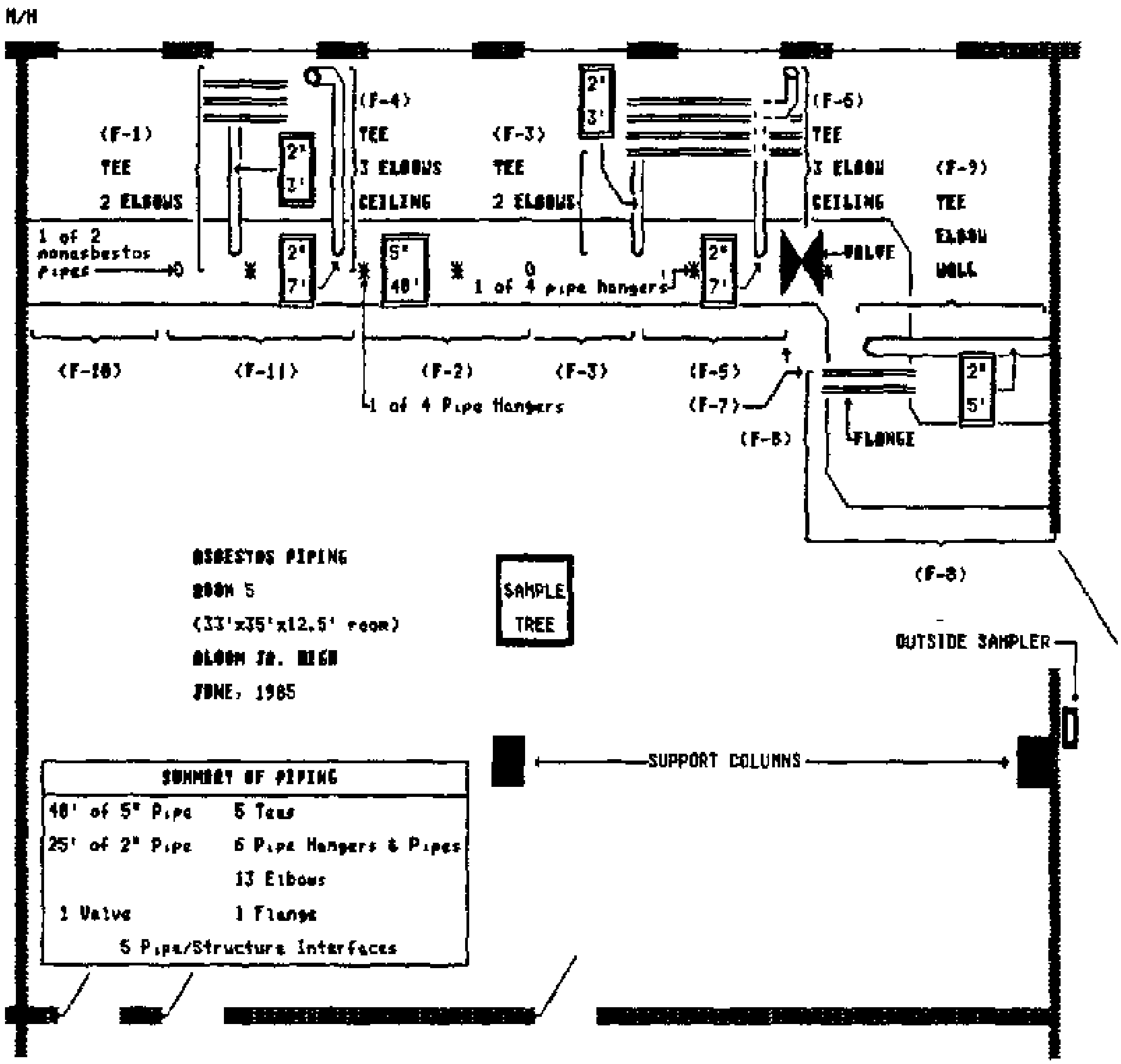


FIGURE B

Schematic Piping Layout of Room 3

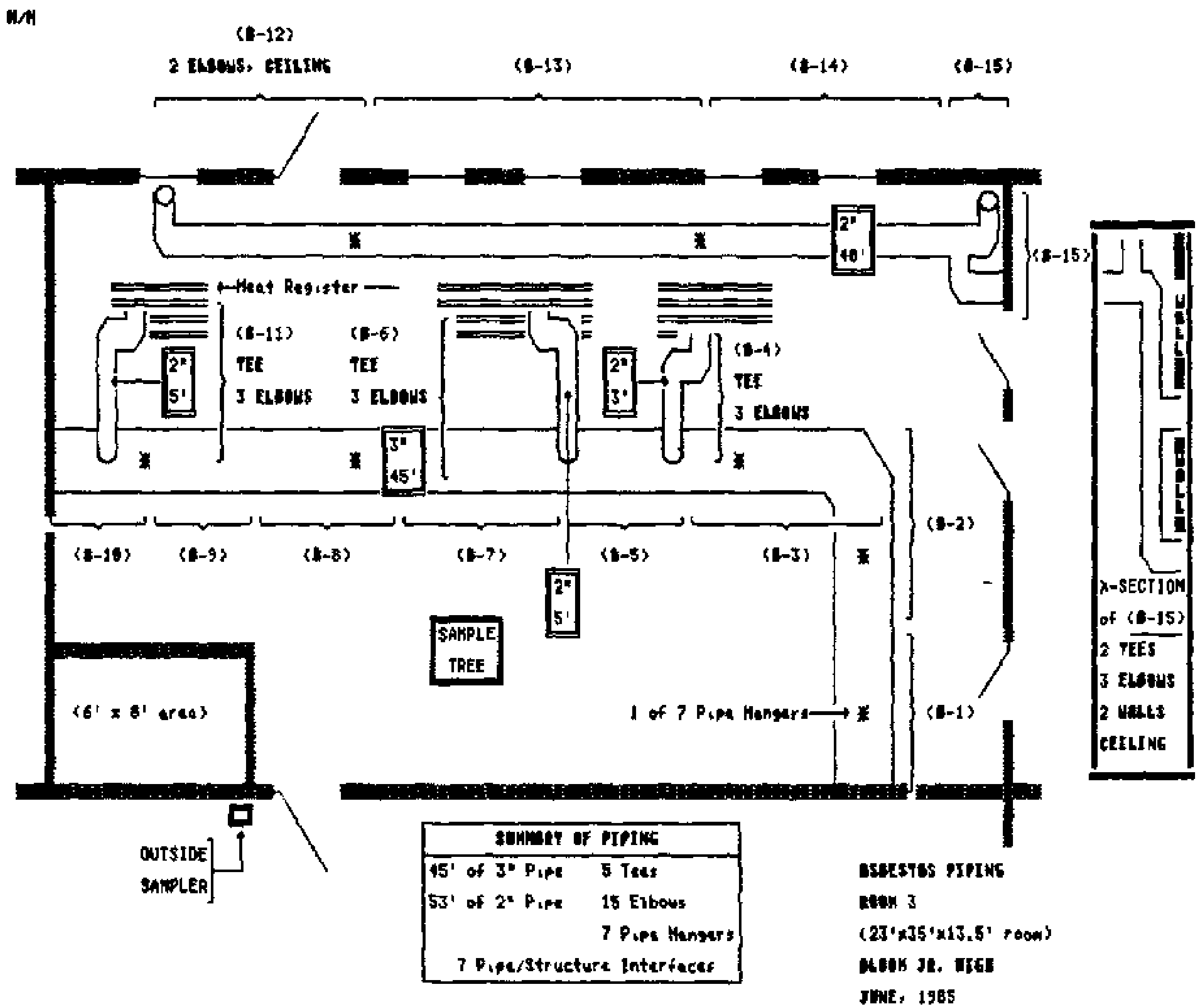
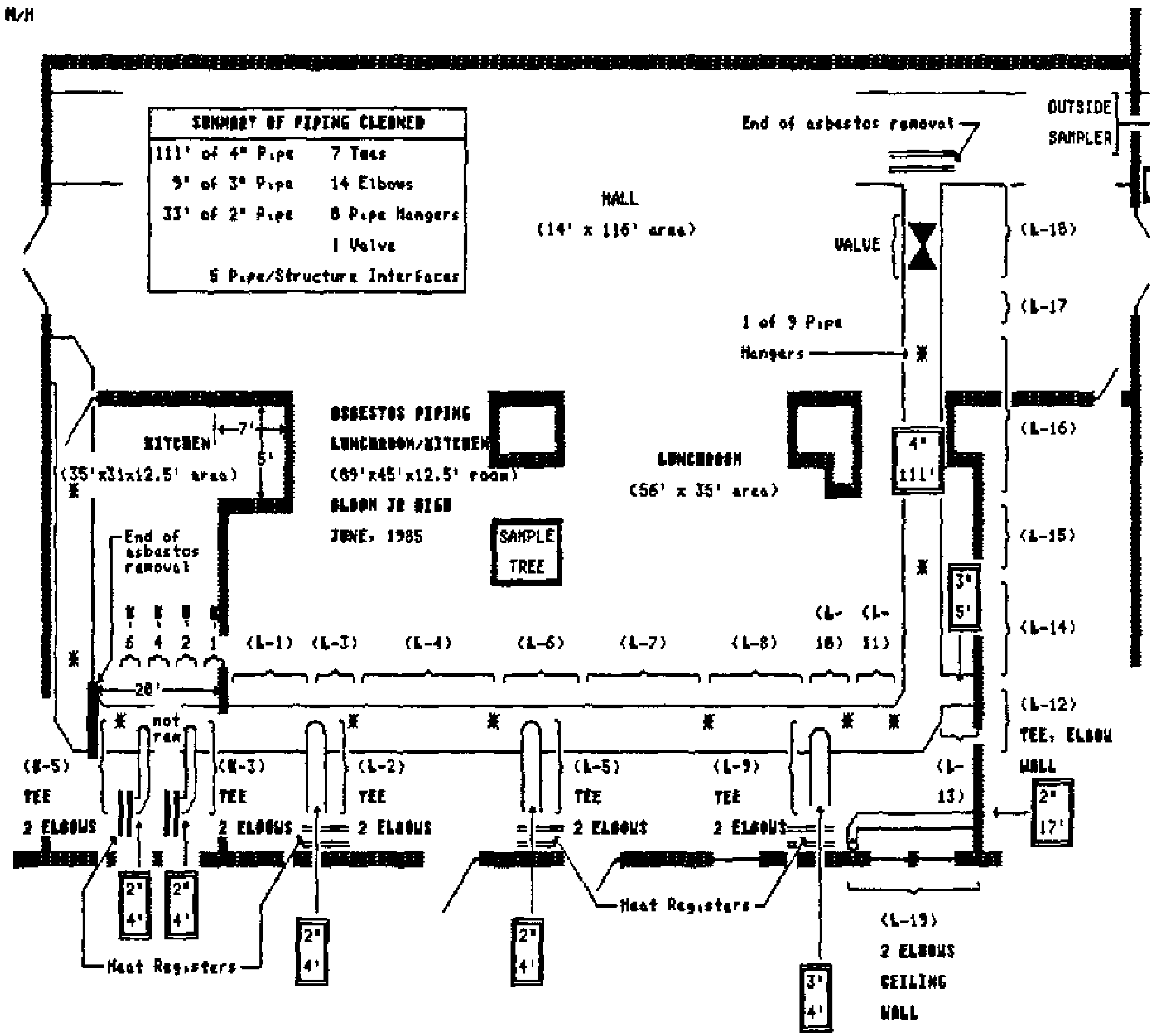


FIGURE C

Schematic Piping Layout of Kitchen/Lunchroom



"poly") and the lighting fixtures are removed Two entrance and egress contamination control facilities are established· one with showers and change rooms for personnel and the other for waste material handling

<u>Removal</u>: The asbestos-containing materials are wetted (saturated, if possible) as they are removed from the structures they cover, then the wet debris is collected and removed from the area Work is accomplished 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 and is exhausted outside the building through high efficiency exhaust filters Air should be exhausted in sufficient quantity and with consideration of the flow patterns within the enclosure to optimize the benefits of dilution air in reducing fiber concentration within the enclosure. The EPA recommends four air changes per hour; however, some contractors use twice this amount When large air volumes cannot be exhausted, a portion of the air cleaning may be performed by recirculating it through filters inside the work area Sometimes local pickup at the point of release is used Work should begin at the point furthest from the exhaust and proceed toward the exhaust The workers inside the containment must wear appropriate, approved respiratory protection, and protective clothing

<u>Decontamination</u>. All of the asbestos fibers remaining after the removal operations are completed must be removed from surfaces and from the air This usually requires multiple cleaning and settling periods combined with continuous air filtration All contaminated waste must be disposed of in accordance with EPA and local government regulations

Practices

As demonstrated by this study, many of the above practices should also apply to glove bag removal, although there are no definate guidelines for glove bag use The techniques observed in the present study are summarized below

<u>Preparation</u>: The contract for asbestos removal in Bloom Middle School required the use of glove bags as the primary control in lieu of total room containment and ventilation It also required the installation of poly barriers in stairways and hallways to separate the work area from the rest of the building Decontamination showers were not required The floors under the pipe being cleaned were usually covered with poly to facilitate cleanup The removal contractor enclosed all of the piping in an envelope fabricated from poly sheeting and duct tape before starting the removal A length of poly sheeting was brought up from under the pipe, folded over the pipe lagging, the edges were rolled together and stapled to the top of the lagging forming a cylinder or envelope enclosing the lagging Duct tape was used to seal the longitudinal seam The envelope was made much larger than the diameter of the lagging to facilitate working inside it the first day, but on subsequent days it was constructed to be merely a loose fit around the lagging 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 before enclosing it in the poly

Removal During the first day the glove bags were hung at widely separated, predetermined intervals as part of an extended envelope The lagging was removed in the envelope, then transferred to the bags through the poly envelope Workers reached through openings they cut in the top of the envelope rather than using the gloves in the bags to accomplish the removal and transfer of the lagging to the bags The glove bag was used as a receptacle rather than as a glove bag The tools for cutting metal bands and lagging were inserted, operated, and transferred between bags through breaches in the enclosure. The lagging was wetted as it was removed from the pipe Water sprayers (hand-pumped garden sprayers having a 2- to 3-gallon capacity) fitted with 30" hoses; were elevated to the working level, and were often hung from the pipes This technique required workers on ladders and platforms to climb down periodically to fill the sprayer with amended water and pump up the pressure The pipe was washed with water and rags after the lagging was removed

It appeared that glove bag removal was a new technique for this crew and that they had little previous experience with it Therefore, on the second day workers were instructed by the NIOSH survey team on improved procedures to enclose and remove the lagging within the glove bags and to transfer contaminated tools to the next glove bag, i e , the tools for cutting metal bands and lagging were placed inside the glove bag and the bag was hung from the pipe Bags were taped to form a seal along the length of pipe and then the bag ends (sleeves) were taped to the poly-jacketed pipe The lagging was wetted as it was removed from the pipe Contaminated tools were transferred to new bags from the previously used bag, inside an inverted glove which was tied closed and cut off Workers were cautioned of the need for increased wetting It was suggested that by using longer hoses, the pressure vessels could remain on the floor and be serviced by a worker on the floor level, thereby eliminating the need for frequent climbing from ladders and scaffolds to accomplish this task

Decontamination: The spilled material was removed from the floor with a portable HEPA vacuum cleaner After the work was finished in an area, the poly was removed from the floor and the floor was wet mopped Bags of waste were removed from the enclosure prior to post-removal air sampling The poly seals on windows, vents, and doors were kept in place to minimize the interaction with the surrounding areas and activities

POTENTIAL HAZARD AND EXPOSURE CRITERIA

Occupational Exposure Criteria

The two sources of occpuational exposure criteria considered in this study are (1) the NIOSH Recommended Exposure Limit (REL), and (2) the Department of Labor OSHA Permissible Exposure Limit (PEL)

NIOSH recommends that employee exposure to asbestos be reduced to the lowest feasible limit, due to the carcinogenic nature of this substance The NIOSH REL published in 1976 is 0 1 fibers greater than 5 µm in length per cubic centimeter (f/cc) [5] NIOSH also recommends that an "action level" of

0.01 f/cc be used when routine (nonaggressive) air quality sampling is conducted inside buildings for screening purposes Action to be taken could be an increase in control surveillance, asbestos confirmation by TEM, and actions to reduce asbestos levels, if warrented.

In 1985, the OSHA PEL was 2 0 fibers per cubic centimeter (f/cc), greater than 5 µm in length, averaged over an 8-hour work day, with a ceiling concentration of 10.0 f/cc, not to be exceeded over a 15-minute period There was also a provision for medical monitoring of workers routinely exposed to levels in excess of 0 1 f/cc

NIOSH submitted an update on the recommended asbestos criteria at the OSHA proposed rule-making hearings for asbestos in June 1984 [6] The NIOSH position is summarized below

> The carcinogenic potential of asbestos is no longer in doubt, however, there is some uncertainty about the toxicological and morphological properties which determine the carcinogenic potency of various fibers NIOSH believes that on the basis of available information, there is no scientific basis for differentiating between asbestos fiber types for regulatory purposes Data available to date provide no evidence for the existence of a threshold level Virtually all levels of asbestos exposure studied to date demonstrated an excess of asbestos-related disease
>
> NIOSH continues to believe that both asbestos and smoking are independently capable of increasing the risk of lung cancer mortality When exposure to both occurs, the combined effect, with respect to lung cancer, appears to be multiplicative rather than additive From the evidence presented, we may conclude that asbestos is a carcinogen capable of causing lung cancer and mesothelioma, independent of smoking
>
> NIOSH has recommended that asbestos be controlled to the lowest detectable limit It is our contention that there is no safe concentration of exposure to asbestos Any standard, no matter how low the concentration, will not ensure absolute protection for all workers from developing cancer as a result of their occupational exposure However, lower exposures carry lower risks
>
> Since the only widely available method, NIOSH Method 7400,[1] is able to achieve (intralaboratory) accuracy of 12 8% RSD at an exposure limit of 0 1 f/cc (100,000 f/m^3) in a 400 liter sample, NIOSH and others have recommended an exposure limit (REL) of 0 1 f/cc for asbestos based on 8-hour time-weighted average concentrations [5] While this is a well understood practice, we can not find compelling arguments to prevent a recommendation based on alternative sampling periods In fact, such an approach may provide more protection than an 8-hour based sampling period that allows short-term exposures 6 or 10 times greater than the 8-hour exposure limits being considered by OSHA Furthermore, since there is uncertainty regarding the cumulative dose required to initiate disease, it seems reasonable to make every attempt to control exposures to as narrow a range of concentrations as possible One way to accomplish this is to restrict the period over which workplace concentrations can be averaged

Personal sampling pumps are available, with flow rates up to 3 5 lpm, which would allow a sampling time of two hours or less

Finally, we still believe that there are occasions, such as mixed fiber exposures, where fiber specificity is necessary Therefore, we recommend the use of electron microscopy in the event of process or product modification, in mixed fiber exposures, or when there are other reasons for characterization of fiber type and morphology

Asbestos removal work fits both of the above mentioned conditions where electron microscopy is needed to characterize the fiber exposure environment The fibers are commonly an unknown mixture of asbestos and various other materials The material being removed and conditions of removal may vary from hour to hour and room to room, not to mention from site to site The variability is not only a factor of the removal process, but also of the original asbestos treatment and the history of maintenance and deterioration from use

As noted, the occupational exposure criteria - the NIOSH REL and the OSHA PEL - are based on the readily available Phase Contrast Microscopy analytical method This method has inherent limitations based on the physics of the optical microscope and upon the ability of the counters to reliably discriminate the specified length to width ratio in a complex sample matrix The minimum diameter routinely observed is on the order of 0 5 µm The NIOSH 7400 method stipulates 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 as the current OSHA standard, and thus have the advantage of relating to current and historical compliance data. They have the potential disadvantage of counting particles that may or may not be fibers In the present study, TEM offers the advantage of being able to determime the actual dimensions of all fibers that were counted, and thus, to differentiate the numbers of fibers with various length to width ratios A coarse analysis of this data indicates that fiber counts using NIOSH 7400-A and 7400-b counting rules would differ by less than 20%

Another concern is that asbestos fibrils as small as 0 02 µm in diameter and less than 1 µm in length are visible only with electron microscopy These fibrils constitute a significant and variable proportion of the total fibers present in the removal environment Thus PCM, in counting only optically visible particles, may not be a good indicator of the total fibers present. Controversy over the health effect of small fibers (and thus what sizes of fibers should be counted) adds further ambiguity to this area

On June 20, 1986, OSHA issued a revised standard PEL, which reduced the PCM level to 0 2 f/cc, as an 8-hour time-weighted average (TWA) exposure It also set an action level of 0 1 f/cc that triggers worker training, medical monitoring, and other requirements The new standard does not set a ceiling or short-term exposure limit

EPA has the jurisdiction over schools and adopted the OSHA standard in 1985 and the revised standard in February 1987

EPA has also established guidelines for clearance of asbestos removal areas for reoccupancy These were first published in the form of recommended practices [7] In 1984/85, the guidance was to perform visual inspection followed by air sampling with PCM analysis The level to be met was based on the lower limits of detection for the NIOSH Method P&CAM 239[8] This ranged from 0 01 to 0 03 f/cc for the recommended sample volumes of 1,000 to 3,000 liters

In the 1985/86 time period, a revised guidance was issued[9] which recognized the validity of NIOSH Method 7400 and recommended a 3,000 l sample when using the old P&CAM 239 methodology, in order to give a minimum detection limit of 0.01 f/cc. This guidance also recommended using aggressive sampling methods, with TEM analyses as the method of choice. Clearance levels for TEM were to be no higher than ambient background levels measured at the same time

In October 1986, the Asbestos Hazard Emergency Response Act was passed which required EPA to set regulations for asbestos removal in schools On April 30, 1987 a proposed rule was published in the Federal Register[10] for comment It includes a proposed regulation for aggressive air sampling to determine if a response action (clearance procedure) has been satisfactorily completed. For two years after the rule becomes effective (until October 7, 1989), ". 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 shall be considered complete when the result of samples collected in the affective 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 of 0 01 f/cc of air."

After two years, the proposed EPA clearance rule, if adopted, will require a three-step process for using TEM to determine successful completion of a removal response action (clearance procedure) The final two steps will involve a sequential evaluation of five samples taken inside the work site and five samples taken outside the work site. If the average concentration of the inside samples does not exceed the "limit of quantitation" for the TEM method, then the removal is considered complete The "limit of quantitation" is proposed to be set at "4 times the analytical sensitivity" of this method which is stated to be no greater than 0 005 f/cc. This is based on an assumed media contamination level of 75 fibers/mm^2 Therefore, the <u>proposed</u> clearance limit for TEM is calculated to be 0.02 f/cc

In relatively clean public buildings and the surrounding ambient environment, where there are proportionally fewer larger airborne fibers due to settling out, it is not at all reliable to presume that the absence of fibers measured by PCM assures that there are no thin fibers as well For these conditions, the EPA has specified the use of the more sophisticated electron microscopy method EM has higher resolution, and is thus capable of seeing all of the asbestos fibers present, however, it is not as well standardized or as readily available

III METHODOLOGY

EVALUATION METHODS

Air Sampling and Analysis

Workplace Sampling

Personal and area air samples were collected and analyzed by Phase Contrast Microscopy (PCM) in accordance with NIOSH Method 7400[3] (using 25-mm cassettes and cellulose ester filters) A Magiscan II automated counting system was intended for use as a screening tool and a number of samples were analyzed using this system, however, lack of agreement with the PCM analysis, under low fiber and light particulate loading, restricted its use in this study. A sequence of 2- or 3-hour, interior area and personal samples was collected over a full work shift, using DuPont P-4000 personal sampling pumps Approximately 400 liters of air were filtered, at 2 5 to 3 5 lpm, for personal samples and area samples. When low concentrations were expected, area samples were collected at flow rates of 2 0 to 3 5 lpm for approximately 8 to 16 hours for a total of approximately 1,500 to 3,000 liters per sample The area samples were taken in duplicate on two media· 37-mm polycarbonate and 25-mm cellulose ester filters The 25-mm cassettes with 2-inch cowls were wrapped with metal foil as a precaution to minimize possible effects of static electricity This sampling array was also used to collect area samples adjacent to but outside the poly baffled entrance to the room.

Pre- and Post-Removal Sampling

Both pre- and post-removal environmental evaluations were accomplished by sampling for an 8-hour period in a nonaggressive mode, followed immediately by an 8-hour sampling period in the aggressive mode Nonaggressive sampling is performed in a quiescent atmosphere, allowing at least 24 hours for the room to dry out if the sampling follows removal and cleaning Aggressive sampling involves the use of forced air equipment, such as a leaf blower, to dislodge free fibers from surfaces, and oscillating pedestal fans to keep the fibers suspended during the 8-hour sampling period

The samples were taken in triplicate on three media: 37-mm polycarbonate, 37-mm cellulose ester, and 25-mm cellulose ester filters. The 25-mm cassettes with 2-inch cowls were wrapped with metal foil as a precaution to minimize possible effects of static electricity. Six of the nine samples at each station were collected at a rate of between 3 0 and 3 5 lpm, utilizing individual limiting orifices The vacuum source was a manifold connected to a Gast 0485 vacuum pump in parallel with a smaller Thomas 106-83F pump The other three samples (one of each filter type) at each station were collected using Dupont P-4000 pumps at 2 5 to 3 5 lpm for 8 full hours Sampling filters were hung face down in alternated positions from a ring which was supported approximately 5 feet above the floor An air sample was collected on a cellulose ester filter located adjacent to but outside the poly-baffled entrance to the room during the post-removal sampling period Two side-by-side ambient outdoor samples were collected during the 16-hour period on 25-mm cellulose ester filters

Air temperature and relative humidity were determined using an aspirated psychrometer

Cellulose ester filters were analyzed using both Magiscan and PCM. All fibers with a 5 1 (or greater) length-to-width ratio were counted using NIOSH Method 7400-B counting rules Selected cellulose ester samples were analyzed by the modified Burdett and Rood method [11]

Polycarbonate filters were analyzed by the Yamate Revision to the EPA Provisional TEM Method [6] The type and size distribution for fibers, clusters, bundles, and clumps were reported from the TEM analyses Level I analysis was used to identify the amphibole, chrysotile, and nonasbestos composition of each type

Real-Time Fiber Monitoring

GCA Fibrous Aerosol Monitors (FAM), Model No 1, were used to observe variations of real-time fibrous aerosol concentrations One FAM was used to observe the effect of process variations, the other was used to monitor fiber contamination levels in the removal area Metrosonics Model No 331 Data loggers were utilized to record sequential FAM readings

EVALUATION STRATEGY

Overview

Personal breathing zone and area air samples were taken within the work enclosure to characterize the effectiveness of source controls Samples were taken outside the work enclosure in adjoining hallways to determine the potential interaction or contamination from activities outside and within the controlled areas Since asbestos removal activities were also being performed in other areas of the building, the asbestos concentrations measured in the hallways could have been affected by these other activities Ambient samples were taken outside the building to establish background levels In cooperation with the EPA, additional samples were taken prior to and following completion of the removal work to assess the efficacy of the removal method and to compare sampling and analytical methods Because of time constraints, and to provide quantifiable comparisons, the post-removal samples were collected after initial cleaning by the removal contractor (see the specific methods used section of the Process Description) but not after visual clearance, as is required for EPA final clearance measurements. Therefore, the post-removal results do not represent the final clearance achieved by the contractor However, they demonstrate the relative merits of the sampling and analytical methods Approximately 260 samples were taken over a 6-day period

Personal Air Samples

Sequential 2- to 3-hour personal samples were taken daily for each of the four workers In addition to these full shift time-weighted average samples, on the second through the fourth days, five to seven 15-minute, short-term exposure samples were collected daily Worker exposures were measured for the site preparation and removal processes and the other associated activities.

Other activities included waste collection and disposal, decontamination, and equipment operation and maintenance About 8 to 15 sequential and short-term personal exposure samples were collected for each 5- to 6-hour work shift

Area Air Samples

Area air samples were taken during the removal activity, both inside and outside the controlled area A series of 2- to 3-hour daily interior (source) samples were collected using a cart-mounted, mobile, sampling tree in the proximity of the removal activity to provide an indication of the effectiveness of the source controls and the magnitude of exposure during different activities These samples were changed on the same schedule as the personal samples A similar series of area samples were collected in the room during the removal activity to determine the level of fibers during removal Daily exterior area samples were taken in the hall adjacent to the study area Outdoor ambient background samples were taken outside windows well removed from the test area

Direct Reading Monitors

Direct reading Fibrous Aerosol Monitors (FAM's) were used to provide insight into the correlation of various process and control parameters with the short-term variations in area concentrations. One FAM with a data logger was positioned adjacent to the interior work area sample tree The data logger recorded sequential observations of the background fiber count inside the enclosure A second cart-mounted, mobile FAM was employed to detect 10-minute changes in fiber concentration in the vicinity of the various work activities.

Use of Personal Protective Equipment

Workers were not required and were not observed to wear protective equipment during the preparation stage, primarily covering the pipes with poly. When removal activity was started in a room, all workers were required to wear disposable coveralls and half face mask cartridge respirators equipped with high efficiency cartridges

Identification of Safety Hazards

In addition to the evaluation of asbestos dust exposure, work practices and the potential for worker exposure to, and the control of, safety and other hazards, such as heat stress, electrical hazards, hazardous surfaces, etc were qualitatively evaluated

IV CONTROL TECHNOLOGY

Occupational exposures can be controlled by the application of a number of well-known principles, including engineering measures, work practices, personal protection, and monitoring These principles may be applied at or near the hazard source, to the general workplace environment, or at the point of occupational exposure to individuals. Controls applied at the source of the hazard, including engineering measures (i.e , material substitution, process/equipment modification, isolation or automation, local ventilation) and work practices, are generally the preferred and most effective means of control both in terms of occupational and environmental concerns Controls which may be applied to hazardous agents that have escaped into the workplace environment include dilution ventilation, dust suppression, air filtration and recirculation, and housekeeping Control measures may also be applied near individual workers, including the use of remote control rooms, isolation booths, supplied-air cabs, work practices, and personal protective equipment

In general, a system comprised of the above control measures is required to provide worker protection under normal operating conditions, as well as under conditions of process upset, failure, and/or maintenance Process and workplace monitoring devices, personal exposure monitoring, and medical monitoring are important mechanisms for providing feedback concerning effectiveness of the controls in use Ongoing monitoring and maintenance of controls to ensure their proper use and operation, and the education and commitment of both workers and management to occupational health are also important ingredients of a complete, effective, and durable control system

Asbestos removal workers are often required to work in areas where there is a potential exposure to high levels of airborne asbestos fibers Therefore, it is incumbent upon the employers of these workers to ensure that procedures which effectively reduce or eliminate exposure to asbestos and other hazardous materials or situations are used

Dust Exposure Control Strategy

In this school, workers' dust exposures were contolled at the sources of the dust, in the general work environment, and at the worker

Source Controls

Potential sources of asbestos dust were controlled by enclosing the pipe lagging in plastic sheeting before removing it from the pipes Plastic glove bags were used to enclose and collect the pipe lagging during removal activities. The pipe lagging was wetted with amended water prior to, during, and after its removal from the pipes

Containment in the Work Environment

To prevent general contamination of the school building by dust from the removal operations in the study areas, overlapping plastic curtains were placed on all doors to halls or other rooms Additionally, all ventilation registers and windows were sealed with plastic sheeting and tape, immovable furniture and fixtures were also covered with plastic sheeting.

Personal Protective Equipment

Since the levels of worker exposure were unpredictable, and unexpected events might cause excessive dust exposures, the removal workers and the field investigators used respirators both during removal operations and during post-removal air sampling periods The removal workers used half-face dust respirators with high efficiency dust filters NIOSH investigators used Racal Air Stream Powered Air Particulate Respirators (Breatheasy-5®) with high efficiency filters In addition, both the workers and the investigators wore disposable Tyvek® coveralls which were replaced daily

V FINDINGS AND OBSERVATIONS

Field Blanks and Lower Limits of Detection

Raw data from PCM analysis are shown in Appendix A When analyses were reported as less than the detection limit, values equal to half of the limit of detection were entered, as noted, and computations were made using these values All of the 20 cellulose ester field blank PCM analyses were below the detection limits, so that no correction for blanks was required

There is a degree of uncertainty regarding the TEM analysis of polycarbonate filters by the EPA provisional method EPA conducted a workshop in April, 1986 to review filter blank contamination Field and media blanks prepared from the same lot of polycarbonate filter media used in this study were analyzed by several laboratories There was an unexpectedly high variability in analytical results both within and between the laboratories. The workshop participants discussed possible causes of these findings [12] While the overall issue could not be resolved, it is clear that standardization of methodology was lacking and that contamination of the filter media was a major problem This subject will be addressed more thoroughly in the final report for this four-school project Because of this uncertainty in blank analyses, no corrections were attempted in reporting the data in Appendix B

Confidence Limits

The PCM fiber counting technique is highly subjective; results reflect the training and experience of the counter and intra and inter laboratory quality assurance The confidence limits are also dependent upon the sample loading (the number of fibers on the filter) and may differ for each sample

The coefficient of variation, CV, (also know as the relative standard deviation, RSD) has two components The process of counting randomly (Poisson) distributed fibers on a filter surface will give a CV component which is a function of the number of fibers counted. The other component of variability comes from "subjective" differences from counter to counter and from laboratory to laboratory NIOSH and UBTL have demonstrated a PCM analysis correlation of 0 91 and an interlaboratory coefficient of variation of 0 41 for this study based on a 25 sample comparison The UBTL results are about 1 5 times the NIOSH results at the 1% significance level However, interlaboratory confidence limits vary widely In the absence of a known CV between laboratories a value of 0 45 is used This would result in lower and upper 95% confidence limits of the mean on the order of one half and three times the reported level, respectively [1]

Tables A-1 and A-2 are included in Appendix A to provide the reader with an appreciation for the range of confidence limits which would apply to the <u>mean result</u> of a single sample analyzed by a group of laboratories, assuming an interlaboratory CV or 0 45 As shown in these tables, the range varies with the number of fibers counted and the sample volume

These tables can be used to approximate the range of confidence limits to be applied when comparing the analytical results of one laboratory to the mean of analyses duplicated in other laboratories. The range is a computed 95% upper and lower limits based on a 100 grid or 100 fiber count and a subjective CV component of 0 45, which is used in the absence of a demonstrated CV between the laboratories being compared [1] (See revision 2 of Reference 1 dated May 1986 for a more complete discussion of confidence limits) Computations were made for a range of fiber counts using three sample volumes 400 l, the approximate volume collected for half-shift samples, 1,500 l, for full shift pre- and post-removal and daily ambient samples, and 2,500 l, for pre- and post-removal double shift ambient samples

TEM analysis preformed by a NIOSH counter for this study has demonstrated an intralaboratory confidence limit of 0 35 for asbestos fibers analysis In general, there is insufficient experience with TEM to fully establish interlaboratory confidence limits EPA has reported findings of studies which indicate an overall CV of about 1 5 with an analytical component of about 1 0 The functional form used in the preparation of the range of PCM confidence limits presented in Tables A-1 and A-2 in Appendix A may not hold for the greater variability associated with TEM To provide some insight into the effect of a CV equal to 1.5 on the 95% confidence bounds for the mean, it may be assumed that the square root of the asbestos concentration as determined by TEM is distributed as a normal variable Then, the approximate 95% confidence interval on the original scale for a 1 25 f/cc TEM result on a 37-mm filter would be 0 to 8 38 f/cc This compares to a 0 638 to 3 913 f/cc interval shown in the Appendix A, Table A-2 for a 1.25 f/cc PCM results on a 37-mm filter

Work Activity Sampling Results

Personal breathing zone time-weighted average and short-term levels, determined by NIOSH method 7400-B, are shown in Table 1 As previously discussed, these levels are calculated from fiber counts made using an aspect ratio of 5 1, whereas the OSHA PEL is based on a 3:1 ratio (A rules), TEM analyses indicate that the reported levels would be less than 20% higher if A rules had been used in the present study

The TWA values reported are for the actual sampling periods, approximately five hours The TWA levels are well below the 2,000,000 f/m^3 [2 0 f/cc] OSHA standard in effect at the time of this study However, half are in excess of the new 200,000 f/m^3 [0 2 f/cc] OSHA standard and all but one are in excess of the 100,000 f/m^3 action level The highest short-term breathing zone measurement exceeded 1,000,000 f/m^3 and two thirds exceeded 500,000 f/m^3 As illustrated by the activity summary for each worker shown in Table 2, the level of worker exposure from preparation activities was an order of magnitude lower than that experienced during removal

TABLE 1

PERSONAL EXPOSURE MEASUREMENTS DURING PREPARATION
AND REMOVAL OF PIPE LAGGING
AT BLOOM MIDDLE SCHOOL

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

WORKER	TYPE*	ACTIVITY	JUNE 18	JUNE 19	JUNE 20	JUNE 21
# 1	TWA		0 250	0 300	0 470	0 170
	ST	REMOVAL			0 380	
	ST	REMOVAL			0 770	
	ST	REMOVAL			1 100	
# 2	TWA		0 014	0.100	0.330	0 120
	ST	PREPARATION		0.030		
	ST	REMOVAL		1 000	0 520	0.340
	ST	REMOVAL			0 140	
# 3	TWA		0 015	0 260	0 490	0 120
	ST	REMOVAL				0 430
	ST	REMOVAL				0 066
# 4	TWA		0 210	0 032	0 310	0 150
	ST	PREPARATION		0 030		
	ST	REMOVAL		0 710	1 100	0 250
	ST	REMOVAL		0 920	1 200	
	ST	REMOVAL		0 950		

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

TABLE 2

PERSONAL SAMPLING RESULTS BY ACTIVITY
AT BLOOM MIDDLE SCHOOL

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

WORKER	JUNE 18 ROOM 5	JUNE 19 ROOM 3	JUNE 20 ROOM 3/ LUNCH	JUNE 21 LUNCH	MEAN	MIN	MAX	ST D*	(n)
= = = = = = = = = =	PREPARATION FOR PIPE LAGGING REMOVAL	= = = = = = = = = =							
1	0 032	0 026			0.029				
2	0 029	0.037			0.033				
3	0.032	0 029			0 030				
4	0 054	0.034			0.044				
PREP AVERAGE	0 037	0.032			0.034	0 026	0 054	0.009	8
= = = = = = = = = = = = = = =	PIPE LAGGING REMOVAL	= = = = = = = = = = = = = = =							
1	0 400				0.400				1
		0 550	0.420		0 480				2
			0.530	0.170	0 350				2
AVG					0.410	0 170	0 550	0.150	5
2	0.003				0.003				1
		0 120	0.360		0.240				2
			0 300	0 120	0.210				2
AVG					0.180	0 003	0.360	0 150	5
3	0 003				0 003				1
		0 450	0 550		0.500				2
			0.430	0 120	0 280				2
AVG					0 310	0.003	0 550	0 240	5
4	0 320				0 320				1
		0 640	0 320		0.480				2
			0 290	0 150	0 220				2
AVG					0 310	0 150	0 640	0 180	5
REMOVAL AVERAGE	0 180	0 440	0 400	0 140	0 312	0 003	0 640	0 180	20
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

Analyses of area samples by PCM and TEM are compared in Tables 3A (for preparation) and 3B (for removal). PCM results for mean levels near the workers were 300,000 f/m^3 during removal and 26,000 f/m^3 during preparation In-room background sample means during removal operations were 300,000 f/m^3 and 16,000 f/m^3 during preparation The mean background level in the halls was 55,000 f/m^3 and the ambient level outside the building was 2,000 f/m^3 TEM results for total asbestos structures are one to two orders of magnitude higher than the PCM A more detailed analysis of the PCM and TEM comparisons will be made in the final technical report for the four school project.

Pre- and Post-Removal Sampling Results

One purpose of the pre- and post-removal study was to compare the evaluation of post-removal conditions by the aggressive and nonaggressive sampling methods for both PCM and TEM analysis. The post-removal samples were collected after initial cleaning (for purpose of clearance) by the removal contractor but before visual inspection and final clearance sampling by the on-site industrial hygienist Appendix B lists the analytical results for each TEM sample; the means for pre- and post-removal TEM measurements are shown in Table 4 The uncorrected TEM analyses of post-removal samples indicate a two-fold increase over the pre-samples in mean total asbestos structures for both nonaggressive and aggressive sampling, averaging about 77,000 and 167,000 as/m^3 for pre- removal and 148,000 and 385,000 as/m^3 for post-removal, respectively This Table also shows that the total asbestos fiber concentration is about equivalent to the total asbestos structure concentration, indicating that most of the asbestos was present as fibers

Comparison of pre- and post-removal TEM and PCM analytical results, by room location, are shown in Table 5 The levels of the aggressive samples are all equal to or higher than the nonaggressive samples in both the pre- and post-removal samples. As noted above, the post-removal results were taken after the contractor completed cleaning, but before clearance testing by the on-site industrial hygienist. Further cleaning may have been done if the site failed clearance by visual inspection or non-aggressive sampling with PCM analysis The emphasis of the present work is on the effectiveness of containment of the glove bag technique and hence on the comparison of asbestos levels before and after the glove bag work is completed

The levels of both aggressive and nonaggressive samples for total asbestos structures exceeded the ambient level measured during these activities The means of the aggressive post-removal sample analyses for asbestos structures longer than 5 µm also exceeded this criteria, whereas the nonaggressive samples did not

The levels of both aggressive and nonaggressive samples for total asbestos structures exceeded the ambient level suggested as "typical" by the EPA[13] (5,000 f/m^3 [0.005 f/cc]) The mean of the aggressive post-removal sample analyses for asbestos structures longer than 5 µm also exceeded this criteria, whereas the nonaggressive samples did not The actual ambient levels were confirmed to be in agreement with the suggested criteria by the TEM analysis of the June 14 ambient sample, less than 3,000 as/m^3 of air The ambient samples analyzed on July 9 showed less than 1500 and 13000 as/m^3

TABLE 3A

AREA SAMPLING RESULTS
PREPARATION FOR PIPE LAGGING REMOVAL
AT BLOOM MIDDLE SCHOOL

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

	JUNE 18		JUNE 19						
	ROOM 5		ROOM 3						
	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
PCM AVG					0 026	0 009	0 040	0 010	6
TEM ANALYSIS									
		(No Data)							
				0.590	0 590	0 540	0 640	0 069	2
TEM AVG				0 590	0 590	0.540	0 640	0 069	2
PCM ANALYSIS									
ROOM	0 019				0 019	0 018	0 019	0 001	2
(BACKGROUND)			0.013		0 013	0 009	0 017	0 005	2
PCM AVG					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
TEM AVG					0.780	0.390	1 200	0 370	4
PCM ANALYSIS									
HALL	0 048				0.048	0 044	0.053	0 007	2
(BACKGROUND)			0 070		0.070	0.043	0.096	0 037	2
PCM AVG					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
TEM AVG					0.575	0.450	0.655	0 096	4
PCM ANALYSIS	0 002								2
OUTDOOR AMBIENT			0 002						2

*f/cc = Total Fibers/cc
as/cc = Asbestos Structures/cc
ST D = Standard Deviation
n = number of samples

TABLE 3B

AREA SAMPLING RESULTS
PIPE LAGGING REMOVAL
AT BLOOM MIDDLE SCHOOL

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

SAMPLING SITE	JUNE 18 ROOM 5 PCM f/cc	(n)	JUNE 18 ROOM 5 TEM as/cc	(n)	JUNE 19 ROOM 3 PCM f/cc	(n)	JUNE 19 ROOM 3 TEM as/cc	(n)	JUNE 20 ROOM 3/LUNCHROOM PCM f/cc	(n)	JUNE 20 ROOM 3/LUNCHROOM TEM as/cc	(n)	JUNE 21 LUNCHROOM PCM f/cc	(n)	JUNE 21 LUNCHROOM TEM as/cc	(n)	MEAN	MIN	MAX	ST D*	(n)
PCM ANALYSIS																					
NEAR WORKERS	0 360	2															0 360	0 310	0.410	0 074	2
					0.470	2			0.350	2							0 410	0.290	0 490	0 086	4
									0 190	2			0 110	2			0 150	0.100	0 200	0 048	4
PCM AVG																	0 300	0.100	0.490	0 140	10
TEM ANALYSIS																					
			3 100	2													3 100	1.700	4 500	2 000	2
							2 400	2			3.500	2					2 950	1.900	4 500	1 100	4
											1 100	2			1 400	2	1 300	0 780	1 800	0 450	4
TEM AVG																	1 500	0 780	4,500	1.600	10
PCM ANALYSIS																					
ROOM	0 410	2															0 410	0 380	0.440	0 040	2
(BACKGROUND)	0 460	2			0 310	2											0 390	0,290	0,590	0.140	4
									0 210	2			0 110	2			0 160	0 091	0.230	0 062	4
PCM AVG																	0 300	0 091	0,590	0 140	10
TEM ANALYSIS																					
			2.100	2													2,100	2.000	2.100	0 059	2
							1 700	2			2.700	2					1 500	0 160	3,000	1.500	4
											1 100	2			0 940	2	1.000	0 840	1.090	0 110	4
TEM AVG																	1 700	0 160	3,000	0 710	10
AREA AVERAGE	0 385	4	2 600	4	0 470	4	2 000	4	0 250	6	2.100	8	0 110	4	1.170	2					
PCM ANALYSIS																					
HALL	0 048	2															0 048	0 044	0 053	0 007	2
(BACKGROUND)					0 070	2			0 130	2							0 100	0 043	0 140	0.042	4
									0 006	2			0 008	2			0 007	0 006	0 009	0 001	4
PCM AVG																	0.052	0 043	0.096	0 049	10
TEM ANALYSIS																					
			0 500	2													0 500	0 450	0 550	0 073	2
							0 650	2			1,300	2					0.980	0 645	1 500	0.410	4
											0 510	2			0 260	2	0 390	0 230	0 620	0.170	4
TEM AVG																	0 630	0 230	1 500	0.375	10
PCM ANALYSIS OUTDOOR AMBIENT	0 002	2			0 002	2			0 003	2			0.002	2			0 002	0 001	0 003	0 001	8

*f/cc = Total Fibers/cc as/cc = Asbestos Structures/cc ST D = Standard Deviation n = number of samples

TABLE 4

MEAN ASBESTOS FIBER AND ASBESTOS STRUCTURE CONCENTRATIONS AT BLOOM MIDDLE SCHOOL

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 5

COMPARISON OF MEAN PRE- AND POST-REMOVAL AREA SAMPLING
AT BLOOM MIDDLE SCHOOL

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 µm long	n	JULY 9 POST-REMOVAL SAMPLES: NIOSH PCM AND TEM f/cc	n	as/cc	n	EPA TEM ANALYSIS* as/cc Total	>5 µm long	n
NONAGGRESSIVE SAMPLING METHOD														
ROOM 5	0 006	6	0 000	1	0.065	0 005	3	0 007	6	0 028	1	0 230	0.005	3
ROOM 3	0 002	6	0 001	1	0 089	0.009	3	0 003	6	0 003	1	0.065	0.005	3
OUTSIDE ROOM 5	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 5	0.021	6	0 160	1	0 190	0 027	3	0 035	6	1 400	1	0 558	0 071	3
ROOM 3	0 015	6	0 028	1	0 140	0.009	3	0 017	6	0.110	1	0.260	0.013	3
OUTSIDE ROOM 5	None Taken							0.005	1	0 220	1			
OUTDOOR AMBIENT	None Taken							0 001	2**	0 006	2**			

f/cc = Total Fibers/cc
as/cc = Asbestos Structures/cc
n = number of samples
* These samples are approximately 1,500 liter volume 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 3,000 liter volumes

The latter appears to be quite high, however, even if it were the true level, the above observations would still be correct It should be noted that the ambient TEM samples were collected on cellulose ester filters There are presently no clear criteria for interpreting the health significance of TEM total asbestos fiber counts, however

PCM analyses of nonaggressive sampling did not reveal an appreciable change in the pre- and post-removal fiber counts. The EPA guideline for clearance sampling analyzed by PCM[8,9] is "every sample value is below the limit of quantification (approximately 10,000 f/m^3 [0 01 f/cc]) " Post- removal nonaggressive PCM samples were all below the 10,000 total f/m^3 level and would, therefore, pass this criterion Aggressive PCM sampling results indicate a slightly increased post-removal level in Room 5 In both of the rooms aggressive samples averaged above 10,000 total f/m^3 before and after removal

Engineering Controls

Two types of glove bags were used during this survey Profo® bags were used on the first three days and both Profo® and Disposalene® bags were used on the fourth Five bags were used in Room 5 during the first day, twelve bags were used in Room 3 during the second and third days; and thirteen bags were used in the Lunchroom and Kitchen during the third and fourth days

Work Practices

The survey team observed and intermittently videotaped the work practices of the removal crew A subjective evaluation of these practices based on observations and review of the tapes is summarized in Table 6

FAM measurements are being analyzed to determine the correlation of real-time observed increases in fiber concentrations with work conditions and activities The results of this analysis will be included in a technical report to be written on the four school project

Monitoring

The removal contractor's program for monitoring airborne exposure to asbestos in the work environment consisted of supplying the shift foreman with one personal sampling pump During the course of this study, that pump was not used for personal sampling because the survey team was monitoring each of the workers. However, the pump was not adequately maintained or calibrated to provide monitoring support There is a need for training if workers are to be assigned monitoring duties

The monitoring program of the Cincinnati Board of Education was implemented by PEI Associates, Inc , under a consulting contract The contracted level of effort was to support one active site at a time, however, the removal contractor received permission from the School District to work on four sites simultaneously This reduced the level of on-site surveillance to less than what is desirable for tight control An observer should be at each site for a time sufficient to insure full compliance of the work specifications

TABLE 6

EVALUATION OF WORK PRACTICES
AT BLOOM MIDDLE SCHOOL

Date	6/18/85	6/19/85	6/20/85	6/21/85
Time	AM / PM	AM / PM	AM / PM	AM / PM
Site	ROOM 5	ROOM 3	LUNCH	LU/KITC*
TASK	**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
* Kitchen from 10 57 am to 12 11 pm

Personal Protection

Contractor personnel wore disposable coveralls in the work area during removal activities In addition, each employee was fitted with a half-face cartridge respirator equipped with high efficiency filters which they wore during removal activities

Safety Considerations

Safety hazards were typical of those associated with insecure footing while working on elevated platforms, ledges, and ladders. Work was often over or around obstructions such as sinks, commodes, light fixtures, 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 great potential for injuries to the hands, care was required when removing the poly from the lagging to avoid punctures and lacerations

Other Observations

The work practices observed during the first day of this removal activity did not reflect adequate training in glove bag control methods The training received on the job was intended to bring the performance closer to the expected normal range of glove bag work practices In the brief period of on-the-job training at this site, it was not possible to achieve uniform quality of work practices

V CONCLUSIONS AND RECOMMENDATIONS

Glove bags are a useful engineering control to reduce worker exposure during asbestos removal operations Workers using work practices observed in this study to remove asbestos in glove bags should use respiratory protection In fact, it is prudent practice to use respiratory protection in <u>any</u> glove bag work because leakage of the glove bag (which is not easily determined by real time monitoring) will allow worker exposure to a known carcinogen OSHA permits high efficiency, air purifying respirators for work with asbestos; however, NIOSH recommends type C positive pressure, supplied air respiratory protection for use with carcinogens

Asbestos exposure, as evidenced by personal breathing-zone air sampling, showed order-of-magnitude increases depending upon the work activity Asbestos fiber concentrations rose from a pre-removal level of 0.004 f/cc to 0 034 f/cc during the preparation of the pipe lagging for removal and to 0 312 f/cc during the actual removal in glove bags These differences indicate that, as used in the present study, glove bags did not provide complete containment of the asbestos being removed (These values are derived from PCM analyses using NIOSH method 7400-B, comparison of total fiber counts from TEM data indicate that fiber counts, hence the reported concentration levels, would be less than 20% higher if the "A" rules had been used)

The limited expertise of the workers observed in the present study is probably typical of infrequent glove bag users Plant maintenance, asbestos operations and maintenance, and many asbestos removal contractors would very likely encounter similar asbestos levels and incomplete containment seen in this study This implies that secondary containment (i e , negative air barrier) should be used as an adjunct when glove bag work is performed It is possible (but not demonstrated) that well trained personnel who use glove bags regularly would be able to obtain better containment

After initial cleanup of the room in which the work was performed, asbestos levels by TEM analysis were higher after glove bag work than before. This gives an additional indication of the incomplete containment provided by the glove bags Since glove bags may often be used without the extra layer of protection provided by a negative air enclosure (as was the case in the present study), there could be appreciable contamination of surrounding areas from glove bag work.

One purpose of the study was to compare the post-removal conditions obtained by the aggressive and nonaggressive sampling methods using both PCM and TEM analysis. Mean concentrations measured by aggressive sampling were generally greater than means obtained by nonaggressive sampling for both pre- and post-removal operations

> The levels of both aggressive and nonaggressive samples for total asbestos structures exceeded the ambient level suggested as "typical" by the EPA [13] (The actual ambient levels were confirmed to be in agreement with the suggested criteria by the TEM analysis; less than 3000 as/m^3 of air during pre-removal and about 6,000 as/m^3 for post-removal) The aggressive samples analyses for asbestos structures longer than 5 µm also exceeded this criteria, whereas the nonaggressive samples did not
>
> Only one of twelve samples taken by the nonaggressive method analyzed by PCM is above the 10,000 fibers/m^3 EPA guideline and would fail clearance using this sampling and analytical method (This sample also exceeds the NIOSH recommended action level of 0 01 f/cc that would require additional surveillance)
>
> Nine of the twelve samples taken by the aggressive method analyzed by PCM are above the 10,000 fibers/m^3 EPA guideline and would have failed clearance using this sampling and analytical method

Based on these post-removal results, a work site would probably pass the clearance guideline requirements with nonaggressive sampling analyzed by PCM, it would probably fail with aggressive sampling analyzed by PCM; and would likely fail with TEM analyses of either sampling method

When using TEM analysis, it is highly advisable to implement the EPA recommendation to evaluate the ambient asbestos fiber concentration outside the work area as a reference for clearance requirements [9]

Options with potential for improving glove bag containment include improved work practices (discussed in the report), improved wetting of the lagging before removal using an injection technique, and the use of glove bags supplied with negative air One or more of these techniques are recommended for additional evaluation.

A summary of key work practices observed in this study which are highly recommended include

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 at pipe interfaces with walls and ceiling to optimize bag flexibility and minimize contamination potential

Make cuts on preformed lagging blocks at the joints to minimize fiber generation

Use long hoses on the amended water sprayers to optimize wetting practices; spray frequently during the removal task to assure that freshly exposed materials are wetted.

Use a HEPA vacuum to contain fibers and to assist in collapsing the glove bag during bag removal

Remove contaminated tools in an inverted glove for transfer to the next glove bag.

There are a number of work practices which have been proposed for use with glove bags but were not observed in this study Some of them are worthy of consideration for increased assurance of control

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 resuspension of loose fiber accumulations

Proper elevated platforms and scaffolding must be provided where needed Improvised platforms utilizing existing structures should be discouraged, expediency should not override the safety of the workers

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 attached. This will provide a cleaner edge to seal the open lagging, provide a dirt free area for the affixing the tape that seals the glove bag, and prevent fraying of the lagging when the sealing tape is removed

Test the effectiveness of the seals by pressure testing each installation of the bag (gently squeeze the bag to observe that the seal is tight)

Confirm the integrety of the glove bag installation technique by means of a smoke test periodically (the frequency or number of bags to be tested will depend on results) Release smoke from a smoke tube inside the bag, then apply gentle pressure to the bag to observe that the seals are secure

Use great care when metal bands, wires, or aluminum jacketing is encountered to avoid lacerations to the hands or glove bag; fold sharp edges in and place on the bottom of the bag

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 judgement and experience; heavily loaded bags create awkward and unsafe conditions Where applicable, support may be provided by the use of a platform and/or slings

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

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

Use a FAM (or other direct reading aerosol monitor) 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

Cordon off working areas when outdoor work is performed Removal of pipe lagging from salvaged or reclaimed pipe should be done in an enclosure appropriate for contamination control

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 carried out in the same area, an auxiliary worker may be utilized to service the amended water sprayers, to assist the others in moving or adjusting the glove bags, and to perform other miscellaneous tasks

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APPENDIX A

PCM DATA TABULATION

TABLE A-1

UPPER AND LOWER 95% CONFIDENCE LIMITS FOR A SINGLE PCM ANALYSIS
USING NIOSH 7400-B METHOD ON A 25-mm CELLULOSE ESTER FILTER,
ASSUMING AN INTERLABORATORY SUBJECTIVE COMPONENT OF 45 AND
1300 FIBERS/mm^2 MAXIMUM ALLOWED LOADING (1,111,500 FIBERS/FILTER)

Fibers counted /100 fds	Fibers/ 25-mm Filter	Factor for, Lower Limit	Factor for, Upper Limit	Mean and Range of Fiber Concentrations within 95% Confidence Limits for Sample Volumes: 400 liters (f/cc)	1500 liters (f/cc)	2500 liters (f/cc)
*	500500	0 51	3 13	1 251	0.334	0 200
				(0 638 - 3 916)	(0 170 - 1.045)	(0 102 - 0 626)
*	250000	0.51	3 13	0 625	0.167	0 100
				(0 319 - 1 956)	(0 085 - 0 523)	(0 051 - 0.313)
*	100000	0 51	3 13	0.250	0 067	0.040
				(0 128 - 0 783)	(0 034 - 0 210)	(0 020 - 0 125)
100	49045	0.51	3 13	0 123	0.033	0 020
				(0 063 - 0 385)	(0.017 - 0 103)	(0 010 - 0.063)
80	39236	0 51	3 14	0 098	0 026	0 016
				(0 050 - 0 308)	(0 013 - 0.082)	(0 008 - 0 050)
60	29427	0 51	3 16	0 074	0 02	0 012
				(0 038 - 0.234)	(0 010 - 0 063)	(0 006 - 0 038)
50	24522	0 51	3 18	0 061	0 016	0 010
				(0.031 - 0 194)	(0 008 - 0 051)	(0 005 - 0 032)
40	19618	0.50	3 20	0 049	0 013	0.008
				(0.025 - 0 157)	(0 007 - 0 042)	(0 004 - 0 026)
30	14713	0 49	3 25	0 037	0.01	0 006
				(0.018 - 0 120)	(0 005 - 0.033)	(0 003 - 0.020)
20	9809	0 47	3 33	0 025	0 007	0.004
				(0 012 - 0.083)	(0 003 - 0 023)	(0.002 - 0 013)
10	4904	0 43	3 57	0 012	0.003	0 002
				(0 005 - 0 043)	(0.001 - 0 011)	(0.001 - 0 007)
7	3433	0 40	3 78	0 009	0 002	0 001
(NIOSH LOD)				(0.004 - 0.034)	(0 001 - 0.008)	(0 000 - 0 004)
3	1471	0 31	4 66	0 004	0 001	0.001
(UBTL LOD)				(0 001 - 0.019)	(0.000 - 0 005)	(0 000 - 0 005)

TABLE A-2

UPPER AND LOWER 95% CONFIDENCE LIMITS FOR A SINGLE PCM ANALYSIS USING NIOSH 7400-B METHOD ON A 37-mm CELLULOSE ESTER FILTER, ASSUMING AN INTERLABORATORY SUBJECTIVE COMPONENT OF .45 AND 1300 FIBERS/mm^2 MAXIMUM ALLOWED LOADING (1,111,500 FIBERS/FILTER)

Fibers counted /100 fds	Fibers/ 37-mm Filter	Factor for: Lower Limit	Upper Limit	Mean and Range of Fiber Concentrations within 95% Confidence Limits for Sample Volumes: 400 liters (f/cc)	1500 liters (f/cc)	2500 liters (f/cc)
*	1111500	0.51	3.13	2.779	0.741	0.445
				(1.417 - 8.698)	(0.378 - 2.319)	(0.227 - 1.393)
*	500000	0.51	3.13	1.25	0.333	0.2
				(0.638 - 3.913)	(0.170 - 1.042)	(0.102 - 0.626)
*	250000	0.51	3.13	0.625	0.167	0.1
				(0.319 - 1.956)	(0.085 - 0.523)	(0.051 - 0.313)
100	108917	0.51	3.13	0.272	0.073	0.044
				(0.139 - 0.851)	(0.037 - 0.228)	(0.022 - 0.138)
80	87134	0.51	3.14	0.218	0.058	0.035
				(0.111 - 0.685)	(0.030 - 0.182)	(0.018 - 0.110)
60	65350	0.51	3.16	0.163	0.044	0.026
				(0.083 - 0.515)	(0.022 - 0.139)	(0.013 - 0.082)
50	54459	0.51	3.18	0.136	0.036	0.022
				(0.069 - 0.432)	(0.018 - 0.114)	(0.011 - 0.070)
40	43567	0.50	3.20	0.109	0.029	0.017
				(0.055 - 0.349)	(0.015 - 0.093)	(0.009 - 0.054)
30	32675	0.49	3.25	0.082	0.022	0.013
				(0.04 - 0.267)	(0.011 - 0.072)	(0.006 - 0.042)
20	21783	0.47	3.33	0.054	0.015	0.009
				(0.025 - 0.18)	(0.007 - 0.05)	(0.004 - 0.030)
10	10892	0.43	3.57	0.027	0.007	0.004
				(0.012 - 0.096)	(0.003 - 0.025)	(0.002 - 0.014)
7	7624	0.40	3.78	0.019	0.005	0.003
(NIOSH LOD)				(0.008 - 0.072)	(0.002 - 0.019)	(0.001 - 0.011)
3	3268	0.31	4.66	0.008	0.002	0.001
(UBTL LOD)				(0.002 - 0.037)	(0.001 - 0.009)	(0.000 - 0.005)

TABLE A-3

LEGEND FOR BLOOM MIDDLE SCHOOL PCM DATA

LOD	Limit of Detection
LOC	(School and room location of sampled activity)
Bxxx	Bloom Middle School
RM3	Room # 3
RM5	Room # 5
109	Room 109
TLG	Teachers Lounge
LRM	Lunchroom
FB	Field Blank no sample taken
CLASSIFICATION	(Sample location, type, 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 (in the immediate vicinity of 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 'Covering etc ' - Full term sequential
RMS	Removal work - 15 minute short term PBZ sample
COS	Preparation 'Covering etc ' - 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
xx/xx	Actual date of blank source
SAMPLE No.	Sample media Identification code and number
AAxxx	25-mm Cellulose Ester Filter Sample Number xxx (With 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)
PCM 7400-B	Phase Contrast Microscopy using NIOSH Method 7400-B counting rules in Total Fibers per cubic centimeter
MAGISCAN II	Magiscan II is a computerized image analysis system for PCM in Total Fibers per cubic centimeter
UBTLPCM	PCM analysis performed by Utah Biological Testing Labs
NIOSHPCM	PCM analysis performed in the NIOSH Laboratory

TABLE A-4

PHASE CONTRAST MICROSCOPY ANALYTICAL RESULTS FOR
AIRBORNE ASBESTOS ANALYSIS
BLOOM MIDDLE SCHOOL
CINCINNATI, OHIO
June 14 -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	UBTLPCM 7400-B Fibers	UBTLPCM 7400-B f/cc	NIOSHPCM 7400-B Fibers	NIOSHPCM 7400-B f/cc
BRM3	IA-PRE-AGGR	AA79	6/14	1811	0211	480	3 25	1560.0	70070	0 045		0.000		
BRM3	IA-PRE-AGGR	AA80	6/14	1811	0211	480	3 20	1536 0	66990	0 044	23000	0 015		
BRM3	IA-PRE-AGGR	AA90	6/14	1811	0211	480	3 25	1560 0	74690	0.048	26000	0 017	25795	0 017
BRM3	IA-PRE-AGGR	M332	6/14	1811	0211	480	3 25	1560 0	101745	0 065	30000	0 019	88065	0 056
BRM3	IA-PRE-AGGR	M334	6/14	1811	0211	480	3 25	1560 0	71820	0 046	35000	0 022		
BRM3	IA-PRE-AGGR	M340	6/14	1811	0211	480	3 20	1536 0	112005	0 073	30000	0 020	58995	0 038
BRM3	IA-PRE-NAGR	AA61	6/14	0938	1738	480	3 25	1560 0	24255	0 016	6000	0 004		
BRM3	IA-PRE-NAGR	AA75	6/14	0938	1738	480	3 00	1440 0	41195	0 029	2000	0 001		
BRM3	IA-PRE-NAGR	AA99	6/14	0938	1738	480	3 25	1560 0	54285	0 035	3000	0 002		
BRM3	IA-PRE-NAGR	M327	6/14	0938	1738	480	3 00	1440 0	30780	0 021	1750	0 001		
BRM3	IA-PRE-NAGR	M331	6/14	0938	1738	480	3 25	1560 0	30780	0 020	4000	0 003		
BRM3	IA-PRE-NAGR	M335	6/14	0938	1738	480	3 25	1560 0	47025	0 030	4000	0 003		
BRM5	IA-PRE-AGGR	AA63	6/14	1923	0330	487	3 25	1582 8	29645	0 019	21000	0 013	33495	0 021
BRM5	IA-PRE-AGGR	AA72	6/14	1923	0330	487	3 25	1582 8	46200	0 029	35000	0 022	37730	0.024
BRM5	IA-PRE-AGGR	AA87	6/14	1923	0330	487	3 00	1461 0	35420	0 024	30000	0 021		
BRM5	IA-PRE-AGGR	M324	6/14	1923	0330	487	3 25	1582 8	73530	0 046	30000	0 019		
BRM5	IA-PRE-AGGR	M325	6/14	1923	0330	487	3 25	1582 8	83790	0 053	44000	0 028	57285	0 036
BRM5	IA-PRE-AGGR	M329	6/14	1923	0330	487	3 00	1461 0	87210	0.060	30000	0 021	56430	0 039
BRM5	IA-PRE-NAGR	AA70	6/14	1037	1840	483	3 30	1593 9	34265	0 021	6000	0 004	16170	0 010
BRM5	IA-PRE-NAGR	AA74	6/14	1037	1840	483	3 25	1569 8	81620	0 052	10000	0 006	16555	0 011
BRM5	IA-PRE-NAGR	AA98	6/14	1037	1840	483	3 25	1569 8	74690	0 048	10000	0 006	26565	0 017
BRM5	IA-PRE-NAGR	M321	6/14	1037	1840	483	3.25	1569 8	47025	0 030	9000	0 006		
BRM5	IA-PRE-NAGR	M338	6/14	1037	1840	483	3 20	1545 6	34200	0 022	10000	0 006		
BRM5	IA-PRE-NAGR	M339	6/14	1037	1840	483	3 25	1569 8	54720	0 035	10000	0 006		
B109	AM-PRE-NAGR	AA68	6/14	1026	1830	484	2 90	1403 6	11165	0 008	750	0 001		
B109	AM-PRE-NAGR	AA89	6/14	1026	1830	484	3 00	1452 0	8855	0 006	750	0 001		
BFB	FB-PRE-AGGR	AA62	6/14						1347		750			
BFB	FB-PRE-AGGR	AA95	6/14						1347		750		1347	
BFB	FB-PRE-NAGR	AA59	6/14						1347		750		1347	
BFB	FB-PRE-NAGR	AA60	6/14						1347		750		1347	
BFB	FB-PRE-NAGR	AA71	6/14						1347		750		1347	
BFB	FB-PRE-NAGR	AA92	6/14						1347		750		1347	
BFB	FB-PRE-NAGR	M322	6/14								1750			
BFB	FB-PRE-NAGR	M330	6/14						2992		1750		2992	
BFB	FB-PRE-NAGR	M337	6/14						2992		1750		2992	

TABLE A-4 (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	UBTLPCM 7400-B Fibers	UBTLPCM 7400-B f/cc	NIOSHPCM 7400-B Fibers	NIOSHPCM 7400-B f/cc
BRM5	BZ-COV-WK#1	AA148	6/18	0930	1126	116	3 10	359 6	87020	0 242			11550	0 032
BRM5	BZ-COV-WK#2	AA111	6/18	0930	1126	116	2.96	343 4	8855	0 026			10010	0 029
BRM5	BZ-COV-WK#3	AA150	6/18	0930	1126	116	3 12	361 9	17325	0.048			11550	0 032
BRM5	BZ-COV-WK#4	AA91	6/18	0930	1126	116	3.06	355 0	20405	0 057			19250	0 054
BRM5	BZ-REM-WK#1	AA51	6/18	1235	1515	160	3 16	505 6	77385	0 153			202895	0 401
BRM5	BZ-REM-WK#2	AA142	6/18	1235	1520	165	2 96	488 4	169015	0 346			1347	0 003
BRM5	BZ-REM-WK#3	AA143	6/18	1235	1515	160	3.12	499 2	219065	0 439			1347	0 003
BRM5	BZ-REM-WK#4	AA138	6/18	1235	1520	165	3.06	504.9	96635	0 191			163625	0 324
BRM5	CT-COV	AA64	6/18	0932	1126	114	3 16	360 2	12705	0 035			10010	0 028
BRM5	CT-COV	AA139	6/18	0932	1126	114	3 02	344 3	8085	0 023			13860	0 040
BRM5	CT-COV	AA140	6/18	0940	1126	106	3 00	318 0	12320	0 039			7315	0 023
BRM5	CT-COV	AA141	6/18	0932	1126	114	3.06	348 8	6930	0 020			9625	0 028
BRM5	CT-REM	AA22	6/18	1240	1520	160	3 00	480 0	72380	0 151			147070	0 306
BRM5	CT-REM	AA52	6/18	1240	1520	160	3.16	505 6	113190	0 224			207515	0 410
BRM5	IA-COV	AA66	6/18	0932	1126	114	3 11	354 5	12705	0 036			6545	0 018
BRM5	IA-COV	AA69	6/18	0932	1126	114	3 14	358 0	9240	0 026			6930	0 019
BRM5	IA-REM	AA24	6/18	1239	1520	161	3 10	499.1	92785	0 186			191730	0 384
BRM5	IA-REM	AA50	6/18	1239	1520	161	3.10	499 1	108185	0 217			219835	0 440
BRM5	OA-SEQ	AA67	6/18	0934	1413	279	3 00	837 0	33495	0 040			44275	0 053
BRM5	OA-SEQ	AA137	6/18	0934	1413	279	3.00	837 0	34265	0 041			36575	0 044
BTLG	AM-SEQ	AA65	6/18	0740	1530	470	3 00	1410 0	31955	0 023			1347	0 001
BTLG	AM-SEQ	AA93	6/18	0740	1530	470	2.80	1316 0	31570	0 024			4235	0 003
BFB	FB-COV-6/14	AA55	6/18						1347				1347	
BFB	FB-REM-6/14	AA56	6/18						1347				1347	

TABLE A-4 (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	UBTLPCM 7400-B Fibers	UBTLPCM 7400-B f/cc	NIOSHPCM 7400-B Fibers	NIOSHPCM 7400-B f/cc
BRM3	BZ-COS-WK#2	AA5	6/19	1043	1058	15	3 00	45 0	2695	0 060			1347	
BRM3	BZ-COS-WK#4	AA48	6/19	1111	1126	15	3 00	45 0	1347	0 030			1347	0 030
BRM3	BZ-COV-WK#1	AA44	6/19	0939	1129	110	3.06	336.6	36190	0.108			8816	0 026
BRM3	BZ-COV-WK#2	AA45	6/19	1038	1129	51	3 12	159 1	15015	0 094			5852	0 037
BRM3	BZ-COV-WK#3	AA43	6/19	0935	1129	114	2 96	337 4	40040	0 119			9779	0 029
BRM3	BZ-COV-WK#4	AA42	6/19	0938	1129	111	3 09	343 0	39270	0 114			11742	0 034
BRM3	BZ-REM-WK#1	AA3	6/19	1249	1448	119	3 06	364 1	197120	0 541			199045	0 547
BRM3	BZ-REM-WK#2	AA47	6/19	1250	1459	129	3 12	402 5	147070	0 365			50050	0 124
BRM3	BZ-REM-WK#3	AA1	6/19	1247	1459	132	3 09	411 0	189035	0 460			184030	0 448
BRM3	BZ-REM-WK#4	AA35	6/19	1248	1429	101	3 00	303 0	108185	0 357			193270	0 638
BRM3	BZ-RMS-WK#2	AA126	6/19	1440	1455	15	3 00	45 0	46585	1 035			47355	1 052
BRM3	BZ-RMS-WK#4	AA7	6/19	1333	1348	15	3 00	45 0	45045	1 001			31955	0 710
BRM3	BZ-RMS-WK#4	AA127	6/19	1448	1503	15	3 00	45 0	35035	0 779			41195	0 915
BRM3	BZ-RMS-WK#4	AA128	6/19	1300	1315	15	3 00	45 0	33880	0 753			42735	0 950
BRM3	CT-COV	AA40	6/19	0933	1130	117	3 05	356 9	22330	0 063			3187	0 009
BRM3	CT-COV	AA41	6/19	0933	1130	117	3 12	365 0	22330	0 061			10510	0 029
BRM3	CT-REM	AA25	6/19	1245	1518	153	3 12	477.4	172865	0 362			211750	0 444
BRM3	CT-REM	AA53	6/19	1245	1518	153	3 00	459 0	194425	0 424			225995	0 492
BRM3	IA-COV	AA37	6/19	0933	1130	117	3 06	358 0	17325	0 048			3207	0 009
BRM3	IA-COV	AA39	6/19	0933	1130	117	3 14	367 4	25025	0 068			6121	0 017
BRM3	IA-REM	AA23	6/19	1245	1518	153	3.06	468 2	176715	0 377			276045	0 590
BRM3	IA-REM	AA28	6/19	1245	1518	153	3 14	480 4	142835	0 297			163240	0 340
BRM3	OA-FTM	AA31	6/19	0933	1406	273	3 16	862 7	48510	0 056			82778	0 096
BRM3	OA-FTM	AA38	6/19	0933	1406	273	3 00	819 0	58135	0 071			35535	0 043
BTLG	AM-SEQ	AA21	6/19	0804	1540	456	3 00	1368 0	19250	0 014			1347	0 001
BTLG	AM-SEQ	AA54	6/19	0804	1540	456	2 70	1231 2	43505	0 035			3888	0 003
BFB	FB-COV	AA4	6/19	0933	0934	1	3 00	3 0	1347				1347	
BFB	FB-COV-6/14	AA57	6/19	0933	0934	1	3 00	3 0	1347				1347	
BFB	FB-REM-6/14	AA58	6/19	1245	1246	1	3 00	3 0	1347				1347	

TABLE A-4 (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	ORTLPCM 7400-B Fibers	ORTLPCM 7400-B f/cc	NIOSHPCM 7400-B Fibers	NIOSHPCM 7400-B f/cc
BLRM	BZ-REM-WK#1	AA13	6/20	1242	1447	125	3 12	390.0	215215	0 528	205975			0 528
BLRM	BZ-REM-WK#2	AA26	6/20	1241	1510	149	3 00	447 0	106570	0 243			133595	0 299
BLRM	BZ-REM-WK#3	AA125	6/20	1240	1510	150	3 02	453.0	100870	0 223			196350	0 433
BLRM	BZ-REM-WK#4	AA12	6/20	1240	1510	150	3 06	459.0	109340	0.238			132440	0 289
BLRM	BZ-RMS-WK#1	AA11	6/20	1408	1423	15	2.50	37 5	18095	0 483			14360	0 383
BLRM	BZ-RMS-WK#2	AA121	6/20	1259	1314	15	2 50	37 5	12320	0 329			5390	0 144
BLRM	BZ-RMS-WK#4	AA20	6/20	1330	1345	15	2.50	37 5	31570	0 842			41965	1 119
BLRM	CT-REM	AA6	6/20	1236	1519	163	3 14	511 8	98945	0 193			104335	0 204
BLRM	CT-REM	AA9	6/20	1236	1519	163	3 00	489 0	83160	0 170			88935	0 182
BLRM	IA-REM	AA2	6/20	1241	1519	158	3 00	474 0	103950	0 219			108955	0 230
BLRM	IA-REM	AA32	6/20	1241	1519	158	3 12	493 0	100870	0 205			94710	0 192
BLRM	OA-SEQ	AA33	6/20	1239	1520	161	3 00	483 0	11165	0 023			2695	0 006
BLRM	OA-SEQ	AA124	6/20	1239	1520	161	3 16	508 8	6160	0 012			3465	0 007
BRM3	BZ-REM-WK#1	AA19	6/20	0751	0957	126	3 17	399 4	162470	0 407			165935	0 415
BRM3	BZ-REM-WK#2	AA14	6/20	0752	0957	125	3 00	375 0	109725	0 293			134365	0 358
BRM3	BZ-REM-WK#3	AA122	6/20	0752	0957	125	3 02	377 5	119735	0 317			209055	0 554
BRM3	BZ-REM-WK#4	AA27	6/20	0754	1008	134	3 06	410 0	99715	0 243			132440	0 323
BRM3	BZ-RMS-WK#1	AA29	6/20	0812	0827	15	2 50	37 5	24640	0 657			28875	0 770
BRM3	BZ-RMS-WK#1	AA123	6/20	1007	1022	15	2 40	36 0	43120	1 198			39655	1 102
BRM3	BZ-RMS-WK#2	AA10	6/20	0947	1002	15	2 40	36 0	26180	0 727			18865	0 524
BRM3	BZ-RMS-WK#4	AA17	6/20	0904	0915	11	2 50	27 5	26180	0 952			32725	1 190
BRM3	CT-REM	AA147	6/20	0755	1054	179	3 00	537 0	108185	0 201			155540	0 290
BRM3	CT-REM	AA149	6/20	0755	1054	179	3 05	546 0	75075	0 138			224840	0 412
BRM3	IA-REM	AA16	6/20	0755	1053	178	3 00	534 0	128975	0 242			177485	0 332
BRM3	IA-REM	AA18	6/20	0755	1053	178	3 00	534 0	130130	0 244			155925	0 292
BRM3	OA-SEQ	AA8	6/20	0754	1104	190	3 11	590 9	91245	0 154			70840	0 120
BRM3	OA-SEQ	AA15	6/20	0754	1104	190	3 00	570 0	72765	0 128			82005	0 144
BTLG	AM-FTM	AA129	6/20	0720	1540	500	2.70	1350 0	75845	0 056			3465	0 003
BTLG	AM-FTM	AA130	6/20	0720	1540	500	2 90	1450 0	65835	0 045			3850	0 003
BFB	FB-REM-6/14	AA97	6/20	0720	0721	1	3 00	3 0	1347				1347	
BFB	FB-REM-6/14	AA146	6/20	0720	0721	1	3 00	3 0	1347				1347	

TABLE A-4 (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	UBTLPCM 7400-B Fibers	UBTLPCM 7400-B f/cc	NIOSHPCM 7400-B Fibers	NIOSHPCM 7400-B f/cc
BLRM	CT-REM	AA151	6/21	0836	1206	210	3 00	630 0	73920	0 117			62755	0 100
BLRM	BZ-REM-WK#4	AA152	6/21	0834	1203	209	3 12	652 1	81620	0 125			95865	0 147
BLRM	BZ-REM-WK#2	AA153	6/21	0842	1203	201	3 00	603 0	63140	0 105			70840	0 117
BLRM	CT-REM	AA154	6/21	0836	1206	210	3 14	659 4	88550	0 134			83930	0 127
BLRM	OA-FTM	AA155	6/21	0832	1209	217	3 00	651 0	48125	0 074			4620	0 007
BLRM	OA-FTM	AA156	6/21	0832	1209	217	3 11	674 9	41195	0 061			5775	0 009
BLRM	BZ-REM-WK#1	AA157	6/21	0836	1203	207	3 06	633 4	168630	0 266			109340	0 173
BLRM	BZ-REM-WK#3	AA158	6/21	0835	1203	208	3 02	628 2	80465	0 128			78155	0 124
BLRM	BZ-RMS-WK#4	AA170	6/21	1027	1042	15	3 00	45 0	16555	0 368			11165	0 248
BLRM	IA-REM	AA171	6/21	0838	1206	208	3 10	644 8	74305	0 115			58520	0 091
BLRM	IA-REM	AA175	6/21	0838	1206	208	3 00	624 0	85470	0 137			82390	0 132
BLRM	BZ-RMS-WK#3	AA176	6/21	0918	0933	15	3 00	45 0	34650	0 770			29645	0 659
BLRM	BZ-RMS-WK#2	AA177	6/21	0943	0959	16	3 00	48 0	20790	0 433			16170	0 337
BLRM	BZ-RMS-WK#3	AA178	6/21	0906	0923	17	3 00	51 0	21945	0 430			21945	0 430
BTLG	AM-FTM	AA159	6/21	0720	1220	300	3 00	900 0	2356	0 003			1347	0 001
BTLG	AM-FTM	AA160	6/21	0720	1220	300	2 70	810 0	26180	0 032			1347	0 002

TABLE A-4 (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	UBTLPCM 7400-B Fibers	UBTLPCM 7400-B f/cc	NIOSHPCM 7400-B Fibers	NIOSHPCM 7400-B f/cc
BRM3	IA-PST-AGGR	AA447	7/09	1801	0207	486	3 00	1458 0	31955	0 022			16901	0 012
BRM3	IA-PST-AGGR	AA454	7/09	1801	0207	486	3 00	1458 0	29529	0 020			27951	0 019
BRM3	IA-PST-AGGR	AA459	7/09	1850	0207	437	3 00	1311 0	38731	0 030			14976	0 011
BRM3	IA-PST-AGGR	M827	7/09	1801	0207	486	3 50	1701 0	37021	0 022			29412	0 017
BRM3	IA-PST-AGGR	M829	7/09	1801	0207	486	3 00	1458 0	67032	0 046			38133	0 026
BRM3	IA-PST-AGGR	M831	7/09	1801	0207	486	3 40	1652 4	64296	0 039			29925	0 018
BRM3	IA-PST-NAGR	AA389	7/09	0900	1700	480	3.05	1464 0	26026	0 018	750	0 001		
BRM3	IA-PST-NAGR	AA417	7/09	0900	1700	480	3 00	1440 0	25025	0.017	2000	0.001		
BRM3	IA-PST-NAGR	AA432	7/09	0900	1700	480	3 00	1440 0	12589	0 009			13744	0 010
BRM3	IA-PST-NAGR	M832	7/09	0900	1700	480	3 20	1536 0	89347	0 058			10944	0 007
BRM3	IA-PST-NAGR	M835	7/09	0900	1700	480	3 15	1512 0	76266	0 050	1750	0 001		
BRM3	IA-PST-NAGR	M837	7/09	0900	1700	480	3 05	1464 0	37021	0 025	1750	0 001		
BRM3	OA-PST-AGGR	AA457	7/09	1801	0207	486	3 20	1555 2	14514	0 009			11627	0 007
BRM3	OA-PST-NAGR	AA416	7/09	0903	1700	477	3 00	1431 0	28952	0 020			9779	0.007
BRM5	IA-PST-AGGR	AA440	7/09	1814	0215	481	3.50	1683 5	52745	0 031			62216	0 037
BRM5	IA-PST-AGGR	AA446	7/09	1814	0215	481	3 00	1443 0	51243	0 036			72649	0 050
BRM5	IA-PST-AGGR	AA453	7/09	1814	0215	481	3 25	1563 3	49742	0 032			62293	0 040
BRM5	IA-PST-AGGR	M833	7/09	1814	0215	481	3 50	1683 5	82849	0 049			76180	0 045
BRM5	IA-PST-AGGR	M834	7/09	1814	0215	481	3 50	1683 5	106789	0 063			51471	0 031
BRM5	IA-PST-AGGR	M836	7/09	1814	0215	481	3 50	1683 5	136287	0 081	8000	0 005		
BRM5	IA-PST-NAGR	AA381	7/09	0900	1700	480	3 00	1440 0	82351	0 057			5852	0 004
BRM5	IA-PST-NAGR	AA383	7/09	0900	1700	480	3 00	1440 0	85932	0 060	750	0 001		
BRM5	IA-PST-NAGR	AA458	7/09	0900	1700	480	2 95	1416 0	80195	0.057			7584	0 005
BRM5	IA-PST-NAGR	M826	7/09	0900	1700	480	3 10	1488 0	122607	0.082			20178	0 014
BRM5	IA-PST-NAGR	M828	7/09	0900	1700	480	3 20	1536 0	129276	0 084			13081	0 009
BRM5	IA-PST-NAGR	M830	7/09	0900	1700	480	3 05	1464 0	70281	0 048			14193	0 010
BRM5	OA-PST-AGGR	AA445	7/09	1814	0215	481	3 20	1539 2	42119	0 027			7584	0 005
BRM5	OA-PST-NAGR	AA374	7/09	0903	1700	477	2 95	1407 2	35343	0.025	4000	0 003		
BTLG	AM-PST-NAGR	AA379	7/09	0853	0320	1107	2.85	3154 9	93247	0 026	750	0 000		
BTLG	AM-PST-NAGR	AA424	7/09	0853	1826	1107	3 00	3321 0	62793	0 018			5121	0 002
BFB	FB-PST-6/21	AA172	7/09	1814	1815				1347		750			
BFB	FB-PST-6/21	AA173	7/09	1814	1815		1 0		1347		750			
BFB	FB-PST-7/18	M950	7/09	1814	1815		1 0		2992		1750			
BFB	FB-PST-7/18	M951	7/09	1814	1815		1 0		10858		1750			

APPENDIX B

TEM DATA TABULATION

TABLE B-1

Bloom Middle School
Pre and Post Removal Sampling Analysis by TEM

Sample Number	STRUCTURES Total	Nonasbestos	Asbestos	Chrysotile	Amphibole	ASBESTOS Matrix	Clusters	Bundles	FIBERS Total	Asbestos	Chrysotile	Amphibole
PRE REMOVAL												
Nonaggressive												
N-363	47707	7951	39756	31805	7951	-	-	15903	31805	23854	15902	7951
N-367	95415	7951	87464	79512	7951	-	7951	15903	71561	63610	55659	7951
N-371	77527	8614	68913	34456	34456	-	-	8614	60299	60299	25842	34456
N-373	200030	104015	96014	88013	8001	-	-	16002	184027	80012	72011	8001
N-375	95348	43340	52008	26004	26004	-	-	-	86680	52008	26004	26004
N-376	576086	456068	120018	56008	64010	-	8001	-	560083	112017	48007	64010
X̄	182018	104657	77362	52633	24729				165743	65300	40571	24729
Aggressive												
N-316	528358	236578	291780	228692	63087	31544	-	15772	457384	228692	165605	63087
N-359	386411	157719	228692	173491	55202	23658	-	-	315437	165605	110403	55202
N-360	936139	780116	156023	78012	78012	8668	-	8668	866796	138687	60676	78012
N-369	440065	328049	112017	88013	24004	-	8001	16002	408061	88013	64010	24004
N-372	146458	91536	54922	27461	27461	-	-	-	146458	54922	27461	27461
N-374	1333532	1173508	160024	120018	40006	-	-	-	1280191	160024	120018	40006
X̄	628494	461251	167243	119281	47962				479054	139324	91361	47962
POST REMOVAL												
Nonaggressive												
N-664	141164	111445	29719	7430	22289	7430	-	-	118875	22289	7430	14859
N-682	199363	86680	112683	95348	17336	-	8668	17336	173359	86680	69344	17336
N-685	312046	286043	26004	17336	8668	-	-	-	225367	26004	17336	8668
N-686	264166	123828	140338	107318	33021	-	8255	-	206380	132083	99062	33021
N-687	545242	293592	251650	167767	83883	-	-	-	511689	251640	167767	83883
N-688	364054	34672	329382	234035	95348	-	-	8668	355386	320714	225367	95348
X̄	304339	156043	148296	104872	43424				265176	139903	97718	42186
Aggressive												
N-667	513657	282511	231146	214024	17122	-	8561	17122	445169	205463	188341	17122
N-668	926779	287301	639477	639477	-	139017	18536	9268	695084	463389	463389	-
N-672	520995	308194	212801	205463	7338	-	7338	44028	396249	161435	154097	7338
N-673	753363	402364	342438	248267	94170	42805	17122	8561	650632	273950	179780	94170
N-673R	659193	419486	231146	196902	34244	25683	-	-	607827	196902	162658	34244
N-674	823803	140047	675519	659043	16476	181237	-	8238	560186	477806	461330	16476
N-683	710603	351309	359294	319372	39922	55890	-	15969	566885	279451	239529	39922
X̄	701199	313030	384546	354650					560290	294057	264161	