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IN-DEPTH SURVEY REPORT

CONTROL TECHNOLOGY FOR ASBESTOS REMOVAL

AT

SANDS ELEMENTARY SCHOOL
Cincinnati, Ohio

REPORT WRITTEN BY:
Bruce A. Hollett
Paul E. Caplan
Thomas C. Cooper
Phillip A. Froehlich

REPORT DATE
August, 1987

REPORT NO.
147-19b

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
Division of Physical Sciences and Engineering
Engineering Control Technology Branch
4676 Columbia Parkway
Cincinnati, Ohio 45226

FACILITY SURVEYED:	Cincinnati Public School System Sands Montessori Elementary School 940 Poplar Street Cincinnati, Ohio 45214
SIC CODE	1799
SURVEY DATES:	June 4, 1985 Walk Through Survey June 13, 1985 Pre-Removal Survey July 1-3, 1985 Removal Survey July 10, 1985 Post-Removal Survey
SURVEY CONDUCTED BY.	Bruce A. Hollett, C I H , P.E. Paul E Caplan, P.E , C I H Thomas C. Cooper
REPRESENTATIVES CONTACTED:	
FACILITY	Mr Harold T Flaherty, Associate Director, Office of Safety Services Mr Rus Wilte, Project Officer Cincinnati Public Schools 2315 Iowa Avenue Cincinnati, OH 45206 (513) 369-4000
CONTRACTOR	Mr James Stern, Vice President Mr Thomas Schroder, Estimator I&F Corporation 5176 Crookschank Road Cincinnati, OH 45238 (513) 922-0203
EMPLOYEES	Mr Daniel C Lichtenfeld, Business Representative Mr Bob Hughes, Crew Foreman International Association of Heat and Frost Insulators Local 8 1216 East McMillan Street Cincinnati, OH 45206 (513) 221-5969
ANALYTICAL WORK PERFORMED BY:	Eugenia Shtrom Frank J Welborn PEI Associates, Inc 11499 Chester Road Cincinnati, OH 45246 (513) 782-4700 Ruth A Kawashiuna Brent E Stephens UBTL, Inc 520 Wakara Way Salt Lake City, Utah 84105 (801) 581-8239

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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 or 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 of 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 Sands Montessori School, Gandee reported damaged and exposed asbestos in many of the occupied areas, in the pool areas, and in the boiler and fan rooms Samples of the boiler lagging and a bag of A.P Green cement insulation found in the boiler room were analyzed The cement was reported to contain no asbestos and the boiler lagging to contain 5% chrysotile 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 Sands Montessori 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 with the following results In the Teachers Lunchroom (lunchroom) the Airseal lagging contained 30-40 % chrysotile asbestos and 40-50 % cellulose and other fibers, the joint cement contained 10-15 % chrysotile and only 1-2 % other fibers Pipe lagging in the boys' restroom (boys room) contained 10-15% chrysotile and 1-2 % cellulose and other fibers No actinolite/tremolite, amosite, or anthophyllite asbestos was detected in these samples

The removal contract for the Sands Montessori School required approximately 2350 linear feet of asbestos pipe lagging to be removed from 12 major rooms and areas During this survey, removal operations were observed in two rooms located on the basement level, the lunchroom, and the boys room.

The pipe lagging in the lunchroom was of the Airseal type (corrugated asbestos paper) There were large overhead ducts in one end of this room (During the blown down period of the pre-removal survey a large cloud of dust was generated in this area) The floor was tile

The lunchroom (Figure A) measured approximately 32'x 23'x 12', enclosing about 8832 cubic feet Insulation was removed from approximately 30' of 6-inch, 15' of 4-inch, 20' of 3-inch, and 85' of 2-inch pipe, including 6 T-joints, 13 elbows, 10 pipe hangers, and 9 pipe/structure intersections

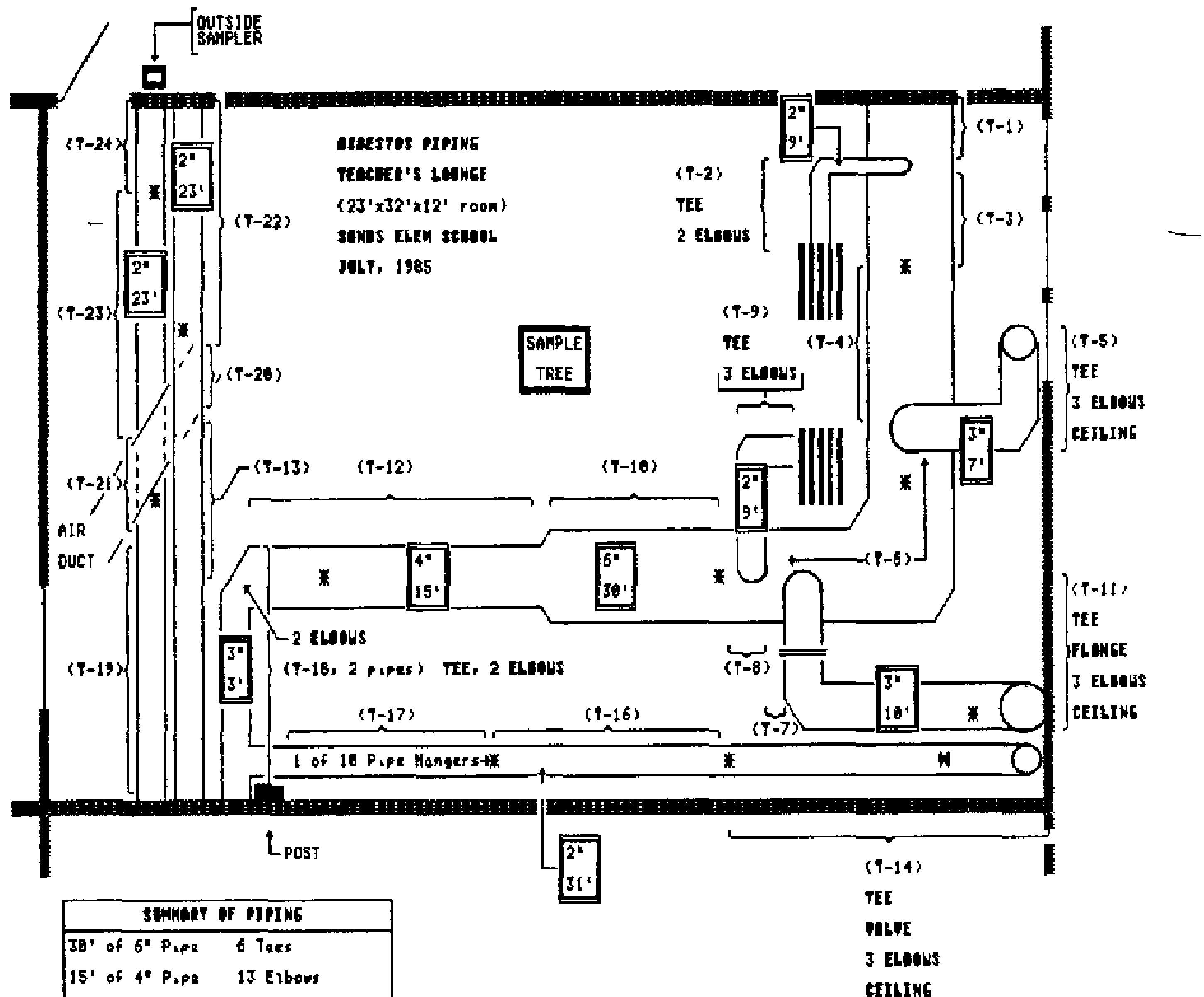
The boys room (Figure B) measured approximately 42'x 25'x 12', enclosing 12,000 cubic feet Insulation was removed from approximately 45' of 6-inch, 15' of 4-inch, 9' of 3-inch, and 53' of 2-inch pipe, including 6 T-joints, 18 elbows, 4 pipe hangers, and 8 pipe/structure intersections

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 Large storage cabinets in the lunchroom were isolated with poly

Figure A

Plot of Piping Layout in Teachers' Lounge (Lunchroom)

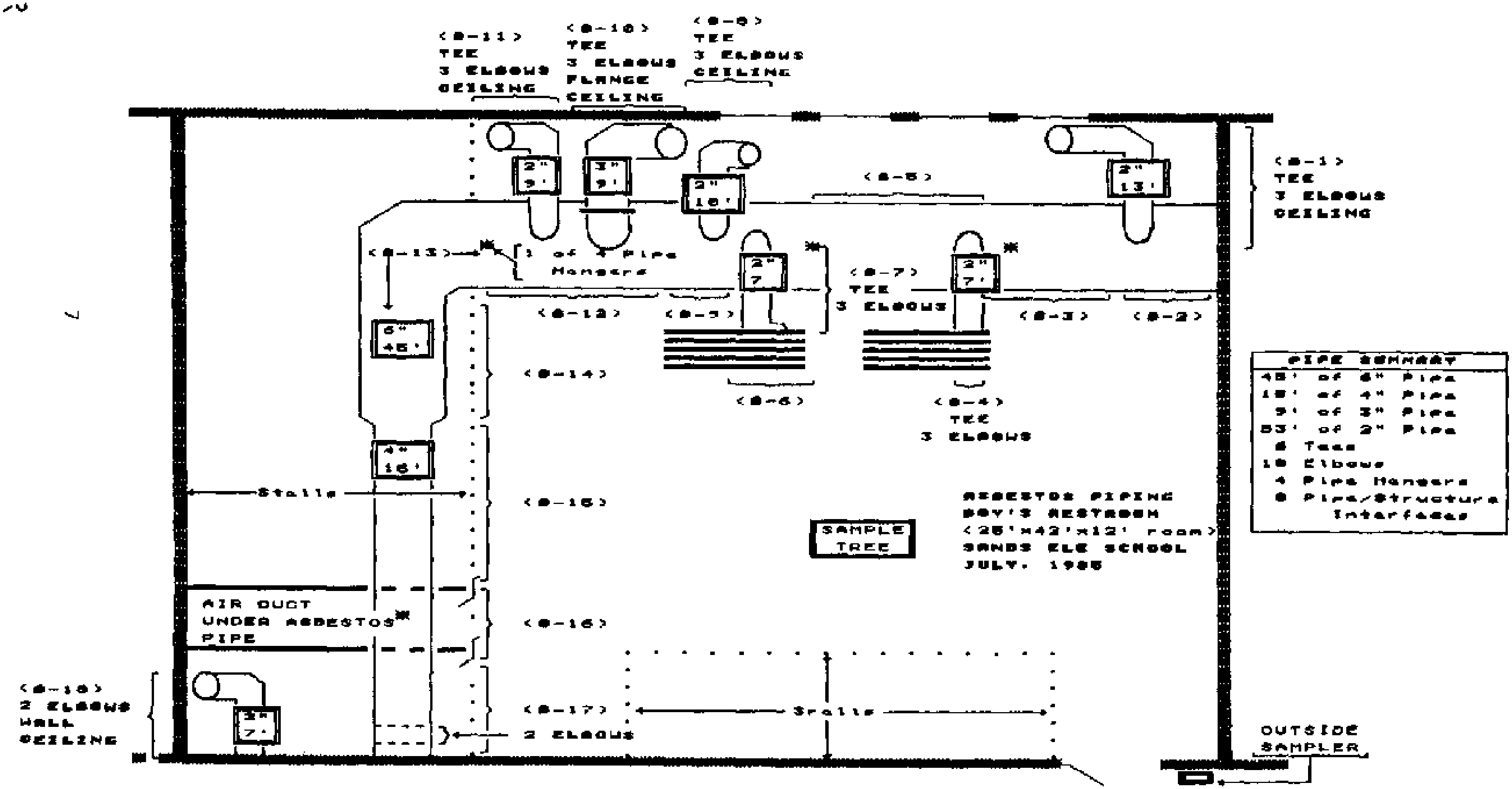
N/H



SUMMARY OF PIPING	
30' of 6" Pipe	6 Tees
15' of 4" Pipe	13 Elbows
20' of 3" Pipe	10 Pipe Hangers
85' of 2" Pipe	9 Pipe/Structure Interfaces
1 Valve	

Figure B

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



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 the activities is summarized below to provide a general 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 Sands Montessori 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 Study

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 Sands Montessori 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 The floor of the lunchroom was tiled and the cement floor of the restroom included a drain which permitted easy washing down after HEPA vacuuming, therefore, no floor covering was provided

Removal--

During the first day in the lunchroom the removal was accomplished using Safety-Strip® bags following instructions received the week before in the Washburn Kindergarten room. The tools for cutting metal bands and lagging were placed inside the glove bag, then the bag was hung from the pipe The bag was zipped to form a seal along the length of pipe and the bag ends (sleeves) were strapped to the poly-jacketed pipe

One of the spray tanks was fitted with 10' - 15' hose so that it was unnecessary to elevate it to the working level This allowed a support worker on the floor to fill the sprayer with amended water and to pump up the pressure, and greatly enhanced the ability and inclination of the removal workers to use sufficient wetting to control 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

Work in the boys room during the following two days was accomplished using the conventional bags with the exception that some Safety Strip® bags were used for vertical sections The methodology used with the conventional bags was modified by the experience with the Safety-Strip® technique Workers attempted to use straps rather than tape to seal the sleeveless bags against the poly envelope Workers continued to use a bottle brush for difficult cleaning tasks Long hoses were added to the remaining two water spray canisters The concrete floor was washed down with a hose periodically

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 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 [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 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

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 submitted 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/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 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 asbestos fibers. As part of the TEM analytical method used in this study, the dimensions of all fibers counted were recorded A rough evaluation 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 results obtained from B rule counting

Another concern is that minute asbestos fibrils (0 5 µm to 0 02 µm in diameter and less than 1 µm in length) are routinely 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 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[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 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, 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 <u>proposed</u> clearance limit for TEM, using a 3000 l sample and a 37-mm filter, is 4 x 0 005 f/cc = 0 02 f/cc The factor of 4, based on the assumption that the polycarbonate media contamination level is 70-75 $fibers/mm^2$, 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 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 of the 18 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 [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 a 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 ration 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/m^3 [2 0 f/cc] OSHA standard in effect at the time of this study However, 11 of 12 are in excess of the new 200,000 f/m^3 [0 2 f/cc] OSHA standard and all are in excess of the 100,000 f/m^3 action level The highest short-term breathing zone measurement exceeded 9,000,000 f/m^3 and 14 of 19 exceeded 500,000 f/m^3 As shown by the activity summary for each worker (Table 2), the average level of worker exposure from preparation activities was an order of magnitude lower than that experienced during removal

TABLE 1 - PERSONAL EXPOSURE MEASUREMENTS DURING PREPARATION
AND REMOVAL OF PIPE LAGGING
AT SANDS MONTESSORI SCHOOL

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

WORKER	TYPE*	ACTIVITY	JULY 01	JULY 02	JULY 03
# 1	TWA		0 345	0 554	0 799
	ST	PREPARATION	0.016		
	ST	REMOVAL	1.0	0 156	0 167
	ST	REMOVAL		2 0	
# 2	TWA		0 295	0 560	0 412
	ST	REMOVAL	0 711	0 756	
# 3	TWA		0 343	0 663	0 475
	ST	PREPARATION	0 017		
	ST	REMOVAL	0 467	3 18	0 711
	ST	REMOVAL	1 27	0 911	
# 4	TWA		0 152	0 639	0.611
	ST	REMOVAL	0 933	2 44	0 622
	ST	REMOVAL		2 78	1 02
	ST	REMOVAL		9 29**	

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

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

TABLE 2 PERSONAL SAMPLING RESULTS BY ACTIVITY
AT SANDS MONTESSORI SCHOOL

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

WORKER	JULY 01 LUNCHROOM	JULY 02 BOYS ROOM	JULY 03	MEAN	MIN	MAX	ST D*	n*
= = = = = = = = = =	PREPARATION FOR PIPE LAGGING REMOVAL							
1	0 011							
2	0 008							
3	0.004							
4	0 016							
PREP AVERAGE	0 01			0 01	0 004	0 016	0 005	4
= = = = = = = = = =	PIPE LAGGING REMOVAL							
1	0 165	0 260	0 799					
	1 03	1 07						
AVG	0 563	0 554	0.799	0 665	0.165	1 07	0 427	5
2	0 40	0 263	0.412					
	0 50	0 315						
AVG	0 446	0 289	0 412	0 378	0 263	0.50	0.092	5
3	0 505	0 457	0 475					
	0 619	1 10						
AVG	0 566	0 663	0.475	0.631	0 457	1.10	0 270	5
4	0.241	0 452	0.611					
	0.287	0 951						
AVG	0.265	0 639	0 611	0.508	0 241	0 951	0 287	5
REMOVAL AVERAGE	0 468	0 604	0 574	0.528	0 165	1 1	0 301	20
AMBIENT	0.001	0 001	0.001	0.001				6

* ST D = Standard Deviation   n = number of samples

In conformity with the reports of the results for the previously surveyed facilities 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 583,000 f/m^3 during removal and 3,000 f/m^3 during preparation In-room background sample means during removal operations were 546,000 f/m^3 and 7,000 f/m^3 during preparation The mean background levels in the halls were 155,000 f/m^3 and 5,000 f/m^3 respectively, the ambient level outside the building was 1,000 f/m^3 As noted earlier, during this survey removal work was also taking place in other rooms opening into the same hallway It is likely that the elevated levels shown here were influenced by emissions from these other work areas which were not always isolated by the use of poly door flaps

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, averaged about 130,000 as/m^3 for both pre- and post-removal This Table also shows that the post-removal total asbestos fiber concentration is 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 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 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 of 5,000 f/m^3 (0 005 f/cc) suggested as "typical" by the EPA[14]. The actual ambient pre- and post-removal levels were confirmed to be in agreement with the suggested criteria by the TEM analyses of the June 13 and July 10 ambient samples, less than 2,000 as/m^3 of air It should be noted that the ambient TEM samples were collected on cellulose ester filters

TABLE 3A - AREA SAMPLING RESULTS
PREPARATION FOR PIPE LAGGING REMOVAL
AT SANDS MONTESSORI SCHOOL

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

JULY 1
LUNCHROOM

SAMPLING SITE	PCM f/cc	TEM as/cc	MEAN	MIN	MAX	ST D*	n*
NEAR WORKERS							
PCM ANALYSIS	0 003		0 003	0 003	0 004	0 000	2
(TEM ANALYSIS NOT COMPLETED)							
ROOM (BACKGROUND)							
PCM ANALYSIS	0 007		0 007	0.004	0 009	0 003	2
(TEM ANALYSIS NOT COMPLETED)							
HALL (BACKGROUND)							
PCM ANALYSIS	0 005		0 005	0 002	0 009	0 003	2
(TEM ANALYSIS NOT COMPLETED)							
OUTDOOR AMBIENT							
PCM ANALYSIS	0 001						2

* f/cc = 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 SANDS MONTESSORI SCHOOL

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

	JULY 01				JULY 02				JULY 03								
	LUNCHROOM				BOYS ROOM				BOYS ROOM								
SAMPLING SITE	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	0 473	2			0 445 0 800	2 2			0 616	2							
AVERAGE	0 473	2			0 623	4			0 616	2			0 583	0 002	0 956	0 31	8
(TEM ANALYSIS NOT COMPLETED)				2				4				2					8
ROOM (BACKGROUND)																	
PCM ANALYSIS	0 383	2			0 467 0 789	2 2			0 546	2							
AVERAGE	0 383	2			0 628	4			0 546	2			0 546	0 258	0 816	0 19	8
(TEM ANALYSIS NOT COMPLETED)				2				4				2					8
AREA AVERAGE	0 428	5			0 625	8			0 581	4			0 565	0 002	0.956	0 24	16
HALL (BACKGROUND)																	
PCM ANALYSIS	0 012	2			0 001 0 451	2 2			0 300	2							
AVERAGE	0 012	2			0 226	4			0 300	2			0 155	0 001	0 458	0 23	8
(TEM ANALYSIS NOT COMPLETED)				2				4				2			8		
OUTDOOR AMBIENT																	
PCM ANALYSIS	0 001	2			0 001	2			0 001	2			0 001				6

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

TABLE 4

MEAN ASBESTOS FIBER AND ASBESTOS STRUCTURE CONCENTRATIONS

AT SANDS MONTESSORI SCHOOL

Analysis by TEM using EPA Provisional Method

Sample	Structures/cc	Fibers/cc
Pre Removal		
Nonaggressive	N/C	N/C
Aggressive	0 13	0 08
Post Removal		
Nonaggressive	N/C	N/C
Aggressive	0 13	0 11

N/C - Analysis not completed

TABLE 5 COMPARISON OF MEAN PRE- AND POST-REMOVAL AREA SAMPLING AT SANDS MONTESSORI SCHOOL

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

LOCATION	JUNE 13 PRE-REMOVAL SAMPLES: NIOSH PCM AND TEM f/cc	n*	as/cc	n	EPA TEM ANALYSIS** as/cc Total	as/cc >5 µm long	n	JULY 10 POST-REMOVAL SAMPLES: NIOSH PCM AND TEM f/cc	n	as/cc	n	EPA TEM ANALYSIS** as/cc Total	as/cc >5 µm long	n
NONAGGRESSIVE SAMPLING METHOD														
BOYS ROOM	0 003	6	N/C		N/C*	N/C	3	0 001	6	N/C		N/C	N/C	3
LUNCHROOM	0 002	6	N/C		N/C	N/C	3	0 001	6	N/C		N/C	N/C	3
HALL BOYS ROOM								0 001	2	N/C				
HALL LUNCHROOM								0 001	2	N/C				
AGGRESSIVE SAMPLING METHOD														
BOYS ROOM	0 075	6	N/C		0 18	I/A*	3	0 002	6	N/C		0 14	I/A	3
LUNCHROOM	0 008	5	N/C		0 06	I/A	3	0 020	6	N/C		0 10	I/A	3
HALL BOYS ROOM								0.000	1	N/C				
HALL LUNCHROOM								0 003	1	N/C				
OUTDOOR AMBIENT	0 002	2	0 002	2***				0 000	2	0 002	2***			

* f/cc = Total Fibers/cc as/cc = Asbestos Structures/cc n = number of samples
N/C - Analysis not completed I/A - Data in analysis, not yet available

** 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 samples were collected on 25mm cellulose ester filters and analyzed by NIOSH Method 7402, March 1987 revision

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 The aggressive PCM sampling results indicate a slightly increased post-removal level in lunchroom (20,000 f/m^3) All of the lunchroom samples (6) exceeded the 10,000 f/m^3 criterion and all of the samples (6) in the boys room were below Two of six pre-removal aggressive samples in each room exceeded 10,000 f/m^3

OTHER OBSERVATIONS

Engineering Controls

Two types of glovebags were used during this survey Nine Safe-T-Strip® bags were used in the lunchroom during the first two days, work in the boys room during the second and third days utilized six Disposalene® bags.

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 SANDS ELEMENTARY SCHOOL

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

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

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. that pump was not used during the this study because the survey team was monitoring each of the workers However, the pump was not adequately maintained or calibrated to provide proper monitoring support There is a need for training if workers are to be assigned monitoring duties

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

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

On the afternoon of July 2, approximately 15 feet of 6-inch pipe lagging fell unexpectedly into the plastic envelope while removal was being performed at another location on this pipe The metal banding had been removed from the entire length of pipe at the time the envelope was installed This was bad judgment, but it did demonstrate the benefit of using the poly envelope technique Had this section of lagging fallen freely to the floor, a very massive release of fibers could have occurred and the cleanup effort would have been much more difficult In addition, one worker slit the envelope, reached in, and attempted to push the loose lagging toward the bag This was noted and the slit was quickly sealed with duct tape before any lagging dropped from the opening, however, an asbestos fiber release did occur A short-time sample taken at that time showed an exposure level exceeding 9 f/cc.

VI CONCLUSIONS AND RECOMMENDATIONS

SITE SPECIFIC

Asbestos exposure, as evidenced by personal breathing-zone air samples analyzed using NIOSH method 7400-B, showed order-of-magnitude increases depending upon the work activity Asbestos fiber concentrations rose from a pre-removal level of 0 001 f/cc to 0 010 f/cc during the preparation of the pipe lagging for removal and to 0 528 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 There is no method to translate these results to what would be achieved had the A rules (used for OSHA compliance) been used, however, the levels attained during removal undoubtedly exceed the OSHA PEL Workers did use respiratory protection at that time and thus were probably protected from excessive amounts of asbestos

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

The average level of the aggressive samples for total asbestos structures exceeded the ambient level and the level suggested as "typical" by the EPA [14]

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.)

All of the post-removal samples (6) taken in the lunchroom by the aggressive method and 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 possibly fail 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 the work practices observed in this study workers should (and did) use respiratory protection It is prudent 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) 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 third school surveyed, and the removal crew gained experience with each survey The limited expertise of the workers observed in the two 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 consistant 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 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 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 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	0 741	0.445
				(1.417 - 8 698)	(0 378 - 2 319)	(0 227 - 1.393)
*	500000	0 51	3 13	1 25	0 333	0 2
				(0 638 - 3 913)	(0 170 - 1 042)	(0 102 - 0 626)
*	250000	0 51	3 13	0 625	0 167	0 1
				(0 319 - 1 956)	(0 085 - 0 523)	(0 051 - 0 313)
100	108917	0 51	3 13	0 272	0 073	0 044
				(0.139 - 0 851)	(0 037 - 0.228)	(0 022 - 0.138)
80	87134	0.51	3 14	0 218	0.058	0 035
				(0 111 - 0.685)	(0 030 - 0 182)	(0 018 - 0 110)
60	65350	0 51	3 16	0 163	0 044	0 026
				(0.083 - 0 515)	(0.022 - 0.139)	(0.013 - 0 082)
50	54459	0 51	3 18	0 136	0 036	0 022
				(0 069 - 0 432)	(0 018 - 0.114)	(0.011 - 0 070)
40	43567	0.50	3 20	0 109	0.029	0 017
				(0 055 - 0.349)	(0 015 - 0.093)	(0 009 - 0.054)
30	32675	0 49	3 25	0.082	0 022	0 013
				(0 04 - 0 267)	(0 011 - 0 072)	(0.006 - 0.042)
20	21783	0 47	3 33	0 054	0 015	0 009
				(0 025 - 0.18)	(0 007 - 0.05)	(0 004 - 0.030)
10	10892	0 43	3 57	0 027	0 007	0.004
				(0.012 - 0 096)	(0.003 - 0.025)	(0.002 - 0.014)
7 (NIOSH LOD)	7624	0.40	3 78	0 019	0 005	0.003
				(0 008 - 0 072)	(0.002 - 0 019)	(0 001 - 0 011)
3 (UBTL LOD)	3268	0.31	4 66	0 008	0 002	0.001
				(0 002 - 0 037)	(0 001 - 0 009)	(0 000 - 0 005)

TABLE A-3

LEGEND FOR SANDS PCM DATA - APPENDIX A

LOC (School and room location of sampled activity)
Sxxx Sands School
TLR Teachers Lunch Room
TLG Teachers Lounge outside window
BR Boys Rest Room

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 Preperation, covering, etc. - Full term sequential
RMS Removal work - 15 minute short term PBZ sample
COS Preperation, 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 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 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
SANDS ELEMENTARY SCHOOL
CINCINNATI, OHIO
June 12 July 1 3 & 10, 1985

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

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

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
SBR	IA-PRE-AGGR	AA073	6/13	2315	0715	480	3.14	1507.2	57305	0.038			87203	0.058
SBR	IA-PRE-AGGR	AA094	6/13	2315	0715	480	3.3	1584.0	93940	0.059			86625	0.055
SBR	IA-PRE-AGGR	AA133	6/13	2315	0715	480	3.3	1584.0	102410	0.065	62000	0.039		
SBR	IA-PRE-AGGR	M293	6/13	2315	0715	480	3.1	1488.0	90630	0.061			134235	0.090
SBR	IA-PRE-AGGR	M294	6/13	2315	0715	480	3.3	1584.0	102600	0.065	-		159885	0.101
SBR	IA-PRE-AGGR	M297	6/13	2315	0715	480	3.2	1536.0	83790	0.055			168435	0.110
SBR	IA-PRE-NAGR	AA084	6/13	1344	2145	481	3.0	1443.0	130515	0.090			1347	0.001
SBR	IA-PRE-NAGR	AA100	6/13	1344	2145	481	3.0	1443.0	73535	0.051			1347	0.001
SBR	IA-PRE-NAGR	AA101	6/13	1344	2145	481	3.1	1491.1	96250	0.065			1347	0.001
SBR	IA-PRE-NAGR	M296	6/13	1344	2145	481	3.0	1443.0	152190	0.105			10260	0.007
SBR	IA-PRE-NAGR	M299	6/13	1344	2145	481	3.2	1539.2	135945	0.088			9405	0.006
SBR	IA-PRE-NAGR	M305	6/13	1344	2145	481	3.2	1539.2	54976	0.036			2992	0.002
STLR	IA-PRE-AGGR	AA077	6/13	2303	0703	480	3.3	1584.0	1347	0.001			6930	0.004
STLR	IA-PRE-AGGR	AA112	6/13	2303	0703	480	3.1	1488.0	65065	0.044			1347	0.001
STLR	IA-PRE-AGGR	AA114	6/13	2303	0703	480	3.3	1584.0	93940	0.059				
STLR	IA-PRE-AGGR	M292	6/13	2303	0703	480	3.3	1584.0	61560	0.039			23085	0.015
STLR	IA-PRE-AGGR	M303	6/13	2303	0703	480	3.2	1536.0	103455	0.067			2992	0.002
STLR	IA-PRE-AGGR	M304	6/13	2303	0703	480	3.2	1536.0	142785	0.093	30000	0.020		
STLR	IA-PRE-AGGR	N320	6/13	2303	0703	480	3.2	1536.0						
STLR	IA-PRE-NAGR	AA081	6/13	1337	2137	480	3.0	1440.0	36768	0.026			1347	0.001
STLR	IA-PRE-NAGR	AA113	6/13	1337	2137	480	3.0	1440.0	24524	0.017	1500	0.001		
STLR	IA-PRE-NAGR	AA115	6/13	1337	2137	480	3.0	1440.0	51975	0.036			1347	0.001
STLR	IA-PRE-NAGR	M291	6/13	1337	2137	480	3.1	1488.0	20520	0.014			2992	0.002
STLR	IA-PRE-NAGR	M301	6/13	1337	2137	480	3.0	1440.0	10858	0.008			2992	0.002
STLR	IA-PRE-NAGR	M302	6/13	1337	2137	480	3.1	1488.0	15219	0.010	4000	0.003		
SFB	FB-PRE-FTER	AA076	6/13						1347		750			
SFB	FB-PRE-FTER	AA078	6/13						1347		750			
SFB	FB-PRE-FTER	AA085	6/13						1347		750			
SFB	FB-PRE-FTER	AA086	6/13						1347		750			
SFB	FB-PRE-FTER	AA088	6/13						3426		750			
SFB	FB-PRE-FTER	AA096	6/13						962		750			
SFB	FB-PRE-FTER	M295	6/13						2992		1750			
SFB	FB-PRE-FTER	M300	6/13						11371				2992	
SFB	FB-PRE-6/14	M328	6/13						7609				2992	
SFB	FB-PRE-6/14	M333	6/13						5472		1750			
SFB	FB-PRE-6/14	M336	6/13						1111		1750			
SLNG	AM-FTER	AA082	6/13	1050	0637	1187	2.8	3323.0	242550	0.073			1347	0.000
SLNG	AM-FTER	AA083	6/13	1050	0637	1187	2.8	3323.6	190960	0.057			1347	0.000

TABLE A-4 (Continued - page 2)

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II Fibers	MAGISCAN II f/cc	UBTLPCM 7400-D Fibers	UBTLPCM 7400-D f/cc	NIOSHPCM 7400 B Fibers	NIOSHPCM 7400 B f/cc
STLR	BZ C&R-WK#1	AA229	7/01	0801	1030	149	2.96	441.0			5000	0.011		
STLR	BZ COS-WK#1	AA321	7/01	0836	0852	16	3.0	48.0			750	0.016		
STLR	BZ-COS WK#3	AA239	7/01	0817	0832	15	3.0	45.0			750	0.017		
STLR	BZ-COV-WK#2	AA238	7/01	0820	1020	120	3.05	366.0			3000	0.008		
STLR	BZ-COV-WK#3	AA240	7/01	0800	1030	150	3.02	453.0			2000	0.004		
STLR	BZ-COV-WK#4	AA254	7/01	0942	1009	37	3.0	111.0			2000	0.018		
STLR	BZ-COV-WK#4	AA318	7/01	0800	1030	150	3.00	450.0			3000	0.007		
STLR	BZ-REM-WK#1	AA226	7/01	1330	1515	105	2.96	310.8			320000	1.030		
STLR	BZ-REM-WK#1	AA244	7/01	1030	1233	123	2.96	364.1			60000	0.165		
STLR	BZ REM-WK#2	AA242	7/01	1030	1233	123	3.05	375.2			150000	0.400		
STLR	BZ-REM-WK#2	AA386	7/01	1330	1515	105	3.05	320.3			160000	0.500		
STLR	BZ-REM-WK#3	AA319	7/01	1030	1233	123	3.02	371.5			230000	0.619		
STLR	BZ-REM-WK#3	AA390	7/01	1330	1515	105	3.02	317.1			160000	0.505		
STLR	BZ-REM-WK#4	AA245	7/01	1037	1233	116	3.00	348.0			100000	0.287		
STLR	BZ-REM-WK#4	AA385	7/01	1330	1515	105	3.00	315.0			76000	0.241		
STLR	BZ-RMS-WK#1	AA333	7/01	1404	1413	9	3.0	27.0			27000	1.000		
STLR	BZ-RMS-WK#2	AA349	7/01	1437	1452	15	3.0	45.0			32000	0.711		
STLR	BZ-RMS-WK#3	AA313	7/01	1047	1102	15	3.0	45.0			21000	0.467		
STLR	BZ RMS-WK#3	AA341	7/01	1337	1352	15	3.0	45.0			57000	1.267		
STLR	BZ-RMS-WK#4	AA334	7/01	1314	1329	15	3.0	45.0			42000	0 933		
STLR	CT-COV	AA277	7/01	0759	1028	149	3.00	447.0			1500	0.003		
STLR	CT-COV	AA280	7/01	0759	1028	149	2.82	420.2			1500	0.004		
STLR	CT-REM	AA232	7/01	1033	1233	120	2.82	338.4			240000	0.709		
STLR	CT-REM	AA276	7/01	1033	1233	120	3.00	360.0			57000	0.158		
STLR	CT-REM	AA335	7/01	1330	1530	120	2.82	338.4			750	0.002		
STLR	CT REM	AA342	7/01	1330	1530	120	3.00	360.0			340000	0.944		
STLR	IA-COV	AA246	7/01	0803	1028	145	3.00	435.0			4000	0.009		
STLR	IA-COV	AA251	7/01	0759	1028	149	3.12	464.9			2000	0.004		
STLR	IA-REM	AA225	7/01	1033	1233	120	3.12	374.4			220000	0.588		
STLR	IA-REM	AA237	7/01	1330	1530	120	3.00	360.0			93000	0.258		
STLR	IA-REM	AA266	7/01	1033	1233	120	3.00	360.0			140000	0.389		
STLR	IA-REM	AA387	7/01	1330	1530	120	3.12	374.4			190000	0.507		
STLR	OA-COV	AA229	7/01	0759	1028	149	3.12	464.9			4000	0.009		
STLR	OA-COV	AA270	7/01	0759	1028	149	3.06	455.9			750	0.002		
STLR	OA-REM	AA236	7/01	1330	1530	120	3.12	374.4			4000	0.011		
STLR	OA-REM	AA241	7/01	1247	1330	43	3.12	134.2			3000	0.022		
STLR	OA-REM	AA256	7/01	1035	1233	118	3.06	361.1			7000	0.019		
STLR	OA-REM	AA257	7/01	1035	1150	75	3.12	234.0			2000	0.009		
STLR	OA-REM	AA388	7/01	1330	1530	120	3.06	367.2			5000	0.014		
SFB	FB COV-6/21	AA164	7/01								750			
SFB	FB-REM 6/21	AA165	7/01								750			
SLNC	AM-FTM	AA267	7/01	0750	1545	475	3.0	1425.0			750	0.001		
SLNC	AM FTM	AA268	7/01	0750	1545	475	2.8	1330.0			750	0.001		

TABLE A-4 (Continued - page 3)

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II Fibers	MAGISCAN II f/cc	UBTLPCM 7400-D Fibers	UBTLPCM 7400-D f/cc	NIOSHPCM 7400-D Fibers	NIOSHPCM 7400-D f/cc
SBRM	BZ-REM WK#1	AA332	7/02	1253	1512	133	2.82	375.1			400000	1.066		
SBRM	BZ REM WK#2	AA345	7/02	1255	1413	78	3.00	234.0			330000	1.410		
SBRM	BZ REM WK#3	AA355	7/02	1327	1512	109	3.00	327.0			360000	1.101		
SBRM	BZ REM WK#4	AA348	7/02	1258	1512	134	3.06	410.0			390000	0.951		
SBRM	BZ-RMS-WK#1	AA368	7/02	1341	1356	15	3.00	45.0			90000	2.000		
SBRM	BZ RMS-WK#3	AA353	7/02	1430	1452	22	3.00	66.0			210000	3.182		
SBRM	BZ-RMS-WK#4	AA359	7/02	1457	1511	14	3.00	42.0			390000	9.286		
SBRM	BZ-RMS-WK#4	AA369	7/02	1313	1331	18	3.00	54.0			150000	2.778		
SBRM	CT REM	AA344	7/02	1257	1520	143	2.82	403.3			260000	0.645		
SBRM	CT-REM	AA358	7/02	1257	1520	143	3.00	429.0			410000	0.956		
SBRM	IA-REM	AA338	7/02	1257	1520	143	3.00	423.0			350000	0.816		
SBRM	IA-REM	AA352	7/02	1257	1520	143	3.12	440.2			340000	0.762		
SBRM	DA-REM	AA329	7/02	1257	1520	143	2.90	414.7			190000	0.458		
SBRM	DA-REM	AA337	7/02	1257	1520	143	3.00	420.0			190000	0.443		
STLR	BZ REM-WK#1	AA362	7/02	0735	1127	232	2.82	654.2			170000	0.260		
STLR	BZ-REM WK#2	AA361	7/02	0735	1119	224	3.05	683.2			180000	0.263		
STLR	BZ REM-WK#3	AA376	7/02	0735	1127	232	3.02	700.6			320000	0.457		
STLR	BZ-REM-WK#4	AA375	7/02	0735	1119	224	3.06	685.4			310000	0.452		
STLR	BZ-RMS-WK#1	AA347	7/02	0812	0827	15	3.00	45.0			7000	0.156		
STLR	BZ RMS-WK#2	AA346	7/02	0832	0847	15	3.00	45.0			34000	0.756		
STLR	BZ-RMS-WK#3	AA354	7/02	0942	0957	15	3.00	45.0			41000	0.911		
STLR	BZ RMS-WK#4	AA360	7/02	1005	1020	15	3.00	45.0			110000	2.444		
STLR	CT REM	AA356	7/02	0735	1127	232	3.00	696.0			300000	0.431		
STLR	CT-REM	AA370	7/02	0735	1127	232	2.82	654.2			300000	0.459		
STLR	IA-REM	AA363	7/02	0735	1127	232	3.00	696.0			390000	0.560		
STLR	IA-REM	AA377	7/02	0735	1127	232	3.12	723.8			270000	0.373		
STLR	DA-REM	AA330	7/02	0735	1128	233	3.12	727.0			750	0.001		
STLR	DA-REM	AA340	7/02	0735	1128	233	3.06	713.0			750	0.001		
SFB	FD-REM 6/21	AA166	7/02								750			
SFB	FB REM 6/21	AA167	7/02								750			
SLNG	AM-FTM	AA331	7/02	0727	1525	478	3.0	1434.0			1500	0.001		
SLNG	AM-FTM	AA339	7/02	0727	1525	478	2.8	1338.4			750	0.001		

TABLE A-4 (Continued - page 4)

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGIDCAN II Fibers	MAGIDCAN II f/cc	UBTLPCM 7400-B Fibers	UBTLPCM 7400-B f/cc	NIOSHPCM 7400-B Fibers	NIOSHPCM 7400-B f/cc
SBRM	BZ REM WK#1	AA366	7/03	0742	1115	213	2.82	600.7			480000	0.799		
SBRM	BZ-REM-WK#2	AA336	7/03	0740	1115	215	3.05	655.8			270000	0.412		
SBRM	BZ REM-WK#3	AA343	7/03	0739	1115	216	3.02	652.3			310000	0.475		
SBRM	BZ-REM WK#4	AA357	7/03	0741	1115	214	3.06	654.8			400000	0.611		
SBRM	BZ RMS WK#1	AA373	7/03	1010	1030	20	3.00	60.0			100000	1.667		
SBRM	BZ RMS-WK#3	AA371	7/03	0816	0831	15	3.00	45.0			32000	0.711		
SBRM	BZ-RMS-WK#4	AA378	7/03	0755	0810	15	3.00	45.0			28000	0.622		
SBRM	BZ RMS WK#4	AA380	7/03	0948	1003	15	3.00	45.0			46000	1.022		
SBRM	CT REM	AA351	7/03	0737	1115	218	2.82	614.8			410000	0.667		
SBRM	CT REM	AA364	7/03	0737	1115	218	3.00	654.0			370000	0.566		
SBRM	IA-REM	AA350	7/03	0737	1115	218	3.00	654.0			310000	0.474		
SBRM	IA-REM	AA372	7/03	0737	1115	218	3.12	680.2			420000	0.617		
SBRM	DA-REM	AA382	7/03	0737	1115	218	3.00	654.0			240000	0.307		
SBRM	DA REM	AA301	7/03	0737	1115	218	2.96	645.3			150000	0.232		
SFB	FB-REM-6/21	AA168	7/03								750			
SFB	FB-REM 6/21	AA169	7/03								750			
SLNG	AM-FTM	AA365	7/03	0720	1150	270	2.8	750.0			750	0.001		
SLNG	AM-FTM	AA367	7/03	0720	1150	270	3.0	810.0			750	0.001		

TABLE A-4 (Continued - page 5)

LOC.	SAMPLE CLASS	SAMPLE No.	SAMPLE Date	PERIOD Start	PERIOD Stop	TIME (min)	RATE (lpm)	VOL. (l)	MAGISCAN II Fibers	MAGISCAN II f/cc	UBTLPCM 7400-B Fibers	UBTLPCM 7400-B f/cc	NIOSHPCM 7400-B Fibers	NIOSHPCM 7400-B f/cc
SBR	IA-PST-AGGR	AA422	7/10	1750	0218	508	3.0	1524.0	26565	0.017	2000	0.001		
SBR	IA-PST AGGR	AA425	7/10	1750	0218	508	3.0	1524.0	28490	0.019	2000	0.001		
SBR	IA-PST-AGGR	AA428	7/10	1750	0218	508	3.0	1524.0	31955	0.021	2000	0.001		
SBR	IA-PST AGGR	M852	7/10	1750	0218	508	3.5	1778.0	74641	0.042			2992	0.002
SBR	IA-PST-AGGR	M853	7/10	1750	0218	508	3.5	1778.0	92340	0.052	1750	0.001		
SBR	IA-PST AGGR	M854	7/10	1750	0218	508	3.5	1778.0	82849	0.047			12996	0.007
SBR	OA-PST AGGR	AA443	7/10	1750	0218	508	3.0	1524.0	86240	0.057	750	0.000		
SBR	IA-PST-NAGR	AA433	7/10	0842	1655	493	3.0	1479.0	24640	0.017	750	0.001		
SBR	IA-PST NAGR	AA438	7/10	0902	1655	473	3.0	1419.0	111650	0.079			1347	0.001
SBR	IA-PST-NAGR	AA439	7/10	0842	1655	493	3.0	1479.0	108570	-0.073	750	0.001		
SBR	IA-PST NAGR	M841	7/10	0842	1655	493	3.3	1626.9	35910	0.022	1750	0.001		
SBR	IA-PST NAGR	M842	7/10	0842	1655	493	3.2	1577.6	22230	0.014	1750	0.001		
SBR	IA-PST NAGR	M843	7/10	0902	1655	473	3.1	1466.3	25650	0.017	1750	0.001		
SBR	OA-PST-NAGR	AA437	7/10	0843	1655	492	3.1	1525.2	45045	0.030	1500	0.001		
STLR	IA-PST-AGGR	AA304	7/10	1603	0208	605	3.3	1996.5	31185	0.016	25000	0.013		
STLR	IA-PST-AGGR	AA442	7/10	1603	0208	605	3.0	1815.0	72765	0.040			40040	0.022
STLR	IA-PST AGGR	AA451	7/10	1603	0208	605	3.5	2117.5	60445	0.029	23000	0.011		
STLR	IA-PST-AGGR	M845	7/10	1603	0208	605	3.5	2117.5	64125	0.030			63270	0.030
STLR	IA-PST-AGGR	M848	7/10	1603	0208	605	3.0	1815.0	45315	0.025	46000	0.025		
STLR	IA-PST AGGR	M849	7/10	1603	0208	605	3.5	2117.5	94050	0.044			43520	0.021
STLR	OA-PST AGGR	AA455	7/10	1603	0208	605	3.5	2117.5	32147	0.015			5390	0.003
STLR	IA-PST-NAGR	AA429	7/10	0845	1655	490	3.0	1470.0	94710	0.064			3465	0.002
STLR	IA-PST NAGR	AA430	7/10	0845	1655	490	3.1	1519.0	55825	0.037	750	0.000		
STLR	IA-PST-NAGR	AA436	7/10	0845	1655	490	3.1	1519.0	33880	0.022	750	0.000		
STLR	IA-PST-NAGR	M844	7/10	0845	1655	490	3.4	1666.0	79515	0.048			2992	0.002
STLR	IA-PST-NAGR	M850	7/10	0845	1655	490	3.5	1715.0	87210	0.051	1750	0.001		
STLR	IA-PST NAGR	M851	7/10	0845	1655	490	3.4	1666.0	84645	0.051	1750	0.001		
STLR	OA-PST NAGR	AA423	7/10	0843	1655	492	3.0	1476.0	46585	0.032			1347	0.001
SFB	FB-PST-7/18	AA479	7/10						10549				1347	
SFB	FB-PST-7/18	M955	7/10						2992				2992	
SFB	FB-PST-7/18	M956	7/10						2992				2992	
SFB	FB-PST-7/18	M960	7/10						17955				2992	
SLNG	AM-PST-FTM	AA452	7/10	0854	0325	1111	3.0	3333.0	227150	0.068	750	0.000		
SLNG	AM-PST FTM	AA460	7/10	0854	0325	1111	2.9	3221.9	217910	0.068	750	0.000		

APPENDIX B

TABULATION OF DATA OBTAINED USING TRANSMISSION ELECTRON MICROSCOPY (TEM)

Appendix B

Sands Elementary School

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

Concentrations per Cubic Centimeter

PRE-REMOVAL

Nonaggressive

TEM REANALYSIS NOT COMPLETED

Aggressive

Sample Number	STRUCTURES Total	Nonasbestos	Asbestos	Chrysotile	Amphibole	ASBESTOS Matrix	Clusters	Bundles	FIBERS Total	Asbestos	Chrysotile	Amphibole
+N-306R	0 673	0 309	0 364	0 350	0 014	0 137	-	0 027	0 399	0 199	0 192	0 007
*N-307R	0 350	0 254	0 096	0 076	0 021	0 048	-	-	0 296	0 048	0 027	0 021
+N-309R	0 588	0 385	0 203	0 181	0 022	0 087	-	0 007	0 486	0 109	0 094	0 015
*N-310R	0 064	0,028	0 035	0 021	0 014	-	-	-	0 057	0 035	0 021	0 014
+N-311R	0 055	0 014	0 041	0 041	-	-	-	-	0 055	0 041	0 041	-
*N-320R	0 282	0 220	0 062	0 041	0 021	0 014	-	-	0 254	0 048	0 027	0 021
X̄	0 319	0 20	0 134	0.118	-	-	-	-	0 258	0 08	0 07	-

POST-REMOVAL

Nonaggressive

TEM RECOUNT NOT COMPLETED

Aggressive

Sample Number	STRUCTURES Total	Nonasbestos	Asbestos	Chrysotile	Amphibole	ASBESTOS Matrix	Clusters	Bundles	FIBERS Total	Asbestos	Chrysotile	Amphibole
*N-665R	0 215	0 072	0 143	0 131	0 012	-	-	0 006	0 209	0 137	0 125	0 012
*N-666R	0 089	0 044	0 044	0 033	0 011	0 011	-	-	0 077	0 033	0 022	0 011
+N-670R	0 485	0 173	0 312	0 201	0 111	0 021	-	0 021	0 416	0 270	0 173	0 097
+N-679R	0 071	0 019	0 052	0 026	0 026	-	-	0 006	0 065	0 045	0 019	0 026
+N-788R	0 130	0 032	0 097	0 091	0 006	-	-	0 013	0 117	0 084	0 078	0 006
*N-790R	0 477	0 364	0 113	0 087	0 024	0 036	-	0 006	0 393	0 072	0 048	0 024
X̄	0 245	0 117	0 127	0 09	0 032	-	-	-	0 212	0 107	0 078	0 029

+ Boy's Room
* Teacher's Lounge