

IN-DEPTH SURVEY REPORT
CONTROL TECHNOLOGY FOR ASBESTOS REMOVAL
AT
WINTON PLACE ELEMENTARY SCHOOL
Cincinnati, Ohio

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PLANT SURVEYED· Cincinnati Public School System
Winton Place Elementary School
4750 Winton Rd
Cincinnati, Ohio 45232

SIC CODE. 1799

SURVEY DATES June 4, 1985 Walk-Through Survey
June 12, 1985 Pre-Removal Survey
July 15-17, 1985 Removal Survey
July 18, 1985 Post-Removal Survey

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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 method to control and reduce occupational exposure to asbestos dust during the removal of asbestos pipe lagging from a public school building.

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

BACKGROUND

Technical

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

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

Environmental Regulation

The EPA has been involved in activities to reduce asbestos emissions and contamination of the environment for many years. A major concern of this Agency is the degradation or disturbance of in-place asbestos-containing materials in buildings which may result in airborne asbestos concentrations several orders of magnitude higher than ambient levels outside the building.

Although no new asbestos fireproofing is used in buildings today, the eventual removal of existing in-place asbestos is a major technical and economic dilemma. A part of the Toxic Substances and Control Act known as the Asbestos-in-Schools rule requires all primary and secondary schools, both private and public, to inspect the buildings for asbestos-containing materials, document the findings, and inform the employees and the PTA or parents

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

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

Analytical

Another adjunct to this study was to utilize 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 for data reported herein because the analytical services used believe that a more reproducible asbestos fiber count can be obtained under these conditions. As discussed later, A rule fiber counts cannot be estimated from B rule results.

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 and because the availability of techniques which may qualitatively differentiate between asbestos and nonasbestos structures. 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 Winton Place Elementary School, Gandee reported damaged and exposed asbestos in many of the occupied areas, in the boiler room, coal room, and fan room. The report emphasized that lagging was to be assumed to be asbestos and that ceiling tile were not required to be analyzed unless they were deteriorated. Samples of the boiler lagging and the ceiling tile in the playroom were taken; however, only the ceiling tile was analyzed. It was reported to contain cellulose and mineral wool but no asbestos. 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: Winton Place 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. Bulk samples of pipe lagging taken at the time of the removal activity were analyzed as follows. A sample from the girls restroom indicated about 5% chrysotile and 15-20% cellulose and other fibers, and the remainder to be nonfibrous material. A sample from the boys restroom contained approximately 20% chrysotile and 10-15% cellulose and other fibers. A sample from Room 14 indicated 5-7% chrysotile asbestos and 2-3% cellulose and other fibers. No actinolite/tremolite, amosite, or anthophyllite asbestos forms were detected in these samples.

The removal contract for the original building at Winton Place Elementary School (constructed in 1887) required approximately 710 linear feet of asbestos pipe lagging to be removed from 10 major rooms and areas. During this survey, removal operations were observed in three rooms located on the basement level, the girls restroom (girls room), the Special Education room (room 14), and the boys restroom (boys room).

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 girls room (Figure A) measured approximately 29'x 25'x 11', enclosing 7975 cubic feet. Insulation was removed from approximately 42' of 3-inch, 9' of 2-inch, and 14' of 1.5-inch pipe, including 4 T-joints, 10 elbows, 4 pipe hangers, and 5 pipe/structure intersections.

The boys room (Figure B) measured approximately 29'x 24'x 11', enclosing 7656 cubic feet. Insulation was removed from approximately 50' of 3-inch, 28' of 2-inch, and 4' of 1.5-inch pipe, including 6 T-joints, 11 elbows, 4 pipe hangers, and 6 pipe/structure intersections.

Room 14 (Figure C) measured approximately 30'x 25'x 9', enclosing 6750 cubic feet. Insulation was removed from approximately 30' of 5-inch, 50' of 3-inch, 28' of 2-inch, and 5' of 1.5-inch pipe, including 5 T-joints, 10 elbows, 4 pipe hangers, and 9 pipe/structure intersections.

Figure A

Plot of Piping Layout in Girls' Rest Room (Girls Room)

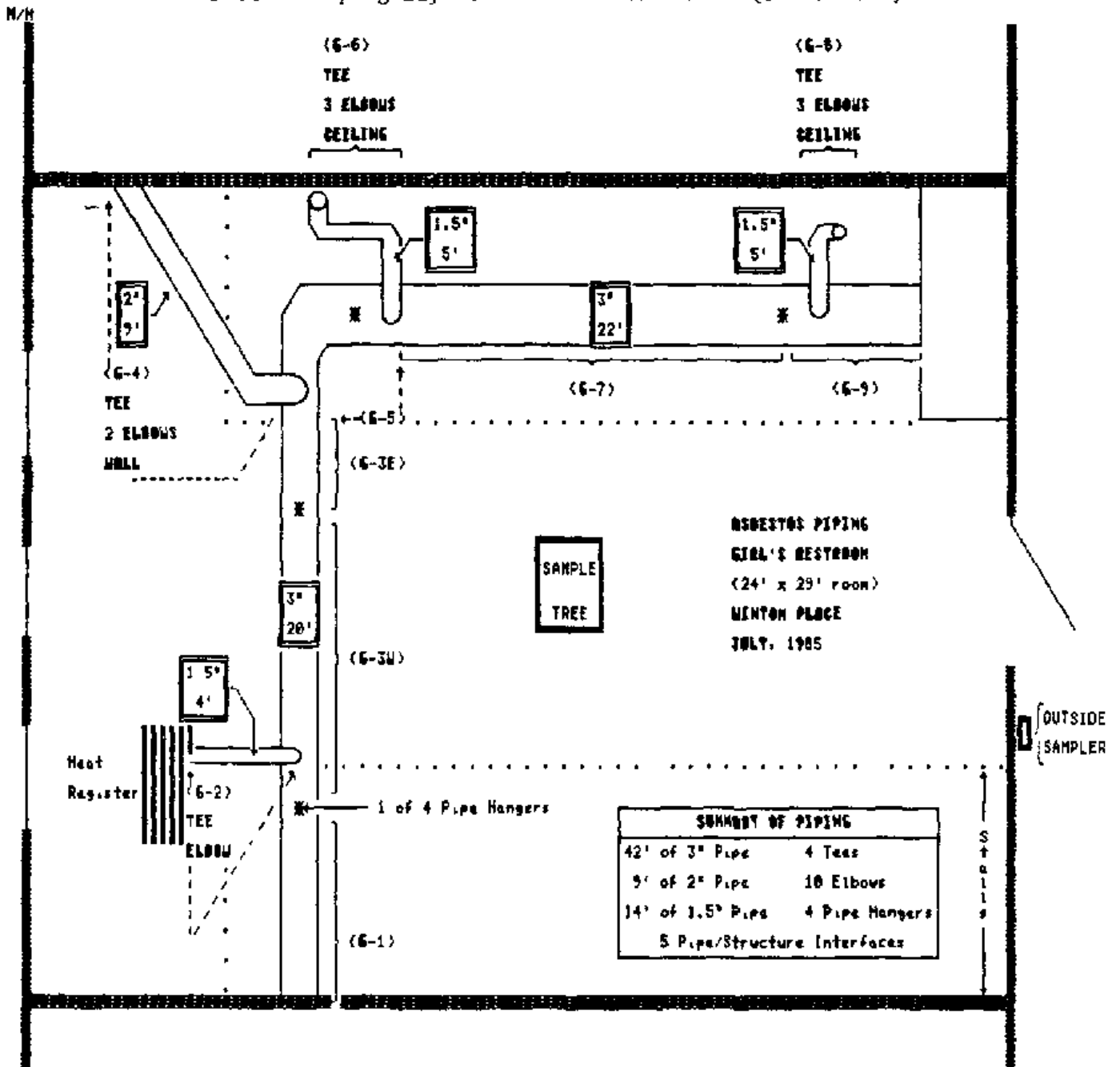


Figure B

Plot of Piping Layout in Boys' Room (Boys Room)

N/M

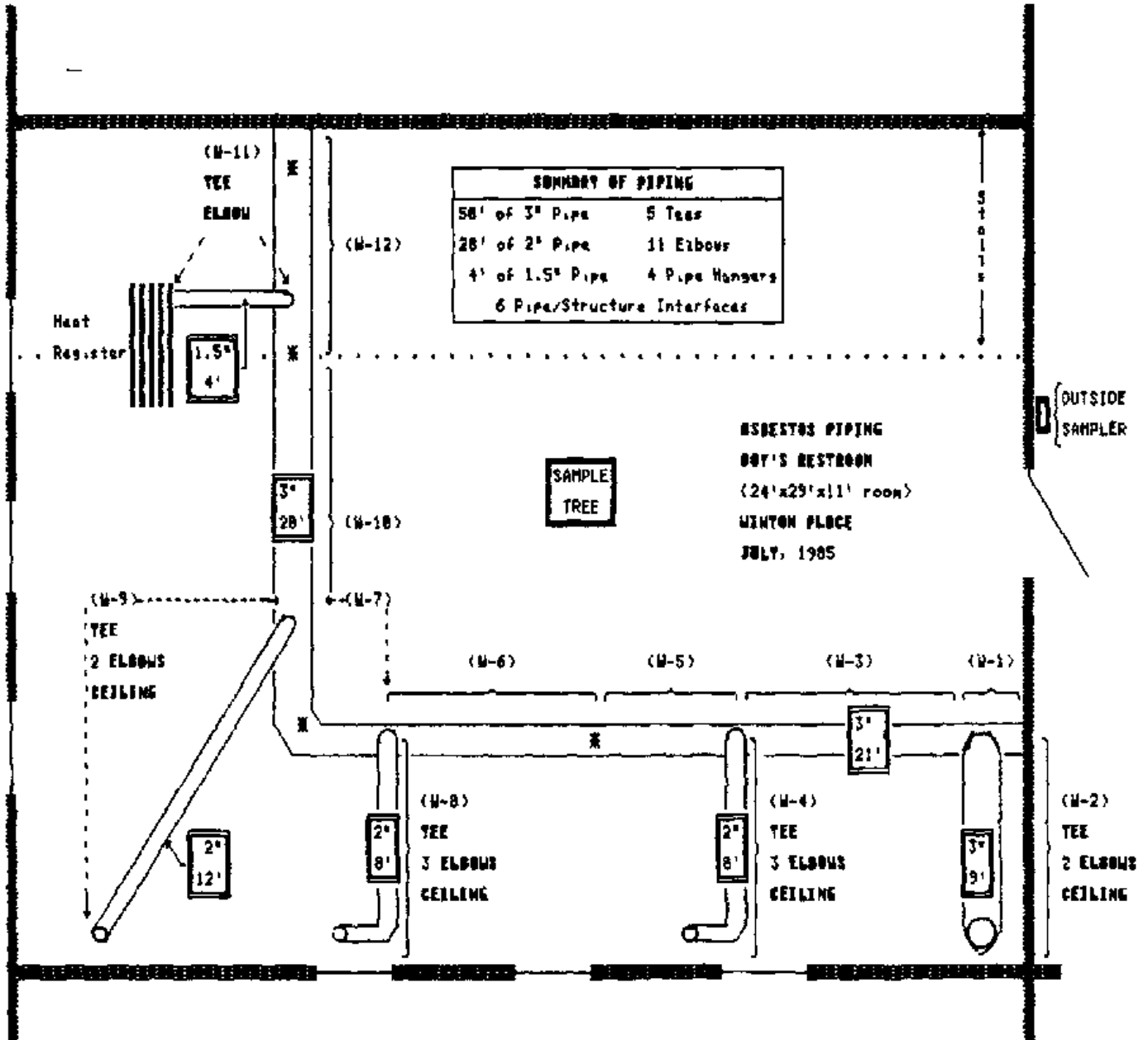
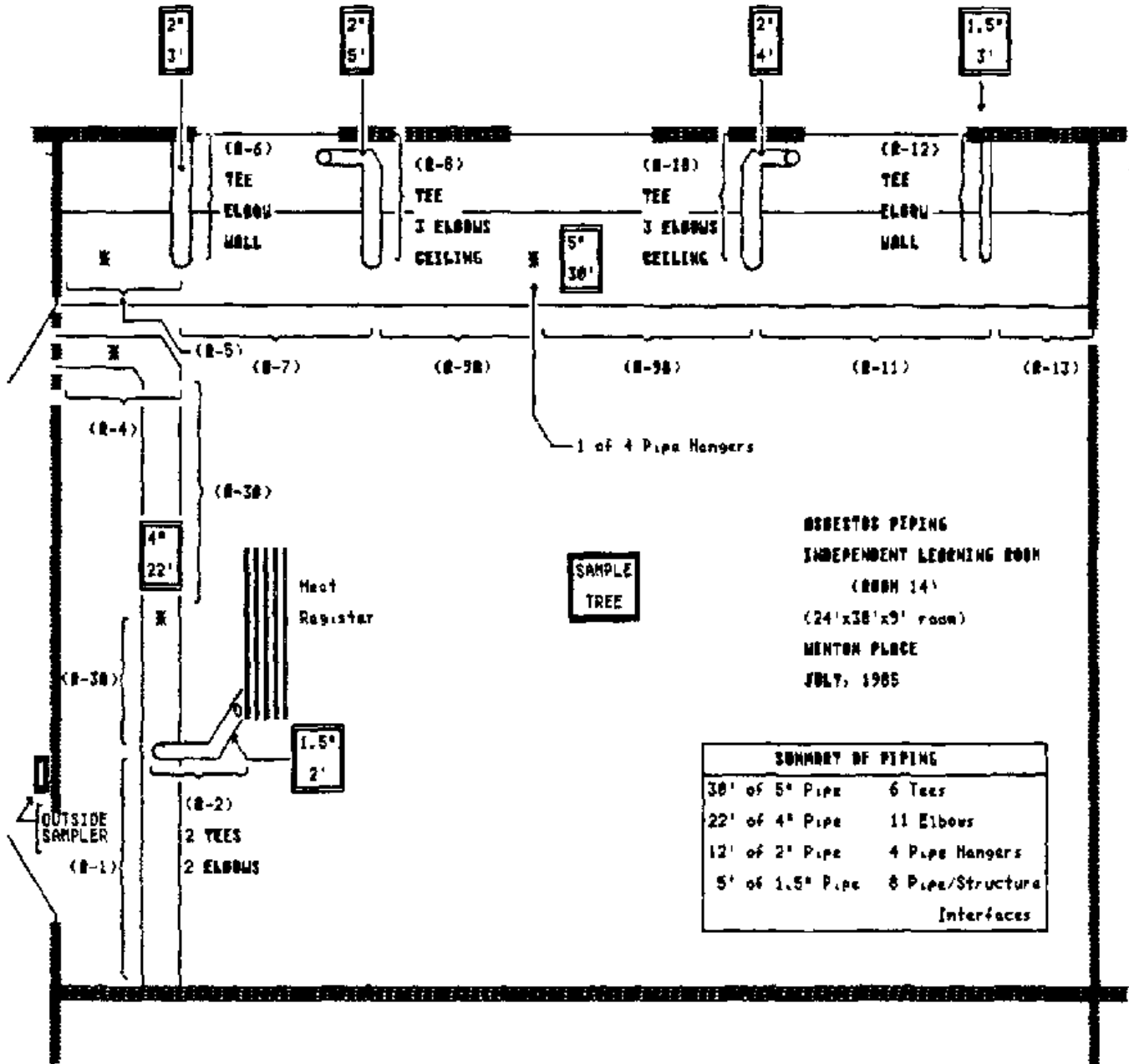


Figure C

Plot of Piping Layout in Independent Learning Room (Room 14)

N/H



PROCESS DESCRIPTION

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 these activities is summarized below to provide an overview of industry practices, however, each job will vary with the specific circumstances. Following this generic description is a review of the removal operations observed at Winton Place Elementary School.

Generic Overview

Preparation--

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

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 Observed in this Survey

Although there are no definite guidelines for glove bag use many of the above practices should also apply to this technique. Observations from the present study are summarized below.

Preparation--

The contract for asbestos removal in Winton Place 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. 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. 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.

Removal--

On the first day, preparation and removal in the girls room was completed and room 14 was prepared for removal. During the second day removal was completed in room 14, on the third day the boys room was prepared and removal completed. The work practices used were developed from removal activities during the previous three weeks, such as

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

The sprayers were fitted with 10' to 15' hoses so that the tanks did not have to be elevated to the working level. This allowed a support worker at floor level to fill the sprayer with amended water and pump up the pressure, and greatly enhanced the ability and inclination of the removal workers to use sufficient wetting for control of fiber emissions.

The poly-envelope and metal bands were removed and the lagging wetted. The lagging jacket was cut longitudinally along the full length of one preformed block and circumferential cuts were made with a wire saw or blade preferably at the block joints. The jacket was removed; the asbestos block was sprayed, then pried apart at the seam and lowered to the bottom of the bag. Amended water was sprayed onto the lagging and the pipe was washed clean. Hard-to-clean places were brushed with a nylon bristle bottle brush. The end sleeve straps were loosened and the bag was slid along the poly covered pipe to the next removal site. When a bag was filled with debris, the interior of the bag was washed down and the bag was 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

Decontamination--

The spilled material was removed from the floor with a HEPA vacuum cleaner throughout the shift. As the work was finished in each area, the floor was wet mopped and the 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

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 μ m 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 [6]. Action to be taken could be an increase in control surveillance, asbestos confirmation by TEM, and actions to reduce asbestos levels, if warranted.

In 1985, the OSHA PEL was 2.0 fibers per cubic centimeter (f/cc), greater than 5 μ m 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.

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.

NIOSH provided an update on the recommended asbestos criteria at the OSHA proposed rule-making hearings for asbestos in June 1984 [7]. 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/m³) 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 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 μ m. The NIOSH 7400 method stipulates that only fibers longer than 5 μ m 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 asbestos fibers. As part of the TEM analytical method used in this study, the dimensions of all fibers counted were recorded. A rough estimation of fiber counts indicates that the difference between the number of fibers having an aspect ratio greater than 5:1 and those having an aspect ratio greater than 3:1 is usually less than 20%. There are, however, several factors other than aspect ratio that enter into the various counting methods, perhaps the most important is that PCM counts include any fiber greater than 5 μm observed, whereas TEM counts include only fibers selected for crystalline asbestiform identification. Therefore, it is not possible to predict A rule fiber counts based on B rule counting results.

Another concern is that minute asbestos fibrils (0.5 μm to 0.02 μm in diameter and less than 1 μm in length) are visible only with electron microscopy. These fibrils constitute a variable, possibly a significant proportion of the total fibers present in the removal environment. Thus PCM, in counting only optically visible particles, may not be a good indicator of the total fibers present. Controversy over the health effect of small fibers (and thus what sizes of fibers should be counted) adds further ambiguity.

Although OSHA regulations do not apply to governmental agencies, the EPA adopted the OSHA standard in 1985 and the revised standard in February 1987 to protect workers in Public Schools where asbestos removal is performed.

Environmental Exposure

The EPA also has established guidelines for clearance of asbestos removal areas for reoccupancy of both private and public schools. These were first published as "recommended practices [8]" 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 [9]. 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 [10] 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. Clearance levels for TEM were to be statistically 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 [11] 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 ACM [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 affected functional space show that the concentration of asbestos for each of five samples is less than or equal to the limit of quantitation for PCM, or 0.01 f/cc of air."

After two years, the proposed EPA clearance rule, if adopted, will require a three-step process for using TEM to determine successful completion of a removal response action (clearance procedure). After visual inspection, the final two steps will involve a sequential evaluation of five samples taken inside the work site, five samples taken outside the work site, two field blanks, and one sealed blank. In the first stage of the analytical sequence, final clearance could be granted if the average concentration of the inside samples is below the "limit of quantitation" for the TEM method.

The "limit of quantitation" is proposed to be set at "4 times the analytical sensitivity" of this method, and the latter is stated to be no greater than 0.005 f/cc. Therefore, the proposed clearance limit for TEM, using a 3000 l sample and a 37-mm filter, is $4 \times 0.005 \text{ f/cc} = 0.02 \text{ f/cc}$. The factor of 4, based on the assumption that the polycarbonate media contamination level is 70-75 fibers/mm², is proposed in order to circumvent the usual laboratory procedure to establish the level of contamination for each media lot by replicate analyses. TEM analyses are very expensive, and would greatly increase the cost of clearance.

In relatively clean public buildings and the surrounding ambient environment, there are proportionally fewer larger airborne fibers due to settling out. Under these conditions, it is not at all reliable to presume that the absence of fibers as 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 detecting all of the asbestos fibers present, however, the analytical methods are not as well standardized nor is the equipment as readily available.

III METHODOLOGY

EVALUATION METHODS

Air Sampling and Analysis

Workplace Sampling--

Personal and area air samples were collected and analyzed by Phase Contrast Microscopy (PCM) in accordance with NIOSH Method 7400^[3] (using 25-mm cassettes and cellulose ester filters). A Magiscan II automated counting system was intended for use as a screening tool and a number of samples were analyzed using this system, however, lack of agreement with the PCM analysis, under low fiber and light particulate loading, restricted its use in this study. A sequence of 2- or 3-hour, interior area and personal samples was collected over a full work shift, using DuPont P-4000 personal sampling pumps. Approximately 400 liters of air were filtered, at 2.5 to 3.5 lpm, for personal samples and area samples. When low concentrations were expected, area samples were collected at flow rates of 2.0 to 3.5 lpm for approximately 8 to 16 hours for a total of approximately 1,500 to 3,000 liters per sample. The area samples were taken in duplicate on two media: 37-mm polycarbonate and 25-mm cellulose ester filters. The 25-mm cassettes with 2-inch cowls were wrapped with metal foil as a precaution to minimize possible effects of static electricity. This sampling array was also used to collect area samples adjacent to but outside the poly baffled entrance to the room.

Pre- and Post-Removal Sampling--

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

The samples were taken in triplicate on three media: 37-mm polycarbonate, 37-mm cellulose ester, and 25-mm cellulose ester filters. The 25-mm cassettes with 2-inch cowls were wrapped with metal foil as a precaution to minimize possible effects of static electricity. Six of the nine samples at each station were collected at a rate of between 3.0 and 3.5 lpm, utilizing individual limiting orifices. The vacuum source was a manifold connected to a Gast 0485 vacuum pump in parallel with a smaller Thomas 106-83F pump. The other three samples (one of each filter type) at each station were collected using DuPont P-4000 pumps at 2.5 to 3.5 lpm for 8 full hours. Sampling filters were hung face down in alternated positions from a ring which was supported approximately 5 feet above the floor. An air sample was collected

on a cellulose ester filter located adjacent to but outside the poly-baffled entrance to the room during the post-removal sampling period. Two side-by-side ambient outdoor samples were collected during the 16-hour period on 25-mm cellulose ester filters.

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

Cellulose ester filters were analyzed using both Magiscan and PCM. All fibers with a 5:1 (or greater) length-to-width ratio were counted using NIOSH Method 7400-B counting rules. Selected cellulose ester samples were analyzed by TEM using the modified Burdett and Rood method [12].

Polycarbonate filters were analyzed by the Yamate Revision to the EPA Provisional TEM Method. [7] 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. Two units were used to observe the effect of process variations, a third unit 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 235 samples were taken over a 5-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) 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. Two cart-mounted, mobile FAMs were 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 controlled 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 Purifying 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 but one of the cellulose ester field blank PCM analyses (16) 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 [13]. 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 known 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, Inc., 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, Inc., 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 mean result 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 10 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 CV 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.

SAMPLING RESULTS

Work Activity

The results of analyses both by Magiscan and PCM are tabulated in Appendix A, Table A-4. 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).

Personal breathing zone time-weighted average and short-term levels, as determined by NIOSH method 7400-B, are shown in Table 1. The TWA values reported are for the actual sampling periods, approximately five hours. These levels are well below the 2,000,000 f/m³ [2.0 f/cc] OSHA standard in effect at the time of this study, and are about an order-of-magnitude below the 100,000 f/m³ [0.1 f/cc] action level of the current standard. Eighteen sequential personal samples were taken, however, one overloaded with particulate matter could not be counted. During removal operations, one sample result was 200,000 f/cc whereas the other 13 were well below 100,000

TABLE 1 - PERSONAL EXPOSURE MEASUREMENTS DURING PREPARATION
AND REMOVAL OF PIPE LAGGING
AT WINTON PLACE SCHOOL

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

<u>WORKER</u>	<u>TYPE*</u>	<u>ACTIVITY</u>	<u>JULY 15</u>	<u>JULY 16</u>	<u>JULY 17</u>
# 1	TWA		0 011	0 015	0 009
	ST	PREPARATION	0 015		
	ST	REMOVAL	0 022	0 016	0 016
	ST	REMOVAL			0 017
# 2	TWA		0 010	0 013	0 005
	ST	PREPARATION	0 006		
	ST	REMOVAL	0 032	0 065	0 034
# 3	TWA		0 004	**	0 008
	ST	PREPARATION	0.002		
	ST	REMOVAL	0 035	0 086	0 017
	ST	REMOVAL		0.20	0 016
# 4	TWA		0 013	***	0 010
	ST	PREPARATION	0 016		
	ST	REMOVAL	0 036		0 044

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

** Filter overloaded with particulates, unable to count

*** Worker not on job this date

As shown by the activity summary for each worker (Table 2), the average level of worker exposure from removal activities was twice that experienced during preparation but, again, well below 0.1 f/cc

In conformity with the reports of the results for the three other schools surveyed in this project, the analyses of area samples by PCM and TEM were to have been compared in Tables 3A (for preparation) and 3B (for removal). However, inconsistencies in the interlaboratory results of the TEM analyses for this survey required a recount of the filters. Because of limited funds, only the pre- and post-removal aggressive samples were reanalyzed by TEM. A more detailed analysis of the PCM and TEM comparisons will be made in the final technical report for the four school project.

PCM results for mean levels near the workers were 6,000 f/m³ both during removal and during preparation. In-room background sample means during removal operations were 12,000 f/m³ and 8,000 f/m³ during preparation. The mean background levels in the halls were 2,000 f/m³ and 1,000 f/m³ respectively, the ambient level outside the building was 1,000 f/m³.

Pre- and Post-Removal Sampling

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. (As noted above, only the aggressive sample TEM analyses were completed for this report.) 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 aggressive sampling by TEM, the means for pre- and post-removal TEM measurements are shown in Table 4. The uncorrected TEM analyses of total asbestos structures indicate a reduction from 270,000 as/m³ for pre-removal to 80,000 as/m³ for post-removal. This Table also shows that the post-removal total asbestos fiber concentration was about equivalent to the total asbestos structure concentration, hence, after cleanup, most of the asbestos present was fibrous.

Comparison of pre- and post-removal PCM and available TEM analytical results, by room location, are shown in Table 5. The PCM levels of the aggressive samples are all equal to or higher than the nonaggressive samples in both the pre- and post-removal samples. As noted above, the post-removal samples 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 nonaggressive 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 aggressive samples for total asbestos structures exceeded the ambient level suggested as "typical" by the EPA^[14] (5,000 f/m³ [0.005 f/cc]), as well as the measured ambient levels of less than 1,000 f/m³.

TABLE 2 PERSONAL SAMPLING RESULTS BY ACTIVITY
AT WINTON PLACE SCHOOL

PCM Analysis f/cc using NIOSH 7400-B Method

WORKER	JULY 15	JULY 16	JULY 17	MEAN	MIN	MAX	ST D*	n*
===== PREPARATION FOR PIPE LAGGING REMOVAL =====								
	Girls Room & Room 14	Girls Room	Boys Room					
1	0.005							
2	0.006							
3	0.002							
4	0.010							
PREP AVERAGE	0.006			0.006	0.002	0.010		4
===== PIPE LAGGING REMOVAL =====								
	Girls Room	Girls Room & Room 14	Boys Room					
1	0.018	0.015	0.002 0.023					
AVG	0.018	0.015	0.012	0.014	0.002	0.023		3
2	0.015	0.013	0.005****					
AVG	0.015	0.013	0.005	0.011	0.005	0.015		3
3	0.005	**	0.004 0.017					
AVG	0.005		0.010	0.009	0.004	0.017		3
4	0.017	***	0.010****	0.014				
AVG	0.017		0.010	0.014				2
REMOVAL AVERAGE	0.013	0.014	0.010	0.012				11
-----	-----	-----	-----	-----	-----	-----	-----	-----
AMBIENT	0.001	0.001	0.001	0.001				

* ST D = Standard Deviation n = number of samples

** Filter overloaded with particulate, unable to count

*** Worker not on job today

**** Only half shift sample, worker on another job first half of day

TABLE 3A - AREA SAMPLING RESULTS
 PREPARATION FOR PIPE LAGGING REMOVAL
 AT WINTON PLACE SCHOOL

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

<u>SAMPLING SITE</u>	<u>JULY 15</u>		<u>MEAN</u>	<u>MIN</u>	<u>MAX</u>	<u>ST D*</u>	<u>n*</u>
	<u>Girls Room</u>						
	<u>PCM</u>	<u>TEM</u>					
	<u>f/cc</u>	<u>as/cc</u>					
<u>NEAR WORKERS</u>							
PCM ANALYSIS	0 006						
	0 006						
AVERAGE	0 006		0.006				2
(TEM ANALYSIS NOT COMPLETED)							
=====							
<u>ROOM (BACKGROUND)</u>							
PCM ANALYSIS	0.003						
	0 013						
AVERAGE	0 008		0 008	0.003	0 013		2
(TEM ANALYSIS NOT COMPLETED)							
=====							
<u>HALL (BACKGROUND)</u>							
PCM ANALYSIS	0 001						
	0 001						
AVERAGE	0 001		0 001				2
(TEM ANALYSIS NOT COMPLETED)							
=====							
<u>OUTDOOR AMBIENT</u>							
PCM ANALYSIS	0 001		0 001				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 WINTON PLACE SCHOOL

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

SAMPLING SITE	JULY 15				JULY 16				JULY 17								
	Girls Room		Girls Room & Rm #14		Boys Room		Boys Room										
	PCM	TEM	PCM	TEM	PCM	TEM	PCM	TEM									
	f/cc	n*	as/cc	n	f/cc	n	as/cc	n	f/cc	n	as/cc	n	MEAN	MIN	MAX	ST D*	n
NEAR WORKERS																	
PCM ANALYSIS	0 007	2	0 013	1**	0 003	2	0 006	2	0 006	0 001	0 013	0 004	7				
AVERAGE	0 007	2	0 013	1	0 004	4			0 006	0 001	0 013	0 004	7				
(TEM ANALYSIS NOT COMPLETED)																	
ROOM (BACKGROUND)																	
PCM ANALYSIS	0 007	2	0 032	2***	0 004	2	0 007	2	0 012	0 002	0 051	0 016	8				
AVERAGE	0 007	2	0 032	2	0 006	4											
(TEM ANALYSIS NOT COMPLETED)																	
AREA AVERAGE	0 007	4	0 025	3	0 005	8											
HALL (BACKGROUND)																	
PCM ANALYSIS	0 002	2	0 002	2	0 001	2	0 004	2	0 002	0 001	0 004	0 001	8				
AVERAGE	0 002	2	0 002	2	0 002	4											
(TEM ANALYSIS NOT COMPLETED)																	
OUTDOOR AMBIENT																	
PCM ANALYSIS	0 001	2	0 001	2	0 001	2	0 001	2	0 001	0 001	0 001	0 001	6				

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

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

*** One of the paired samples was overloaded with particulates; unable to count However, a 20 min short term area sample which measured 0 051 f/cc was included in this average .

TABLE 4

MEAN ASBESTOS FIBER AND ASBESTOS STRUCTURE CONCENTRATIONS
AT WINTON PLACE SCHOOL

Analysis by TEM using EPA Provisional Method

<u>Sample</u>	<u>Structures/m³</u>	<u>Fibers/m³</u>
Pre Removal		
Nonaggressive	N/C	N/C
Aggressive	270,000	200,000
Post Removal		
Nonaggressive	N/C	N/C
Aggressive	80,000	62,000

N/C - Analysis not completed

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

LOCATION	JULY 12 PRE REMOVAL SAMPLES				JULY 18 POST REMOVAL SAMPLES			
	NIOSH PCM AND TEM	EPA TEM ANALYSIS**	EPA PCM AND TEM	NIOSH PCM AND TEM	EPA TEM ANALYSIS**	EPA PCM AND TEM	NIOSH PCM AND TEM	EPA TEM ANALYSIS**
	f/cc	n*	as/cc	n	f/cc	n	as/cc	n
	Total >5 µm long				Total >5 µm long			

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

NONAGGRESSIVE SAMPLING METHOD

ROOM #14	0.002	6	N/C*	N/C	0.001	6	N/C	N/C	3
GIRLS ROOM	0.001	6	N/C	N/C	0.001	6	N/C	N/C	3
ROOM #14 HALL	0.001	1	N/C	N/C	0.003	1	N/C	N/C	3
GIRLS ROOM HALL	0.001	1	N/C	N/C	0.001	1	N/C	N/C	3

AGGRESSIVE SAMPLING METHOD

ROOM #14	0.010	6	N/C	I/A*	0.003	6	N/C	0.10	I/A	3
GIRLS ROOM	0.004	6	N/C	I/A	0.002	6	N/C	0.07	I/A	3
ROOM #14 HALL	0.026	1	N/C		0.000	1	N/C			
GIRLS ROOM HALL	0.001	1	N/C		0.001	1	N/C			
OUTDOOR AMBIENT	0.001	2	0.001	2***	0.001	2	0.001	2***		

* f/cc = total fibers/cc as/cc = asbestos structures/cc n = number of samples
N/C - Analysis not completed for these samples I/A - Data in analysis; not yet available

** These samples are approximately 1,500 liter volume The TEM lower limit of detection (LOD) is 0.010 as/cc Analyses reported below the LOD are entered at half of the LOD (0.005 as/cc)

*** These ambient samples were collected on 25mm cellulose ester filters and analyzed by NIOSH method 7402 March 1987 revision The lower limit of detection for a 3000 l sample is about 0.002 as/cc None detected values are reported here at half the LOD

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/m³ [0.01 f/cc])". Post-removal nonaggressive PCM samples were all below the 10,000 total f/m³ level. Aggressive sampling PCM results indicate a decreased post-removal level for both Room 14 and the girls room, both were well below the 10,000 f/m³ level after removal operations were completed.

OTHER OBSERVATIONS

Engineering Controls

Safe-T-Strip[®] and Disposalene[®] glove bags were used during this survey; six were used in the girls room during the first day, six were used in room 14 during the second day, and on the third day eight were used in the boys room.

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.

TABLE 6

EVALUATION OF WORK PRACTICES
AT WINTON PLACE ELEMENTARY SCHOOL

Date	7/15/85	7/16/85	7/17/85
Time	AM / PM	AM / PM	AM / PM
Site	<u>Girls Room</u>	<u>Room 14</u>	<u>Boys Room</u>
<u>TASK</u>	<u>WORK PRACTICE RATING#</u>		
Prepare Pipe	A / -	- / -	- / -
Install Bag	G / -	- / -	- / -
Wet Pipe Lagging	A / A	A / -	G / G
Remove Lagging (use of bag)	G / A	A / -	A / A
Move Bag	G / G	A / -	G / A
Remove Bag	G / G	G / -	A / A
Clean Pipe	G / G	A / -	G / G
Decontaminate Room	- / G	A / -	- / G
Number of Bags Removed	(6)	(6)	(8)

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

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 the work specifications.

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.

VI CONCLUSIONS AND RECOMMENDATIONS

SITE SPECIFIC

Asbestos exposure, as evidenced by personal breathing-zone air samples analyzed using NIOSH method 7400-B, showed increases depending upon the work activity. Asbestos fiber concentrations rose from a pre-removal level of 0.001 f/cc to 0.006 f/cc during the preparation of the pipe lagging for removal and to 0.013 f/cc during the actual removal in glove bags. There is no method to translate these results to what would be achieved had the A rules (used for OSHA compliance) been used. However, time-weighted-average levels this low would indicate, that as used in the present study, glove bags were effective in controlling the asbestos emissions to below the present OSHA PEL, but did not provide complete containment of the asbestos being removed.

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 aggressive sampling concentrations analyzed by PCM are generally greater than means obtained by nonaggressive sampling for both pre- and post-removal operations. This trend was also observed in results using TEM analyses in prior studies, however, due to the analytical problems previously described, only aggressive TEM data is discussed here.

Results of aggressive sampling for total asbestos structures exceeded the ambient level of 5,000 f/m³ (0.005 f/cc) suggested as "typical" by the EPA[14], as well as the measured ambient levels of less than 1,000 f/m³.

All post-removal samples taken by both the aggressive and nonaggressive methods analyzed by PCM indicate contamination levels are below the 10,000 fibers/m³ 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.)

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 pass with aggressive sampling analyzed by PCM, and would likely fail with TEM analyses of the aggressive sampling method.

When using TEM analysis, it is highly advisable to implement the EPA recommendation to evaluate the ambient asbestos fiber concentration outside the work area as a reference for clearance requirements[10]. This will provide a more accurate basis for comparison because it reflects the local conditions as determined by replicate analytical methods.

Key work practices observed in this study which are highly recommended include

Pre-mist all lagging with amended water.

Wrap all pipe with poly prior to the start of removal work

Use a bag properly designed for the task (i.e., specially designed bags for working around large valves or fittings)

Start with a clean empty bag at pipe interfaces with walls and ceiling to optimize bag flexibility and minimize contamination potential

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

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

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

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

Based on this study, there are several options with potential for improving glove bag containment: improved work practices, 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.

GENERIC OR NON-SITE SPECIFIC

Glove bags are a useful engineering control to reduce worker exposure during asbestos removal operations. Considering the work practices observed in this study workers should (and did) use respiratory protection. It is prudent to use respiratory protection in any glove bag work because leakage of the glove bag (which is not easily determined by real-time monitoring) or an accidental rupture of the bag or the seals will allow the workers to be exposed to a known carcinogen. OSHA permits the use of high efficiency, air purifying respirators for work with asbestos, however, NIOSH recommends that type C positive pressure, supplied air respiratory protection be used when carcinogens are present.

This is the last of four schools surveyed, and the removal crew gained experience with each survey. The limited expertise of the workers observed in the three previous surveys 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 these surveys. This implies that secondary containment (i.e., negative air barrier) should be used as an adjunct when such glove bag work is performed. As demonstrated in this survey, experienced personnel with proper training appear to be able to obtain better containment.

A number of work practices have been proposed for use with glove bags that were not observed in this study. The following should be considered 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 to be 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 integrity of the glove bag installation technique periodically by means of a smoke test (the frequency or number of bags to be tested will depend on results). Fill the bag with smoke using a smoke tube inside the bag, then apply gentle pressure to the bag to observe that the seals are secure. The pressure applied should be consistent with the forces exerted on the bag during the removal of the pipe lagging.

Use great care when metal bands, wires, or aluminum jacketing is encountered to avoid lacerations to the hands or to the glove bag, sharp edges should be folded in and gently placed in the bottom of the bag.

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

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

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

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

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

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APPENDIX A

TABULATION OF DATA OBTAINED USING
PHASE CONTRAST MICROSCOPY (PCM)

TABLE A-1

UPPER AND LOWER 95% CONFIDENCE LIMITS FOR A SINGLE PCM ANALYSIS
 USING NIOSH 7400-B METHOD ON A 25mm 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/ 25MM dia Filter =====	Factor for		Mean and Range of Fiber Concentrations within 95% Confidence Limits for Sample Volumes		
		Lower Limit =====	Upper Limit =====	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 37mm 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/ 37MM dia Filter =====	Factor for		Mean and Range of Fiber Concentrations within 95% Confidence Limits for Sample Volumes		
		Lower Limit =====	Upper Limit =====	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 WINTON PLACE PCM DATA

<u>LOC</u>	(School and room location of sampled activity)
W1xx	Winton Place Elementary School
14	Room #14 Spec Ed
GR	Girls Rest Room
BR	Boys Rest Room
ce	Combined Exposure Areas Rm 14 and GR
PO	Principle's Office
<u>CLASSIFICATION</u>	(Sample location, type, activity, and ID)
<u>Location</u>	
FB	Field Blank
IA	Interior Area (Background in the work room)
OA	Outside Area (in the hall)
AM	Ambient (Outside the building)
BZ	Personal Breathing Zone
CT	Mobile Sampling Cart (proximate to work activity)
<u>Activity</u>	
PRE	Pre-removal activity - Full term sample
PST	Post-removal activity - Full term sample
REM	Removal work - Full term sequential sample
COV	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
FTM	Ambient Sample - Full Term Monitoring, 8 to 16 hours
<u>ID</u>	
AGGR	Aggressive sampling mode
NAGR	Nonaggressive sampling mode
WK#x	Worker #x BZ sample
XX/XX	Actual date of blank source
<u>SAMPLE No.</u>	Sample media Identification code and number
AAxxx	25mm Cellulose Ester Filter Sample Number xxx (With a foil wrapped 2 inch cowl)
Mxxx	37mm Cellulose Ester Filter Sample Number xxx
Nxxx	37mm 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, results 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
 WINTON PLACE ELEMENTARY SCHOOL
 CINCINNATI, OHIO
 July 12 July 15-18, 1985

NOTE: For samples reported less than detectable,
 one half of the limit of detection is used
 as follows: LAB 25 mm Filter 37 mm Filter
UBTL 750 1750
NIDSH 1347 2992

LOC.	SAMPLE CLASS	SAMPLE		PERIOD		TIME (min)	RATE (µm)	VOL. (µ)	MAGISCAN II		UBTL PCM 7400-B		NIDSH PCM 7400-B	
		Nu.	Date	Start	Stop				Fibers./f.c.	f.c.	Fibers./f.c.	f.c.		
W114	IA-PRE-AGGR	AA393	7/12	1800	0201	481	2.50	1202.5	43505	0.036	12000	0.010	1347	0.001
W114	IA-PRE-AGGR	AA401	7/12	1800	0201	481	2.75	1322.8	57750	0.044	10000	0.008	1347	0.001
W114	IA-PRE-AGGR	AA448	7/12	1800	0201	481	2.50	1202.5	46970	0.039	10000	0.008	1347	0.001
W114	IA-PRE-AGGR	M864	7/12	1800	0201	481	2.75	1322.8	53550	0.041	20000	0.014	24966	0.019
W114	IA-PRE-AGGR	M871	7/12	1800	0201	481	3.00	1443.0	47965	0.033	20000	0.014	24966	0.019
W114	IA-PRE-AGGR	M872	7/12	1800	0201	481	2.75	1322.8	95760	0.072	2000	0.001	1347	0.001
W114	DA-PRE-AGGR	AA427	7/12	1800	0201	481	3.00	1443.0	17671	0.012	2000	0.001	1347	0.001
W114	IA-PRE-NAGR	AA405	7/12	0906	1700	474	2.50	1232.4	31933	0.026	2000	0.002	1347	0.001
W114	IA-PRE-NAGR	AA406	7/12	0906	1700	474	2.70	1279.8	33841	0.026	2000	0.002	1347	0.001
W114	IA-PRE-NAGR	AA444	7/12	0906	1700	474	3.15	1493.1	32147	0.022	3500	0.002	4158	0.003
W114	IA-PRE-NAGR	M857	7/12	0906	1700	474	3.00	1422.0	49077	0.035	3500	0.002	4158	0.003
W114	IA-PRE-NAGR	M855	7/12	0906	1700	474	3.15	1493.1	16208	0.011	1750	0.001	1347	0.001
W114	IA-PRE-NAGR	M859	7/12	0906	1700	474	2.95	1398.3	47065	0.034	1750	0.001	1347	0.001
W114	DA-PRE-NAGR	AA397	7/12	0905	1700	475	3.05	1448.8	27989	0.019	750	0.001	1347	0.001
W1GR	IA-PRE-AGGR	AA394	7/12	1752	0152	480	2.50	1190.0	43890	0.037	6000	0.005	1347	0.001
W1GR	IA-PRE-AGGR	AA399	7/12	1752	0152	480	3.00	1428.0	50435	0.035	4000	0.003	1347	0.001
W1GR	IA-PRE-AGGR	AA407	7/12	1752	0152	480	2.75	1309.0	40040	0.031	4000	0.003	1347	0.001
W1GR	IA-PRE-AGGR	M867	7/12	1752	0152	480	3.00	1428.0	55062	0.039	4000	0.003	1347	0.001
W1GR	IA-PRE-AGGR	M870	7/12	1752	0152	480	2.75	1309.0	53950	0.041	4000	0.003	1347	0.001
W1GR	IA-PRE-AGGR	M873	7/12	1752	0152	480	3.00	1428.0	39244	0.027	4000	0.003	1347	0.001
W1GR	DA-PRE-AGGR	AA404	7/12	1752	0152	480	3.00	1428.0	15939	0.011	4000	0.003	1347	0.001
W1GR	IA-PRE-NAGR	AA402	7/12	0904	1700	476	3.00	1428.0	21098	0.015	750	0.001	1347	0.001
W1GR	IA-PRE-NAGR	AA409	7/12	0904	1700	476	2.70	1285.2	16208	0.013	750	0.001	1347	0.001
W1GR	IA-PRE-NAGR	AA426	7/12	0904	1700	476	2.60	1237.6	23793	0.019	750	0.001	1347	0.001
W1GR	IA-PRE-NAGR	M856	7/12	0904	1700	476	2.95	1404.2	36808	0.026	750	0.001	1347	0.001
W1GR	IA-PRE-NAGR	M874	7/12	0904	1700	476	2.90	1380.4	38133	0.028	1750	0.001	1347	0.001
W1GR	IA-PRE-NAGR	M875	7/12	0904	1700	476	3.00	1428.0	47367	0.033	1750	0.001	1347	0.001
W1GR	DA-PRE-NAGR	AA396	7/12	0904	1700	476	3.00	1428.0	64295	0.045	750	0.001	1347	0.001
W1FB	FB-PRE-7/12	M863	7/12						53266		1750			
W1FB	FB-PRE-7/12	M866	7/12						9832		1750			
W1FB	FB-PRE-7/12	M962	7/12						47965		1750			
W1FB	FB-PRE-7/12	M963	7/12						27018		1750			
W1FB	FB-PRE-7/12	M964	7/12						7609		1750			
W1FB	FB-PRE-7/12	M965	7/12						7609		1750			
W1PO	AM-F1M	AA400	7/12	0915	0230	1035	2.90	3001.5	43120	0.014	750	0.000	3889	0.001
W1PO	AM-F1M	AA456	7/12	0915	0230	1035	3.00	3105.0	38263	0.012	750	0.000	3889	0.001

TABLE A-4 (Continued - page 2)

LDC.	SAMPLE CLASS	SAMPLE		PERIOD	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II		LBT L PCM 7400-B		WIO9 PCM 7400-B	
		No.	Date					Start	Stop	Fibers	f/cf	Fibers	f/cf
W114	BZ-COV-WK#1	AA471	7/15	0842	0502	20	2.50			750	0.015		
W114	BZ-COV-WK#2	AA503	7/15	0822	0837	15	3.70			750	0.014		
W1GR	BZ-COV-WK#4	AA500	7/15	0938	0953	15	3.20			750	0.016		
W1GR	BZ-REM-WK#1	AA465	7/15	1045	1245	120	2.75			6000	0.018		
W1GR	BZ-REM-WK#2	AA464	7/15	1045	1252	127	3.20			6000	0.015		
W1GR	BZ-REM-WK#3	AA494	7/15	1043	1245	122	3.00			2000	0.005		
W1GR	BZ-REM-WK#4	AA466	7/15	1044	1245	121	2.90			6000	0.017		
W1GR	BZ-RMS-WK#1	AA501	7/15	1326	1341	15	2.30			750	0.022		
W1GR	BZ-RMS-WK#2	AA477	7/15	1306	1321	15	3.15			1500	0.032		
W1GR	BZ-RMS-WK#3	AA470	7/15	1108	1123	15	3.10			2000	0.043		
W1GR	BZ-RMS-WK#3	AA511	7/15	1345	1355	10	3.20			750	0.023		
W1GR	BZ-RMS-WK#4	AA461	7/15	1357	1410	13	3.20			1500	0.036		
W1GR	CT-COV	AA473	7/15	0755	1045	170	3.10			3000	0.006		
W1GR	CT-COV	AA510	7/15	0755	1045	170	3.10			3000	0.006		
W1GR	CT-REM	AA474	7/15	1045	1243	118	2.10			3000	0.008		
W1GR	CT-REM	AA490	7/15	1045	1243	118	3.00			2000	0.006		
W1GR	IA-COV	AA495	7/15	0755	1045	170	2.20			7000	0.013		
W1GR	IA-REM	AA497	7/15	1045	1241	111	3.30			1500	0.003		
W1GR	IA-REM	AA498	7/15	1045	1241	116	3.20			2000	0.005		
W1GR	OA-REM	AA47C	7/15	1048	1243	115	3.30			3000	0.008		
W1GR	OA-REM	AA507	7/15	1048	1243	115	3.30			750	0.002		
										750	0.002		
W1ce	BZ-COV-WK#1	AA506	7/15	0810	1045	155	2.80			2000	0.005		
W1ce	BZ-COV-WK#2	AA514	7/15	0811	1045	154	2.20			3000	0.006		
W1ce	BZ-COV-WK#3	AA468	7/15	0811	1030	139	2.80			750	0.002		
W1ce	BZ-COV-WK#4	AA472	7/15	0811	1044	153	3.20			5000	0.010		
W1ce	OA-COV	AA504	7/15	0755	1045	170	3.20			750	0.001		
W1ce	OA-COV	AA509	7/15	0755	1045	170	3.20			750	0.001		
W1FB	FB-COV-7/18	AA525	7/15							750			
W1FB	FB-REM-7/18	AA545	7/15							750			
W1PO	AM-FTM	AA467	7/15	0816	1420	364	3.00			750	0.001		
W1PO	AM-FTM	AA469	7/15	0816	1420	364	2.90			750	0.001		

TABLE A-4 (Continued - page 3)

LDC#	SAMPLE CLASS	SAMPLE		PERIOD	TIME	RATE	VOL	MAGISCAN J1		UBILPCM 7400 B		NIDCMPCM 7400 B	
		No.	Date					Start	Stop	(1)	Fibers	f/ct	Fibers
WI14	BZ-REM-WK#1	AA411	7/16	0750	1130	214	3.20	684.8		10000	0.015		
WI14	BZ-REM-WK#2	AA480	7/16	0750	1130	214	3.15	674.1		9000	0.013		
WI14	BZ-REM-WK#3	AA491	7/16	0750	1130	214	3.00	642.0					
WI14	BZ-RMS-WK#1	AA485	7/16	0950	1014	15	3.20	48.0		750	0.010		
WI14	BZ-RMS-WK#2	AA483	7/16	0824	0839	15	3.10	46.5		3000	0.065		
WI14	BZ-RMS-WK#3	AA484	7/16	0803	0818	15	3.00	45.0		9000	0.200		
WI14	BZ-RMS-WK#3	AA486	7/16	0941	0956	15	3.10	46.5		4000	0.086		
WI14	CT-REM	AA480	7/16	0745	1130	225	3.00	675.0		9000	0.013		
WI14	CT-REM	AA505	7/16	0745	1130	225	3.00	675.0		4000	0.051		
WI14	IA-REM	AA475	7/16	0750	0822	26	3.00	78.0					
WI14	IA-REM	AA487	7/16	0745	1130	225	3.20	720.0		9000	0.013		
WI14	IA-REM	AA488	7/16	0745	1130	225	3.20	720.0		2000	0.003		
WI14	OA-REM	AA462	7/16	0743	1130	227	3.20	726.4		750	0.001		
WI14	OA-REM	AA463	7/16	0743	1130	227	3.40	771.8					
WIFB	FB-REM-7/18	AA554	7/16							750			
WIFB	FB-REM-7/18	AA555	7/16							750			
WIPO	AM-FTM	AA492	7/16	0737	1325	348	2.80	974.4		750	0.001		
WIPO	AM-FTM	AA499	7/16	0737	1325	348	2.90	1009.2		750	0.001		

TABLE A-4 (Continued - page 4)

LOC.	SAMPLE CLASS	SAMPLE		PERIOD	TIME (min)	RATE (lb/min)	VOL. (L)	MAGISCAN II		MIOGIPGM 7400 B		MIOGIPGM 7400 D	
		Ng	Date					Start	Stop	Figure	f/sec	Figure	f/sec
WIBR	BZ-REM-WK#1	AA502	7/17	0924	129	2.95	380.6			750	0.002		
WIBR	BZ-REM-WK#1	AA536	7/17	1243	60	2.90	174.0			4000	0.023		
WIBR	BZ-REM-WK#2	AA515	7/17	1040	181	3.15	570.2			3000	0.005		
WIBR	BZ-REM-WK#3	AA482	7/17	0922	131	3.00	393.0			1500	0.004		
WIBR	BZ-REM-WK#3	AA544	7/17	1243	57	3.10	176.7			3000	0.017		
WIBR	BZ-REM-WK#4	AA496	7/17	1230	65	3.10	201.5			2000	0.010		
WIBR	BZ-RMG-WK#1	AA528	7/17	1313	15	3.00	45.0			750	0.017		
WIBR	BZ-RMG-WK#1	AA535	7/17	0936	15	3.05	45.8			750	0.016		
WIBR	BZ-RMG-WK#2	AA543	7/17	1332	8	2.75	22.0			750	0.034		
WIBR	BZ-RMG-WK#3	AA527	7/17	1100	15	3.00	45.0			750	0.017		
WIBR	BZ-RMG-WK#3	AA532	7/17	0956	15	3.20	48.0			750	0.016		
WIBR	BZ-RMG-WK#4	AA542	7/17	1257	15	3.05	45.8			2000	0.044		
WIBR	CT-REM	AA478	7/17	0730	244	3.10	756.4			4000	0.005		
WIBR	CT-REM	AA481	7/17	0730	244	3.00	732.0			750	0.001		
WIBR	CT-REM	AA521	7/17	1240	61	3.20	195.2			750	0.004		
WIBR	CT-REM	AA537	7/17	1240	61	3.30	201.3			1500	0.007		
WIBR	IA-REM	AA512	7/17	0730	244	3.15	768.6			5000	0.007		
WIBR	IA-REM	AA516	7/17	0730	244	3.10	756.4			1500	0.002		
WIBR	IA-REM	AA517	7/17	0730	61	3.10	189.1			2000	0.011		
WIBR	IA-REM	AA519	7/17	1240	61	3.40	207.4			750	0.004		
WIBR	DA-REM	AA493	7/17	0730	244	3.40	823.6			750	0.001		
WIBR	DA-REM	AA513	7/17	0730	244	3.30	805.2			750	0.001		
WIBR	DA-REM	AA526	7/17	1240	61	3.40	207.4			750	0.004		
WIBR	DA-REM	AA534	7/17	1240	61	3.30	201.3			750	0.004		
WIFB	FB-REM-7/18	AA558	7/17							750			
WIFB	FB-REM-7/18	AA562	7/17							750			
WIPO	AM-FTM	AA520	7/17	0745	386	3.00	1158.0			750	0.001		
WIPO	AM-FTM	AA540	7/17	0745	386	2.90	1119.4			750	0.001		

TABLE A-4 (Continued - page 5)

LOG	SAMPLE CLASS	SAMPLE		PERIOD	TIME (min)	RATE (L/min)	VOL. (L)	MAGISCAN II		WESTPOM 7400-D		NICHROM 7400-D	
		No.	Date					Diata Stop	Labels	f/SS	Labels	f/SS	Labels
WI14	IA-PST-AGGR	AA538	7/18	1638	482	3.50	1687.0	85085	0.050	7000	0.004		
WI14	IA-PST-AGGR	AA552	7/18	1638	482	3.25	1566.5	94710	0.060	5000	0.003		
WI14	IA-PST-AGGR	AA553	7/18	1638	482	3.25	1566.5	51590	0.033	3000	0.002	10395	0.007
WI14	IA-PST-AGGR	M958	7/18	1638	482	3.50	1687.0	41040	0.024	9000	0.005		
WI14	IA-PST-AGGR	M968	7/18	1638	482	3.00	1446.0	73102	0.051	1750	0.001	2992	0.002
WI14	IA-PST-AGGR	M969	7/18	1638	482	3.50	1687.0	129105	0.077	7000	0.004		
WI14	DA-PST-AGGR	AA557	7/18	1645	475	3.25	1543.8	54285	0.035	750	0.000		
WI14	IA-PST-NAGR	AA549	7/18	0727	483	3.20	1545.6	54285	0.075	1500	0.001	7315	0.005
WI14	IA-PST-NAGR	AA550	7/18	0727	483	3.10	1497.3	43120	0.023	750	0.001		
WI14	IA-PST-NAGR	AA560	7/18	0727	483	3.20	1545.6	31185	0.020	2000	0.001		
WI14	IA-PST-NAGR	M957	7/18	0727	483	3.15	1521.5	54720	0.036	1750	0.001	2992	0.002
WI14	IA-PST-NAGR	M959	7/18	0727	483	3.50	1690.5	50445	0.030	3500	0.002		
WI14	IA-PST-NAGR	M973	7/18	0727	483	3.50	1690.5	69393	0.041	3500	0.002	2992	0.002
WI14	DA-PST-NAGR	AA548	7/18	0727	483	3.05	1473.2	45045	0.031	4000	0.003	7893	0.005
WIGR	IA-PST-AGGR	AA523	7/18	1625	490	3.50	1715.0	97405	0.057	3000	0.002	1347	0.001
WIGR	IA-PST-AGGR	AA551	7/18	1625	490	3.00	1470.0	165550	0.113	4000	0.003		
WIGR	IA-PST-AGGR	AA566	7/18	1625	490	3.25	1592.5	60060	0.038	2000	0.001		
WIGR	IA-PST-AGGR	M961	7/18	1625	490	3.50	1715.0	29925	0.017	3500	0.002		
WIGR	IA-PST-AGGR	M966	7/18	1625	490	3.00	1470.0	34200	0.023	5000	0.003		
WIGR	IA-PST-AGGR	M974	7/18	1625	490	3.50	1715.0	50530	0.029	1750	0.001		
WIGR	DA-PST-AGGR	AA556	7/18	1625	490	3.00	1470.0	99330	0.068	2000	0.001	6160	0.004
WIGR	IA-PST-NAGR	AA550	7/18	0726	484	3.25	1573.0	8701	0.006	750	0.000	8701	0.005
WIGR	IA-PST-NAGR	AA563	7/18	0726	484	3.15	1524.6	48095	0.032	750	0.000		
WIGR	IA-PST-NAGR	AA565	7/18	0728	482	2.90	1397.8	77385	0.055	750	0.001		
WIGR	IA-PST-NAGR	M952	7/18	0728	482	3.00	1446.0	29070	0.020	1750	0.001	11115	0.008
WIGR	IA-PST-NAGR	M967	7/18	0726	484	3.20	1548.8	29925	0.019	1750	0.001		
WIGR	IA-PST-NAGR	M970	7/18	0726	484	3.40	1645.6	73102	0.044	1750	0.001	2992	0.002
WIGR	DA-PST-NAGR	AA564	7/18	0728	482	3.10	1494.2	78155	0.052	750	0.001		
WIFB	FB-PST-7/18	AA520	7/18					16340		750			
WIFB	FB-PST-7/18	AA524	7/18					5813		1750			
WIFB	FB-PST-7/18	M971	7/18					3249		1750			
WIFB	FB-PST-7/18	M972	7/18					4275					
WIPO	AM-FTM	AA547	7/18	0729	1026	3.00	3078.0	108185	0.035	750	0.000		
WIPO	AM-FTM	AA561	7/18	0729	1026	2.90	2375.4	45045	0.015	2000	0.001		

APPENDIX B

TABULATION OF DATA OBTAINED USING
TRANSMISSION ELECTRON MICROSCOPY (TEM)

Appendix B

Winton Place Elementary School

Pre- and Post-Removal Sampling Analysis by TEM (Recounted)

Concentrations per Cubic Centimeter

Sample Number	STRUCTURES			ASBESTOS			FIBERS					
	Total	Nonasbestos	Asbestos	Chrysotile	Amphibole	Matrix	Clusters	Bundles	Total	Asbestos	Chrysotile	Amphibole
*N-801R	0.386	0.149	0.237	0.193	0.044	0.044	-	0.018	0.325	0.176	0.141	0.035
*N-802R	0.363	0.237	0.106	0.083	0.023	0.015	-	0.008	0.302	0.083	0.060	0.023
*N-806D	0.817	0.246	0.571	0.518	0.053	0.132	-	0.079	0.562	0.360	0.307	0.053
+N-807D	1.331	1.102	0.228	0.108	0.121	-	-	0.027	1.277	0.202	0.081	0.121
+N-808D	0.444	0.052	0.392	0.318	0.074	-	-	0.059	0.377	0.333	0.259	0.074
+N-809D	1.645	1.548	0.097	0.081	0.016	-	-	0.032	1.435	0.065	0.048	0.016
\bar{x}	0.831	0.509	0.272	0.217	0.055	-	-	0.037	0.711	0.203	0.149	0.054

PRE-REMOVAL

Nonaggressive

TEM RECOUNT NOT COMPLETED

Aggressive

POST-REMOVAL

Nonaggressive

TEM RECOUNT NOT COMPLETED

Aggressive

*N-917R	0.150	0.069	0.081	0.069	0.013	0.025	-	0.006	0.119	0.050	0.038	0.013
*N-937D	2.107	1.940	0.167	0.167	-	0.021	-	0.021	1.710	0.125	0.125	-
*N-940D	1.123	1.101	0.022	0.011	0.011	-	-	-	0.887	0.022	0.011	0.011
+N-944R	0.201	0.108	0.093	0.036	0.057	0.014	-	0.007	0.172	0.072	0.014	0.057
+N-947R	0.239	0.206	0.033	0.020	0.011	0.007	-	-	0.206	0.027	0.013	0.013
+N-949R	0.398	0.312	0.086	0.060	0.027	-	-	0.013	0.332	0.073	0.046	0.027
\bar{x}	0.703	0.622	0.080	0.061	-	-	-	-	0.571	0.062	0.041	-

+ Girl's Room
* Room No. 14