IN-DEPTH SURVEY REPORT:

CONTROL TECHNOLOGY FOR ASBESTOS REMOVAL

AT

Washburn Elementary School
Cincinnati, Ohio

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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 more definite building clearance procedures for asbestos removal operations. 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 a number of 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 exposures and environmental releases. One important subset of asbestos abatement activities involves 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 thus contained for final disposal in a sanitary landfill. Glove bags are widely used both in building abatement and in operations 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

A further 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 Education

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 Washburn Elementary 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. A sample of asbestos boiler packing was reported to contain 45% chrysotile and 53% cellulose. 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: Washburn Elementary School.

II. SITE AND PROCESS DESCRIPTION

SITE DESCRIPTION

During a walk-through visit on June 4, 1985, the NIOSH survey team noted that the remaining asbestos lagging was generally in good repair; however, there were instances of torn or separated lagging at pipe interfaces with walls and structural members. Analyses of bulk samples of pipe lagging taken at the time of the removal activity in the girls restroom (girls room) indicated 20 to 25% chrysotile, 3 to 5% cellulose and other fibers, and the remainder to be nonfibrous material. No amosite, actinolite/tremolite, or anthophyllite asbestos forms were detected. Numerous small, dried wads of tissue were observed adhering to the upper walls of the girls room; under aggressive sampling procedures, these wads could contribute fibrous materials to the contamination of the room air.

The removal contract for the Washburn Elementary School required approximately 1230 linear feet of asbestos pipe lagging to be removed from 13 major rooms and areas. During this survey, removal operations were observed in two of these rooms located on the basement level; the kindergarten, and the girls room (Figures A and B). The kindergarten furniture and throw carpet were removed and the floors were cleaned just prior to preparation for the removal activity; large storage cabinets were left in place.

Pre- and post-removal studies were conducted in these rooms. 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.

The kindergarten (Figure A) measured approximately 41'x 36'x 15', enclosing 22,140 cubic feet. During the 4 days of the sampling, less than half of the actual removal was completed. The contractor completed the remaining work (which was much quicker due to prior setup and easier accessibility), and the work area was cleaned by wet mopping. Final post-removal samples were then taken. Insulation from approximately 45' of 6-inch, 12' of 3-inch, and 2' of 2-inch pipe was removed; including 4 T-joints, 9 elbows, 3 pipe hangers, 1 flange, and 6 pipe/structure intersections. Work completed by the same removal team prior to the post-removal study, but not observed by the survey team consisted of insulation removal from approximately 30' of 6-inch, 45' of 3-inch, and 2' of 2-inch pipe; including 4 T-joints, 13 elbows, 5 pipe hangers, 1 flange, and 6 pipe/structure interfaces. In addition, approximately 27' of 6-inch pipe lagging in a storage area not included in the original enclosure envelope was reportedly removed while the poly barriers were open to the area and without the use of glove bag control techniques.

The girls room (Figure B) measured approximately 33'x 22'x 15', enclosing 10,890 cubic feet. Insulation was removed from approximately 58' of 5-inch, 70' of 3-inch, and 15' of 2-inch pipe, including 7 T-joints, 21 elbows, 2 flanges, 7 pipe hangers, and 6 pipe/structure intersections.

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.

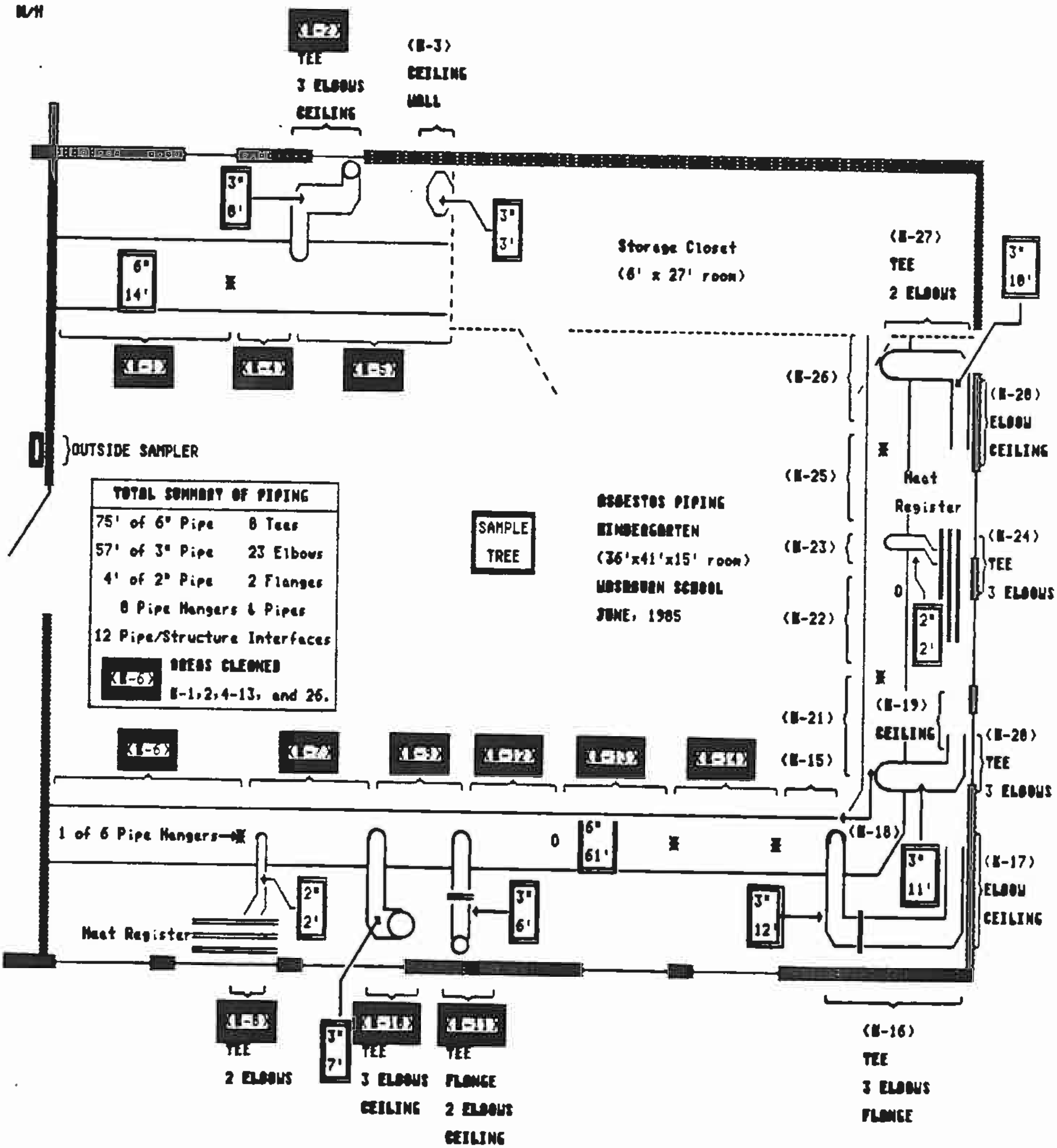
Asbestos removal is a complex task which requires special knowledge and exceptional controls. There is a need for careful planning by an expert consultant to assure that the building owner, occupants, and removal workers are protected by a definitive and complete specification of work and that a competent 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:

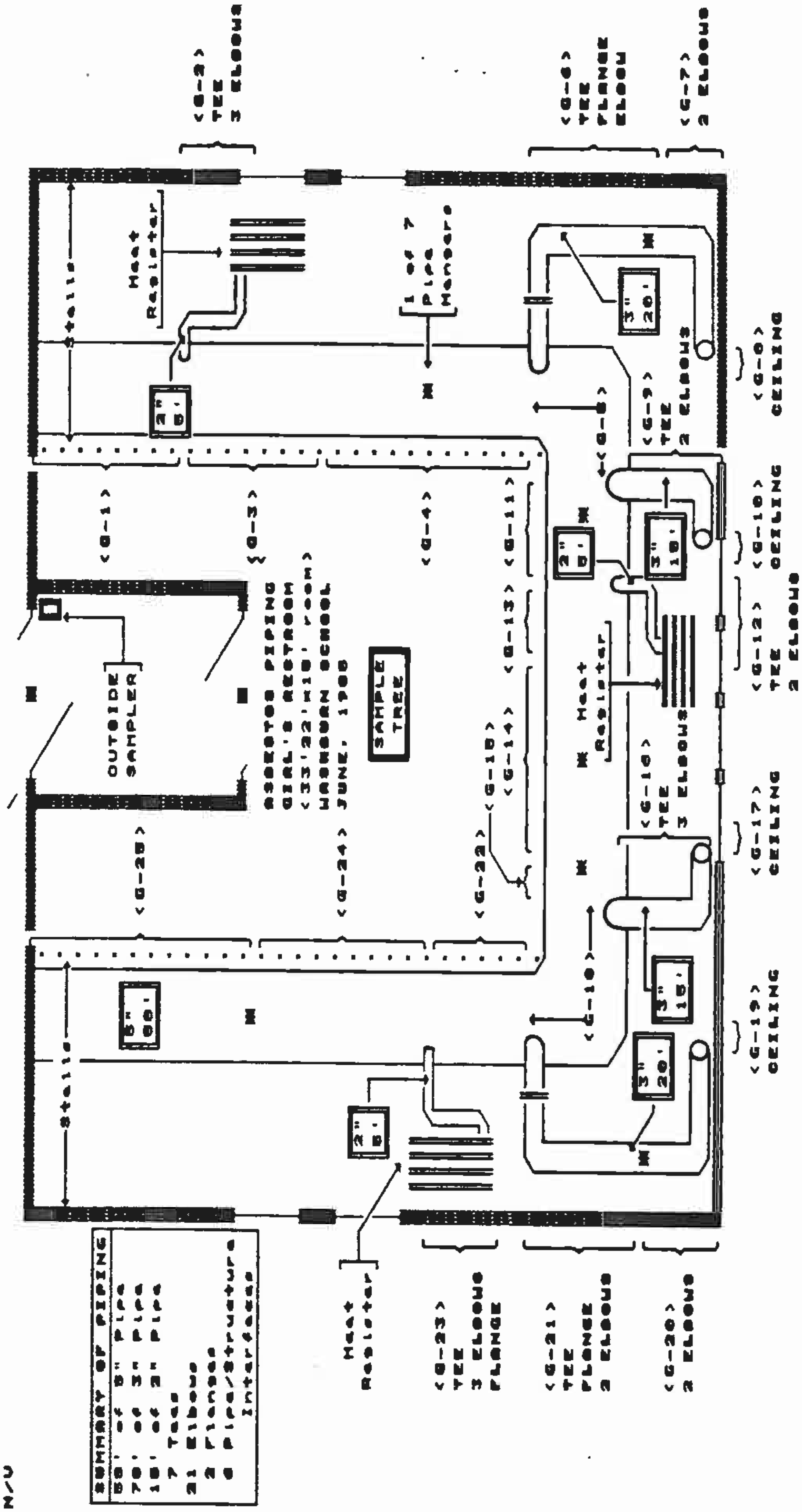
<u>Preparation</u>: The site is cleaned, cleared of all movable materials, and isolated by sealing off all access with plastic sheeting taped to windows, air vents, doors, etc. Surfaces not involved in the removal are covered

FIGURE A

SCHEMATIC PIPING LAYOUT FOR KINDERGARTEN



SCHEMATIC PIPING LAYOUT OF GIRLS ROOM



and sealed with plastic sheeting (usually polyethylene, commonly called "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.

Removal: 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.

Decontamination: 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 definite guidelines for glove bag use. The techniques observed in the present study are summarized below:

Preparation: The contract for asbestos removal in Washburn Elementary 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 to be 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. The floor of the kindergarten was covered with poly to facilitate cleanup. Since the cement floor of the restroom included a drain, which permitted easy washing down after HEPA vacuuming, no covering was provided.

Removal: On the first day, work in the girls room was accomplished using guidelines established the previous week in the Bloom Middle School removal activity. The tools for cutting metal bands and lagging were placed inside the glove bag and the bag was hung from the pipe. Disposalene® 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. Water sprayers (hand-pumped garden sprayers, 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 scrubbed with a brush after the lagging was removed, but while the glove bag was still in place. It was washed again with rags and much more water after the bag was moved.

On the third and fourth days, in the kindergarten room, the crew was trained in the use of new Safe-T-Strip® bags, which utilize double zippers instead of duct tape to close and support the bags on the pipe lagging, and sleeves closed with straps to seal edges of the bags to the pipe. The proper use of these bags was demonstrated, but the supply of bags was very limited. The combination of this limited supply and the unfamiliarity of the workers with these bags did not permit a valid test of their use. The proper technique for using these bags is as follows:

> After the properly shaped bag is selected and installed using the zippers and straps, the poly-envelope and metal bands are removed and the lagging is wetted.
>
> The lagging jacket is cut longitudinally along the full length of one preformed block of insulation. Circumferential cuts are made with a wire saw or blade, preferably at the block joints.
>
> The jacket is removed. The asbestos block is sprayed and then pried apart at the seam and lowered into the bottom of the bag. Amended water is sprayed onto the lagging and the pipe is washed clean. Hard to clean places are brushed with a nylon bristle bottle brush. The bag interior is washed down and the accumulated debris is thoroughly wetted. The end sleeve straps are loosened and the bag is slid along the poly-covered pipe. The double zipper is used to pass by obstacles such as pipe hangers while maintaining closure integrity.
>
> The interior of the bag is again washed down and the bag is drawn together, using a HEPA-filtered vacuum system to evacuate the air and a strap to compress the bag, prior to releasing the seal for removal from the pipe.

This training also included a reinforcement of work practices previously discussed, i.e., the need to fit sprayers with longer hoses (10' - 15') so that the tanks do not have to be elevated to the working level. This allows a support worker on the ground to service the sprayer, filling it with amended water and pumping up the pressure. Since the removal worker does not have to climb from ladders or platforms to perform these tasks, this procedure greatly enhances the ability and inclination to use sufficient wetting to control fiber emissions.

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 occupational 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 provided 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 <u>should</u> 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 2 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

<u>Workplace Sampling</u>
Personal and area air samples were collected and analyzed by Phase Contrast Microscopy (PCM) in accordance with NIOSH Method 7400[1] (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-Rude method.[11]

Polycarbonate filters were analyzed by the Yamate Revision to the EPA Provisional TEM Method.[2] 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 255 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, about eight 15-minute, short-term exposure samples were collected daily. Worker exposures were measured for the site preparation and removal processes and for other associated activities. Other activities included waste collection and disposal, decontamination, and equipment operation and maintenance. About 14 to 16 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 was 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. Outside ambient background samples were taken through 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 of 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; 1500 l, for full shift pre- and post-removal and daily ambient samples, and 2500 l, for pre- and post-removal double shift ambient samples.

TEM analysis performed 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 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. On June 25 and 28, when removal was performed for a full shift, the TWAs were in excess of the 100,000 f/m^3 [0.1 f/cc] action level and 6 of 8 were in excess of the new 200,000 f/m^3 [0.2 f/cc] standard. Seven of the 24 sequential personal samples taken during removal operations were overloaded with particulates and, therefore, were not amenable to fiber analysis. Six of the seven occurred during removal activities in the girls room. Half of the 20 short-term removal sample results equaled or exceeded 500,000 f/m^3; the highest was 2,900,000 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. The results of analyses both by Magiscan and PCM are tabulated in Appendix A, Table A-4.

Analyses of area samples by PCM and TEM are compared in Tables 3A (preparation) and 3B (removal). PCM results for mean levels near workers were 18,000 f/m^3 during preparation and 260,000 f/m^3 during removal. In-room background sample means during preparation were 15,000 f/m^3 and 260,000 f/m^3 during removal. Mean background levels in the halls were 26,000 f/m^3 during preparation and 110,000 f/m^3 during removal days. Ambient levels outside the building were approximately 1,000 f/m^3. TEM results for total asbestos structures are one and two orders of magnitude higher than the PCM results for removal and preparation, respectively. A more detailed analysis of the PCM and TEM comparisons will be made in the final technical report for the four school project.

TABLE 1 - PERSONAL EXPOSURE MEASUREMENTS DURING PREPARATION AND REMOVAL OF PIPE LAGGING AT WASHBURN ELEMENTARY SCHOOL

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

WORKER	TYPE*	ACTIVITY	JUNE 25	JUNE 26	JUNE 27	JUNE 28
# 1	TWA		0.024	0.161	0.022**	0.259
	ST	PREPARATION	0.017		0.045	
	ST	REMOVAL		0.188	0.956	0.178
	ST	REMOVAL	1.33	0.667		0.333
# 2	TWA		0.338	0.348	0.054**	0.198
	ST	PREPARATION	0.017		0.044	
	ST	REMOVAL	1.38	0.286	***	0.233
	ST	REMOVAL	0.91	0.756		0.400
# 3	TWA		0.224	0.216	0.311	0.351
	ST	PREPARATION	0.025		0.033	
	ST	REMOVAL	0.711	0.457	0.867	0.233
	ST	REMOVAL		0.222		0.688
# 4	TWA		0.010	0.290	0.022**	0.354**
	ST	PREPARATION			0.033	
	ST	REMOVAL	2.91	0.244	0.521	1.93
		REMOVAL		0.250		

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

** The TWA reported is for the afternoon activity sample period only. The morning sample during removal was overloaded with particulates.

*** Not counted - sample overloaded with particulates.

TABLE 2 - PERSONAL SAMPLING RESULTS BY ACTIVITY
AT WASHBURN ELEMENTARY SCHOOL

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

WORKER	JUNE 25 GIRLS ROOM	JUNE 26 GIRLS ROOM	JUNE 27 GRM/KINDERGARTEN	JUNE 28	MEAN	MIN	MAX	ST D*	n*
PREPARATION FOR PIPE LAGGING REMOVAL									
1	0.010		0.022		0.016				
2	0.016		0.054		0.035				
3	0.005		0.022		0.013				
4	0.010		0.022		0.016				
AVERAGE	0.010		0.030		0.020	0.005	0.054	0.015	8
PIPE LAGGING REMOVAL									
1	0.043	0.161 (**)	(**)		0.102				2
				0.278 0.169	0.223				2
AVG				0.223	0.163	0.043	0.278	0.083	4
2	0.606	0.362 0.315	(**)		0.511				3
				0.060 0.231	0.145				2
AVG		0.339		0.145	0.315	0.060	0.606	0.178	5
3	0.522	0.216 (**)	0.475		0.404				3
				0.323 0.454	0.388				2
AVG				0.389	0.398	0.216	0.522	0.112	5
4	(**)	0.287 0.298	(**)		0.292				2
				0.354 (**)	0.354				1
AVG		0.292			0.313	0.287	0.354	0.029	3
REMOVAL AVERAGE	0.390	0.223	0.475	0.267	0.289	0.06	0.61	0.153	17
AMBIENT	0.001	0.001	0.001	0.001	0.001				8

* ST D = Standard Deviation n = number of samples
** Filter Overloaded with Particulate - unable to count.

TABLE 3A - AREA SAMPLING RESULTS
PREPARATION FOR PIPE LAGGING REMOVAL
AT WASHBURN ELEMENTARY SCHOOL

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

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

* f/cc = 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 WASHBURN ELEMENTARY SCHOOL

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

SAMPLING SITE	JUNE 25 GIRLS ROOM PCM f/cc	n*	JUNE 25 GIRLS ROOM TEM as/cc	n	JUNE 26 GIRLS ROOM PCM f/cc	n	JUNE 26 GIRLS ROOM TEM as/cc	n	JUNE 27 GIRLS ROOM PCM f/cc	n	JUNE 27 GIRLS ROOM TEM as/cc	n	JUNE 28 KINDERGARTEN PCM f/cc	n	JUNE 28 KINDERGARTEN TEM as/cc	n	MEAN	MIN	MAX	ST D*	n
NEAR WORKERS																					
PCM ANALYSIS	0.52	2			0.15	4			0.38	2							0.30	0.09	0.58	0.17	8
													0.17	4			0.17	0.05	0.33	0.10	4
AVERAGE																	0.26	0.05	0.58	0.16	12
TEM ANALYSIS			2.526	2			1.169	2			2.371	2					2.022	0.832	3.756	1.001	6
															2.597	4	2.597	1.203	5.018	1.459	4
AVERAGE																	2.252	0.832	5.018	1.238	10
ROOM (BACKGROUND)																					
PCM ANALYSIS	0.61	2			0.17	4			0.23	2							0.30	0.03	0.77	0.22	8
													0.18	4			0.18	0.09	0.34	0.10	4
AVERAGE																	0.26	0.30	0.77	0.20	12
TEM ANALYSIS			3.238	2			2.166	4			1.551	2					2.280	1.334	3.215	0.769	8
															2.925	4	2.925	1.203	4.511	1.275	4
AVERAGE																	2.495	1.203	4.511	1.014	12
AREA AVERAGE	0.57	4	2.882	4	0.16	8	1.834	6	0.31	4	1.961	4	0.18	8	2.761	8					
HALL (BACKGROUND)																					
PCM ANALYSIS	0.35	2			0.13	4			0.01	2							0.16	0.01	0.43	0.16	8
													0.02	4			0.02	0.00	0.04	0.01	4
AVERAGE																	0.11	0.00	0.43	0.14	12
TEM ANALYSIS			1.559	2			2.271	4			1.026	2					1.781	0.605	2.514	0.646	8
															1.298	4	1.298	0.463	2.347	0.826	4
AVERAGE																	1.620	0.463	2.514	0.747	12
OUTDOOR AMBIENT																					
PCM ANALYSIS	0.001	2			0.001	2			0.001	2			0.001	2			0.001	0.001	0.001	0.000	8

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

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.

TABLE 4 - MEAN ASBESTOS STRUCTURE AND ASBESTOS FIBER CONCENTRATIONS AT WASHBURN ELEMENTARY SCHOOL

Analysis by TEM using EPA Provisional Method

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

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 86,000 and 120,000 as/m^3 for pre-removal and 260,000 and 280,000 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 higher than the nonaggressive samples in both the pre- and post-removal samples for three of four possible comparisons. 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

TABLE 5 - COMPARISON OF MEAN PRE- AND POST-REMOVAL AREA SAMPLING AT WASHBURN ELEMENTARY SCHOOL

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

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

* f/cc = 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 are 25-mm cellulose ester filter samples analyzed by NIOSH 7402 method, March, 1987 revision. The Lower Limit of Detection for a 2500 l sample is about 0.002 as/cc.

longer than 5 μm also exceeded this criteria, whereas the nonaggressive samples did not. 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[9,10] 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 an increased post-removal level in both rooms, compared to similar pre-removal sampling (mean levels equal to 0.008 vrs 0.001 f/cc in the girls room and 0.037 vrs 0.002 f/cc in the kindergarten). The PCM aggressive samples taken in the kindergarten exceeded 10,000 f/m^3 both before and after removal, whereas comparable samples in the girls room were at or near the 10,000 level after removal, but not before.

Engineering Controls

There were two types of glove bags used during this survey; three Disposalene® bags in the girls room on the first day, six on the second day, and seven on the third day; four Safe-T-Strip® bags were filled in the kindergarten on the fourth day and several were partially filled at the end of the day.

Work Practices

The survey team observed and intermittently videotaped the work practices of the removal crew. A subjective evaluation of these practices based on observation 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 summary 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 with all work specifications.

TABLE 6 - EVALUATION OF WORK PRACTICES
AT WASHBURN ELEMENTARY SCHOOL

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

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

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 at the beginning of this second week of removal activity did not reflect adequate training in glove bag control methods. The midweek training by Mr. Ken Nash, W. W. Nash & Sons, Inc. (the supplier of the Safe-T-Strip® glove bag) was intended to bring the performance of the removal crew closer to the expected norm for glove bag work practices. It was also hoped that any differences effected by the use of Safe-T-Strip® bags during the removal in the kindergarten could be assessed. In the brief period of retraining at this site it was not possible to achieve uniform quality of work practices. However, the workers were subjectively judged to have improved their techniques over this time.

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 the use of 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 0.002 f/cc to 0.020 f/cc during the preparation of the pipe lagging for removal and to 0.289 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 are 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 and the level suggested as "typical" by the EPA.[13] The aggressive post-removal sample analyses for asbestos structures longer than 5 µm also exceeded this criteria, whereas the nonaggressive samples did not.
>
> All twelve samples taken by the nonaggressive method analyzed by PCM are below the 10,000 fibers/m^3 EPA guideline and would pass clearance using this sampling and analytical method. (These samples are also below the NIOSH recommended action level of 0.01 f/cc that would require additional surveillance.)
>
> Seven of the twelve samples (one in the girls room and six in the kindergarten) 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.

Options 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 assist in the collapsing or the glove bags 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 minimun 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/sq mm 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 (0.638 - 3.916)	0.334 (0.170 - 1.045)	0.200 (0.102 - 0.626)
*	250000	0.51	3.13	0.625 (0.319 - 1.956)	0.167 (0.085 - 0.523)	0.100 (0.051 - 0.313)
*	100000	0.51	3.13	0.250 (0.128 - 0.783)	0.067 (0.034 - 0.210)	0.040 (0.020 - 0.125)
100	49045	0.51	3.13	0.123 (0.063 - 0.385)	0.033 (0.017 - 0.103)	0.020 (0.010 - 0.063)
80	39236	0.51	3.14	0.098 (0.050 - 0.308)	0.026 (0.013 - 0.082)	0.016 (0.008 - 0.050)
60	29427	0.51	3.16	0.074 (0.038 - 0.234)	0.02 (0.010 - 0.063)	0.012 (0.006 - 0.038)
50	24522	0.51	3.18	0.061 (0.031 - 0.194)	0.016 (0.008 - 0.051)	0.010 (0.005 - 0.032)
40	19618	0.50	3.20	0.049 (0.025 - 0.157)	0.013 (0.007 - 0.042)	0.008 (0.004 - 0.026)
30	14713	0.49	3.25	0.037 (0.018 - 0.120)	0.01 (0.005 - 0.033)	0.006 (0.003 - 0.020)
20	9809	0.47	3.33	0.025 (0.012 - 0.083)	0.007 (0.003 - 0.023)	0.004 (0.002 - 0.013)
10	4904	0.43	3.57	0.012 (0.005 - 0.043)	0.003 (0.001 - 0.011)	0.002 (0.001 - 0.007)
7 (NIOSH LOD)	3433	0.40	3.78	0.009 (0.004 - 0.034)	0.002 (0.001 - 0.008)	0.001 (0.000 - 0.004)
3 (UBTL LOD)	1471	0.31	4.66	0.004 (0.001 - 0.019)	0.001 (0.000 - 0.005)	0.001 (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	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)
*	1111500	0.51	3.13	2.779 (1.417 - 8.698)	0.741 (0.378 - 2.319)	0.445 (0.227 - 1.393)
*	500000	0.51	3.13	1.25 (0.638 - 3.913)	0.333 (0.170 - 1.042)	0.2 (0.102 - 0.626)
*	250000	0.51	3.13	0.625 (0.319 - 1.956)	0.167 (0.085 - 0.523)	0.1 (0.051 - 0.313)
100	108917	0.51	3.13	0.272 (0.139 - 0.851)	0.073 (0.037 - 0.228)	0.044 (0.022 - 0.138)
80	87134	0.51	3.14	0.218 (0.111 - 0.685)	0.058 (0.030 - 0.182)	0.035 (0.018 - 0.110)
60	65350	0.51	3.16	0.163 (0.083 - 0.515)	0.044 (0.022 - 0.139)	0.026 (0.013 - 0.082)
50	54459	0.51	3.18	0.136 (0.069 - 0.432)	0.036 (0.018 - 0.114)	0.022 (0.011 - 0.070)
40	43567	0.50	3.20	0.109 (0.055 - 0.349)	0.029 (0.015 - 0.093)	0.017 (0.009 - 0.054)
30	32675	0.49	3.25	0.082 (0.04 - 0.267)	0.022 (0.011 - 0.072)	0.013 (0.006 - 0.042)
20	21783	0.47	3.33	0.054 (0.025 - 0.18)	0.015 (0.007 - 0.05)	0.009 (0.004 - 0.030)
10	10892	0.43	3.57	0.027 (0.012 - 0.096)	0.007 (0.003 - 0.025)	0.004 (0.002 - 0.014)
7 (NIOSH LOD)	7624	0.40	3.78	0.019 (0.008 - 0.072)	0.005 (0.002 - 0.019)	0.003 (0.001 - 0.011)
3 (UBTL LOD)	3268	0.31	4.66	0.008 (0.002 - 0.037)	0.002 (0.001 - 0.009)	0.001 (0.000 - 0.005)

TABLE A-3

LEGEND FOR WASHBURN PCM DATA - APPENDIX A

LOC (School and room location of sampled activity)

- WAxx Washburn Elementary School
  - KG Kindergarten
  - GR Girls Room
  - EW Outside the Executive Washroom window
  - FB Field Blank no sample taken

SAMPLE CLASS (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 (proximate to work activity)
- Activity
  - PRE Pre-removal activity - Full-term sample
  - PST Post-removal activity - Full-term sample
  - REM Removal work - Full-term sequential sample
  - COV Preparation, covering, etc. - Full-term sequential
  - RMS Removal work - 15-minute short-term PBZ sample
  - COS Preparation, covering, etc. - 15-minute short-term BZ
  - SEQ Sample period covers sequential work activities
- ID
  - AGGR Aggressive sampling mode
  - NAGR Nonaggressive sampling mode
  - WK#x Worker #x BZ sample
  - 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 analytical results 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; results in total fibers per cubic centimeter

UBTL PCM analysis performed by Utah Biological Testing Labs

NIOSH PCM analysis performed in the NIOSH Laboratory

POL Particulate Overload - Unable to count.

TABLE A-4

PHASE CONTRAST MICROSCOPY ANALYTICAL RESULTS
FOR AIRBORNE ASBESTOS ANALYSIS
WASHBURN ELEMENTARY 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
WAGR	IA-PRE-AGGR	AA106	6/12	2316	0723	487	3.25	1582.8	45045	0.028	3000	0.002		
WAGR	IA-PRE-AGGR	AA107	6/12	2316	0723	487	3.25	1582.8	21945	0.014	750	0.000		
WAGR	IA-PRE-NAGR	AA116	6/12	1320	2134	494	3.12	1541.3	39270	0.025	750	0.000		
WAGR	IA-PRE-NAGR	AA117	6/12	1320	2134	494	3.25	1605.5	76230	0.047			1347	0.001
WAGR	IA-PRE-NAGR	AA118	6/12	1320	2134	494	3.25	1605.5	60445	0.038	2000	0.001		
WAGR	IA-PRE-AGGR	AA120	6/12	2316	0723	487	3.14	1529.2	39655	0.026			5621	0.004
WAGR	IA-PRE-NAGR	M262	6/12	1320	2134	494	3.12	1541.3	29925	0.019	1750	0.001		
WAGR	IA-PRE-AGGR	M268	6/12	2316	0723	487	3.25	1582.8	29070	0.018	1750	0.001		
WAGR	IA-PRE-AGGR	M270	6/12	2316	0723	487	3.06	1490.2	33601	0.023			2992	0.002
WAGR	IA-PRE-NAGR	M272	6/12	1320	2134	494	3.25	1605.5	10780	0.007	1750	0.001		
WAGR	IA-PRE-AGGR	M274	6/12	2316	0723	487	3.25	1582.8	65322	0.041	1750	0.001		
WAGR	IA-PRE-NAGR	M278	6/12	1320	2134	494	3.25	1605.5	33687	0.021			2992	0.002
WAKG	IA-PRE-AGGR	AA108	6/12	2358	0802	484	3.11	1505.2	43505	0.029			27335	0.018
WAKG	IA-PRE-AGGR	AA109	6/12	2358	0802	484	3.25	1573.0	50820	0.032	15000	0.010		
WAKG	IA-PRE-AGGR	AA119	6/12	2358	0802	484	3.25	1573.0	69685	0.044	10000	0.006		
WAKG	IA-PRE-NAGR	AA134	6/12	1334	2153	499	3.00	1497.0	33706	0.023			7084	0.005
WAKG	IA-PRE-NAGR	AA135	6/12	1334	2153	499	2.96	1477.0	35343	0.024	750	0.001		
WAKG	IA-PRE-NAGR	AA136	6/12	1334	2153	499	3.25	1621.8	15207	0.009	750	0.000		
WAKG	IA-PRE-NAGR	M252	6/12	1334	2153	499	3.25	1621.8	21375	0.013	1750	0.001		
WAKG	IA-PRE-NAGR	M254	6/12	1334	2153	499	3.16	1576.8	33345	0.021	1750	0.001		
WAKG	IA-PRE-AGGR	M256	6/12	2358	0802	484	3.25	1573.0	90630	0.058	30000	0.019		
WAKG	IA-PRE-NAGR	M258	6/12	1334	2153	499	3.25	1621.8	28215	0.017	3500	0.002		
WAKG	IA-PRE-AGGR	M260	6/12	2358	0802	484	3.25	1573.0	90630	0.058			51300	0.033
WAKG	IA-PRE-AGGR	M264	6/12	2358	0802	484	3.16	1529.4	66690	0.044	20000	0.013		
WAEW	AM-PRE-FTER	AA104	6/12	1700	0700	840	3.00	2520.0	85085	0.034			1347	
WAEW	AM-PRE-FTER	AA105	6/12	1700	0700	840	2.75	2310.0	88165	0.038			1347	
WAFB	FB-PRE-FTRM	AA102	6/12								750			
WAFB	FB-PRE-FTRM	AA103	6/12								750			
WAFB	FB-PRE-FTRM	AA131	6/12						1463		750			
WAFB	FB-PRE-NAGR	AA132	6/12						34265		750			
WAFB	FB-PRE-FTRM	M266	6/12						2992					
WAFB	FB-PRE-NAGR	M276	6/12						4360		1750			
WAFB	FB-PRE-6/14	M298	6/12						3249					
WAFB	FB-PRE-6/14	M323	6/12						28129				2992	
WAFB	FB-PRE-6/14	M326	6/12						3249					

TABLE A-4: PHASE CONTRAST MICROSCOPY ANALYTICAL RESULTS (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
WAGR	BZ-COS-WK#1	AA186	6/25	1020	1035	15	3.00	45.0			750	0.017		
WAGR	BZ-COS-WK#2	AA190	6/25	1000	1015	15	3.00	45.0			750	0.017		
WAGR	BZ-COS-WK#3	AA179	6/25	0930	0950	20	3.00	60.0			1500	0.025		
WAGR	BZ-COV-WK#1	AA184	6/25	0807	1126	199	3.14	624.9			6000	0.010		
WAGR	BZ-COV-WK#2	AA198	6/25	0932	1133	121	3.05	369.1			6000	0.016		
WAGR	BZ-COV-WK#3	AA187	6/25	0807	1126	199	3.02	601.0			3000	0.005		
WAGR	BZ-COV-WK#4	AA205	6/25	0929	1114	105	3.00	315.0			3000	0.010		
WAGR	BZ-REM-WK#1	AA194	6/25	1245	1507	142	2.96	420.3			18000	0.043		
WAGR	BZ-REM-WK#2	AA195	6/25	1241	1507	146	3.05	445.3			270000	0.606		
WAGR	BZ-REM-WK#3	AA201	6/25	1241	1507	146	3.02	440.9			230000	0.522		
WAGR	BZ-REM-WK#4	AA207	6/25	1240	1507	147	3.00	441.0			POL*			
WAGR	BZ-RMS-WK#1	AA197	6/25	1430	1445	15	3.00	45.0			60000	1.333		
WAGR	BZ-RMS-WK#2	AA200	6/25	1450	1505	15	3.00	45.0			62000	1.378		
WAGR	BZ-RMS-WK#2	AA202	6/25	1300	1315	15	3.00	45.0			41000	0.911		
WAGR	BZ-RMS-WK#3	AA185	6/25	1319	1334	15	3.00	45.0			32000	0.711		
WAGR	BZ-RMS-WK#4	AA203	6/25	1403	1419	16	3.00	48.0			140000	2.917		
WAGR	CT-COV	AA180	6/25	0757	1127	210	3.00	630.0			7000	0.011		
WAGR	CT-COV	AA193	6/25	0757	1127	210	3.11	653.1			9000	0.014		
WAGR	CT-REM	AA182	6/25	1242	1506	144	3.11	447.8			210000	0.469		
WAGR	CT-REM	AA196	6/25	1242	1506	144	3.00	432.0			250000	0.579		
WAGR	IA-COV	AA183	6/25	0757	1127	210	3.00	630.0			8000	0.013		
WAGR	IA-COV	AA191	6/25	0757	1127	210	3.00	630.0			10000	0.016		
WAGR	IA-REM	AA192	6/25	1243	1506	143	3.00	429.0			330000	0.769		
WAGR	IA-REM	AA199	6/25	1243	1506	143	3.00	429.0			190000	0.443		
WAGR	OA-COV	AA189	6/25	0757	1127	210	3.09	648.9			5000	0.008		
WAGR	OA-COV	AA206	6/25	0757	1127	210	3.12	655.2			4000	0.006		
WAGR	OA-REM	AA181	6/25	1244	1506	142	3.12	443.0			190000	0.429		
WAGR	OA-REM	AA208	6/25	1244	1506	142	3.09	438.8			120000	0.273		
WAEW	AM-REM	AA188	6/25	0736	1515	459	2.80	1285.2			750	0.001		
WAEW	AM-REM	AA204	6/25	0736	1515	459	2.70	1239.3			750	0.001		
WAFB	FB-COV-6/19	AA030	6/25								750			

TABLE A-4: PHASE CONTRAST MICROSCOPY ANALYTICAL RESULTS (Continued - page 3)

		SAMPLE		PERIOD		TIME	RATE	VOL.	MAGISCAN II		UBTLPCM 7400-B		NIOSHPCM 7400-B	
LOC.	SAMPLE CLASS	No.	Date	Start	Stop	(min)	(lpm)	(l)	Fibers	f/cc	Fibers	f/cc	Fibers	f/cc
WAGR	BZ-REM-WK#1	AA219	6/26	0745	1115	210	2.96	621.6			100000	0.161		
WAGR	BZ-REM-WK#1	AA285	6/26	1330	1446	76	2.96	225.0			POL*			
WAGR	BZ-REM-WK#2	AA210	6/26	0814	1115	181	3.05	552.1			200000	0.362		
WAGR	BZ-REM-WK#2	AA296	6/26	1330	1448	78	3.05	237.9			75000	0.315		
WAGR	BZ-REM-WK#3	AA220	6/26	0743	1115	212	3.02	640.2			POL*			
WAGR	BZ-REM-WK#3	AA311	6/26	1331	1446	75	3.02	226.5			49000	0.216		
WAGR	BZ-REM-WK#4	AA211	6/26	0746	1115	209	3.00	627.0			180000	0.287		
WAGR	BZ-REM-WK#4	AA291	6/26	1333	1448	75	3.00	225.0			67000	0.298		
WAGR	BZ-RMS-WK#1	AA284	6/26	0944	1000	16	3.00	48.0			9000	0.188		
WAGR	BZ-RMS-WK#1	AA295	6/26	1345	1400	15	3.00	45.0			30000	0.667		
WAGR	BZ-RMS-WK#2	AA297	6/26	1406	1421	15	3.50	52.5			15000	0.286		
WAGR	BZ-RMS-WK#2	AA301	6/26	0836	0851	15	3.00	45.0			34000	0.756		
WAGR	BZ-RMS-WK#3	AA303	6/26	1020	1035	15	3.00	45.0			10000	0.222		
WAGR	BZ-RMS-WK#3	AA308	6/26	1422	1437	15	3.50	52.5			24000	0.457		
WAGR	BZ-RMS-WK#4	AA294	6/26	1001	1016	15	3.00	45.0			11000	0.244		
WAGR	BZ-RMS-WK#4	AA322	6/26	1440	1448	8	3.50	28.0			7000	0.250		
WAGR	CT-REM	AA214	6/26	0737	1117	220	3.00	660.0			110000	0.167		
WAGR	CT-REM	AA218	6/26	0737	1117	220	3.00	660.0			110000	0.167		
WAGR	CT-REM	AA286	6/26	1330	1450	80	3.00	240.0			35000	0.146		
WAGR	CT-REM	AA326	6/26	1330	1450	80	3.00	240.0			21000	0.088		
WAGR	IA-REM	AA215	6/26	0737	1117	220	3.00	660.0			160000	0.242		
WAGR	IA-REM	AA217	6/26	0737	1117	220	3.06	673.2			110000	0.163		
WAGR	IA-REM	AA279	6/26	1330	1450	80	3.06	244.8			26000	0.106		
WAGR	IA-REM	AA325	6/26	1330	1450	80	3.00	240.0			42000	0.175		
WAGR	OA-REM	AA221	6/26	0737	1117	220	3.09	679.8			10000	0.015		
WAGR	OA-REM	AA222	6/26	0737	1117	220	3.12	686.4			10000	0.015		
WAGR	OA-REM	AA292	6/26	1330	1450	80	3.12	249.6			51000	0.204		
WAGR	OA-REM	AA300	6/26	1330	1450	80	3.09	247.2			75000	0.303		
WAEW	AM-REM	AA209	6/26	0717	1515	478	2.60	1242.8			750	0.001		
WAEW	AM-REM	AA216	6/26	0717	1515	478	2.90	1386.2			750	0.001		
WAFB	FB-REM-6/19	AA034	6/26								750			
WAFB	FB-REM-6/21	AA161	6/26								750			

TABLE A-4: PHASE CONTRAST MICROSCOPY ANALYTICAL RESULTS (Continued - page 4)

		SAMPLE		PERIOD		TIME	RATE	VOL.	MAGISCAN II		UBTLPCM 7400-B		NIOSHPCM 7400-B	
LOC.	SAMPLE CLASS	No.	Date	Start	Stop	(min)	(lpm)	(l)	Fibers	f/cc	Fibers	f/cc	Fibers	f/cc
WAGR	BZ-REM-WK#1	AA281	6/27	0740	1117	217	2.96	642.3			POL*			
WAGR	BZ-REM-WK#2	AA283	6/27	0740	1116	216	3.05	658.8			POL*			
WAGR	BZ-REM-WK#3	AA282	6/27	0741	1117	216	3.02	652.3			310000	0.475		
WAGR	BZ-REM-WK#4	AA293	6/27	0738	1119	221	3.00	663.0			POL*			
WAGR	BZ-RMS-WK#1	AA312	6/27	1020	1035	15	3.00	45.0			43000	0.956		
WAGR	BZ-RMS-WK#2	AA298	6/27	0809	0824	15	3.00	45.0			POL*			
WAGR	BZ-RMS-WK#3	AA306	6/27	0826	0841	15	3.00	45.0			39000	0.867		
WAGR	BZ-RMS-WK#4	AA290	6/27	0945	1001	16	3.00	48.0			25000	0.521		
WAGR	CT-REM	AA272	6/27	0736	1122	226	3.00	678.0			310000	0.457		
WAGR	CT-REM	AA287	6/27	0736	1122	226	3.00	678.0			210000	0.310		
WAGR	IA-REM	AA320	6/27	0736	1122	226	3.00	678.0			20000	0.029		
WAGR	IA-REM	AA324	6/27	0736	1122	226	3.06	691.6			POL*			
WAGR	OA-REM	AA299	6/27	0736	1123	227	3.00	681.0			8000	0.012		
WAGR	OA-REM	AA323	6/27	0736	1123	227	3.06	694.6			8000	0.012		
WAKG	BZ-COV-WK#1	AA305	6/27	1318	1519	121	2.96	358.2			8000	0.022		
WAKG	BZ-COV-WK#2	AA307	6/27	1318	1519	121	3.05	369.1			20000	0.054		
WAKG	BZ-COV-WK#3	AA316	6/27	1317	1519	122	3.02	368.4			8000	0.022		
WAKG	BZ-COV-WK#4	AA304	6/27	1318	1519	121	3.00	363.0			8000	0.022		
WAKG	BZ-COS-WK#1	AA250	6/27	1427	1442	15	2.96	44.4			2000	0.045		
WAKG	BZ-COS-WK#2	AA228	6/27	1404	1419	15	3.00	45.0			2000	0.044		
WAKG	BZ-COS-WK#3	AA255	6/27	1326	1341	15	3.00	45.0			1500	0.033		
WAKG	BZ-COS-WK#4	AA213	6/27	1447	1502	15	3.00	45.0			1500	0.033		
WAKG	CT-COV	AA243	6/27	1301	1523	142	3.00	426.0			10000	0.023		
WAKG	CT-COV	AA247	6/27	1301	1523	142	3.00	426.0			10000	0.023		
WAKG	IA-COV	AA234	6/27	1302	1523	141	3.06	431.5			5000	0.012		
WAKG	IA-COV	AA253	6/27	1302	1523	141	3.00	423.0			8000	0.019		
WAKG	OA-COV	AA227	6/27	1302	1520	138	3.12	430.6			28000	0.065		
WAKG	OA-COV	AA289	6/27	1302	1520	138	3.00	414.0			10000	0.024		
WAEW	AM-FTM	AA309	6/27	0721	1525	484	3.00	1452.0			750	0.001		
WAEW	AM-FTM	AA310	6/27	0721	1525	484	3.00	1452.0			750	0.001		
WAFB	FB-COV-6/19	AA036	6/27								750			
WAFB	FB-COV-6/21	AA162	6/27								750			

TABLE A-4: PHASE CONTRAST MICROSCOPY ANALYTICAL RESULTS (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
WAKG	BZ-REM-WK#1	AA271	6/28	0744	1135	231	2.96	683.8			190000	0.278		
WAKG	BZ-REM-WK#1	AA327	6/28	1244	1348	64	2.96	189.4			32000	0.169		
WAKG	BZ-REM-WK#2	AA248	6/28	0744	1135	231	3.00	693.0			160000	0.231		
WAKG	BZ-REM-WK#2	AA278	6/28	1243	1338	55	3.05	167.8			10000	0.060		
WAKG	BZ-REM-WK#3	AA252	6/28	0742	1139	237	3.00	711.0			230000	0.323		
WAKG	BZ-REM-WK#3	AA275	6/28	1243	1345	62	3.02	187.2			85000	0.454		
WAKG	BZ-REM-WK#4	AA212	6/28	0743	1135	232	3.00	696.0			POL*			
WAKG	BZ-REM-WK#4	AA314	6/28	1243	1348	65	3.00	195.0			69000	0.354		
WAKG	BZ-RMS-WK#1	AA231	6/28	1303	1318	15	3.00	45.0			8000	0.178		
WAKG	BZ-RMS-WK#1	AA260	6/28	0945	1001	16	3.00	48.0			16000	0.333		
WAKG	BZ-RMS-WK#2	AA230	6/28	1320	1335	15	3.00	45.0			3000	0.067		
WAKG	BZ-RMS-WK#2	AA235	6/28	0825	0840	15	3.00	45.0			18000	0.400		
WAKG	BZ-RMS-WK#3	AA233	6/28	1008	1023	15	3.00	45.0			31000	0.689		
WAKG	BZ-RMS-WK#3	AA258	6/28	1336	1347	11	3.00	33.0			7000	0.212		
WAKG	BZ-RMS-WK#4	AA265	6/28	0803	0822	19	3.00	57.0			110000	1.930		
WAKG	CT-REM	AA224	6/28	0740	1142	242	3.00	726.0			240000	0.331		
WAKG	CT-REM	AA263	6/28	0740	1142	242	3.00	726.0			130000	0.179		
WAKG	CT-REM	AA273	6/28	1240	1344	64	3.00	192.0			23000	0.120		
WAKG	OA-REM	AA274	6/28	1240	1345	65	3.09	200.9			750	0.004		
WAKG	CT-REM	AA328	6/28	1240	1344	64	3.00	192.0			10000	0.052		
WAKG	IA-REM	AA249	6/28	0740	1142	242	3.00	726.0			250000	0.344		
WAKG	IA-REM	AA261	6/28	0740	1142	242	3.00	726.0			65000	0.090		
WAKG	IA-REM	AA288	6/28	1240	1344	64	3.00	192.0			33000	0.172		
WAKG	IA-REM	AA302	6/28	1240	1344	64	3.06	195.8			21000	0.107		
WAKG	OA-REM	AA259	6/28	0740	1142	242	3.09	747.8			10000	0.013		
WAKG	OA-REM	AA262	6/28	0740	1142	242	3.09	747.8			6000	0.008		
WAKG	OA-REM	AA317	6/28	1240	1345	65	3.12	202.8			9000	0.044		
WAEW	AM-FTM	AA223	6/28	0715	1355	400	3.00	1200.0			750	0.001		
WAEW	AM-FTM	AA264	6/28	0715	1355	400	2.80	1120.0			750	0.001		
WAFB	FB-REM-6/21	AA163	6/28								750			
WAFB	FB-REM-6/28	AA315	6/28								750			
WAFB	FB-REM-FTER	AA316	6/28								LOST			

TABLE A-4: PHASE CONTRAST MICROSCOPY ANALYTICAL RESULTS (Continued - page 6)

		SAMPLE		PERIOD		TIME	RATE	VOL.	MAGISCAN II		UBTLPCM 7400-B		NIOSHPCM 7400-B	
LOC.	SAMPLE CLASS	No.	Date	Start	Stop	(min)	(lpm)	(l)	Fibers	f/cc	Fibers	f/cc	Fibers	f/cc
WAGR	IA-PST-AGGR	AA395	7/11	0013	0715	422	3.00	1266.0	13398	0.011	7000	0.006	24986	0.020
WAGR	IA-PST-AGGR	AA412	7/11	0013	0715	422	3.25	1371.5	189035	0.138	8000	0.006		
WAGR	IA-PST-AGGR	AA414	7/11	0013	0715	422	3.00	1266.0	164395	0.130	10000	0.008	19366	0.015
WAGR	IA-PST-AGGR	M860	7/11	0013	0715	422	3.00	1266.0	68400	0.054	10000	0.008	33345	0.026
WAGR	IA-PST-AGGR	M861	7/11	0013	0715	422	3.00	1266.0	173565	0.137	20000	0.016	42750	0.034
WAGR	IA-PST-AGGR	M862	7/11	0013	0715	422	3.00	1266.0	116280	0.092	10000	0.008	26505	0.021
WAGR	IA-PST-NAGR	AA410	7/11	0827	1630	483	3.00	1449.0	82775	0.057	2000	0.001	5621	0.004
WAGR	IA-PST-NAGR	AA418	7/11	0827	1630	483	3.15	1521.5	38885	0.026	2000	0.001		
WAGR	IA-PST-NAGR	AA419	7/11	0827	1630	483	2.90	1400.7	48125	0.034	2000	0.001		
WAGR	IA-PST-NAGR	M840	7/11	0827	1630	483	3.00	1449.0	123120	0.085	3500	0.002		
WAGR	IA-PST-NAGR	M847	7/11	0827	1630	483	3.05	1473.2	127315	0.086	1750	0.001		
WAGR	IA-PST-NAGR	M855	7/11	0827	1630	483	3.15	1521.5	70965	0.047	1750	0.001		
WAGR	OA-PST-AGGR	AA413	7/11	0013	0715	422	3.00	1266.0	198660	0.157	4000	0.003		
WAGR	OA-PST-NAGR	AA431	7/11	0827	1630	483	2.95	1424.9	43120	0.030	2000	0.001		
WAKG	IA-PST-AGGR	AA392	7/11	2300	0715	495	3.10	1534.5	123585	0.081	42000	0.027		
WAKG	IA-PST-AGGR	AA398	7/11	2300	0715	495	3.50	1732.5	92015	0.053	36000	0.021		
WAKG	IA-PST-AGGR	AA420	7/11	2300	0715	495	3.50	1732.5	58135	0.034	32000	0.018		
WAKG	IA-PST-AGGR	M858	7/11	2300	0715	495	3.50	1732.5	169290	0.098	97000	0.056	78404	0.045
WAKG	IA-PST-AGGR	M859	7/11	2300	0715	495	3.00	1485.0	94905	0.064	93000	0.063	91485	0.062
WAKG	IA-PST-AGGR	M868	7/11	2300	0715	495	3.50	1732.5	106875	0.062	59000	0.034	102600	0.059
WAKG	IA-PST-NAGR	AA415	7/11	0827	1630	483	3.05	1473.2	52745	0.036	3000	0.002		
WAKG	IA-PST-NAGR	AA421	7/11	0827	1630	483	3.00	1449.0	51590	0.036	4000	0.003		
WAKG	IA-PST-NAGR	AA450	7/11	0827	1630	483	3.10	1497.3	77000	0.051	3000	0.002	7700	0.005
WAKG	IA-PST-NAGR	M838	7/11	0827	1630	483	3.20	1545.6	106875	0.069	1750	0.001	13595	0.009
WAKG	IA-PST-NAGR	M839	7/11	0827	1630	483	3.15	1521.5	90630	0.060	1750	0.001		
WAKG	IA-PST-NAGR	M846	7/11	0827	1630	483	3.25	1569.8	129960	0.083	5000	0.003	9747	0.006
WAKG	OA-PST-AGGR	AA403	7/11	2300	0715	495	3.25	1608.8	103565	0.064	9000	0.006		
WAKG	OA-PST-NAGR	AA435	7/11	0827	1630	483	3.00	1449.0	20405	0.014	3000	0.002		
WAEW	AM-PST-FTER	AA434	7/11	0850	1630	460	3.00	1380.0	41580	0.030	750	0.001		
WAEW	AM-PST-FTER	AA441	7/11	1024	0707	1243	3.00	3729.0	182490	0.049	750	0.000	1347	0.000
WAEW	AM-PST-FTER	AA449	7/11	0850	1630	460	2.90	1334.0	20790	0.016	750	0.001		
WAEW	AM-PST-FTER	AA408	7/11	1024	0707	1243	3.00	3729.0	162470	0.044	2000	0.001		
WAFB	FB-PST-6/21	AA174	7/11						6314		750		9770	
WAFB	FB-PST-7/18	M953	7/11						2992		1750			
WAFB	FB-PST-7/18	M954	7/11						2992		1750			

APPENDIX B

TEM DATA TABULATION

TABLE B-1

Washburn Elementary 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-257	100052	38481	61570	53874	7696	-	-	-	100052	61570	53874	7696
N-263	56666	32380	24285	16190	8095	-	-	-	56666	24285	16190	8095
N-267	69970	15549	54421	54421	-	-	-	15549	54421	38872	38872	-
N-273	100052	15393	84659	46178	38481	-	-	15393	84659	69267	30785	38481
N-277	637504	482015	155489	62195	93293	-	-	15549	621955	139940	46647	93293
N-279	225893	92031	133863	100397	33466	-	-	25099	200794	108763	75298	33466
X̄	198356	112642	85715	55543					186424	73783	43611	
Aggressive												
N-253	152259	93047	59212	16918	42294	-	-	-	152259	59212	16918	42294
N-261	86745	31544	55202	31544	23658	-	-	-	86745	55202	31544	23658
N-265	380883	333273	47610	23805	23805	-	-	-	341208	47610	23805	23805
N-269	321305	186019	135286	67643	67643	-	-	-	287484	126831	67643	59188
N-271	2697922	2327619	370303	132251	238052	26450	-	-	2512771	343853	105801	238052
N-275	181377	134061	47316	15772	31544	-	-	-	181377	47316	15772	31544
X̄	636749	517594	119154	47989	71166				593640	113337	43580	69757
POST REMOVAL												
Nonaggressive												
N-675	633555	316777	316777	183397	133380	8336	-	16673	600210	291769	166725	125044
N-676	347257	226121	121136	56530	64606	-	8076	16152	314954	96909	32303	64606
N-680	331105	121136	209969	185742	24227	-	-	24227	290727	169590	153439	16151
N-789	266760	1000035	166725	108371	58354	8336	-	8336	233415	141716	83362	58354
N-792	1511194	876493	634701	272015	362687	-	30224	15112	1420522	589366	226679	362687
N-793	626974	516830	110144	93199	16945	-	-	8473	584610	101671	84726	16945
X̄	619474	359565	259909	149876	110033			14829	574073	231837	124539	107298
Aggressive												
N-671	985929	828180	157749	98593	59156	-	-	9859	897195	147889	88734	59156
N-795	847899	561979	285919	276060	9859	39437	-	-	700009	226764	226764	-
N-796	2401512	2113330	264166	216136	48030	48030	-	-	1705073	168106	120076	48030
N-797	2425527	2233406	192121	96060	96060	24015	-	-	2113330	120076	72045	48030
N-799	3286429	2662008	624422	525829	98593	32864	-	-	3023515	525829	427236	98593
N-800	626795	453886	172909	172909	-	50432	-	-	518727	115273	115273	-
X̄	1762348	1475465	282881	230931					1492975	217323	175021	