PLAINTIFF'S EXHIBIT

CON-38

EVALUATION OF EXPOSURES TO AIRBORNE FIBERS DURING MAINTENANCE OF ASBESTOS-CONTAINING RESILIENT FLOOR TILES USING RECOMMENDED WORK PRACTICES

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CONTENTS

I. EXECUTIVE SUMMARY

Maintenance of asbestos-containing floor tiles in an occupational setting is subject to the standard set by the Occupational Safety and Health Administration (OSHA) for occupational exposure to asbestos in general industry (29 CFR 1910.1001). This standard requires employers to assure that worker exposures to asbestos do not exceed the permissible exposure limit (PEL) of 0.2 fibers per cubic centimeter (f/cc) of air for an 8-hour time weighted average (TWA) or the excursion limit of 1.0 f/cc averaged over a 30-minute period.

The OSHA asbestos standard requires initial monitoring of employee exposure at the start of a job to determine whether employee exposure exceeds either the action level (0.1 f/cc for an 8-hour TWA),[1] or the excursion limit (1.0 f/cc over 30 minutes). The standard also provides that, in lieu of initial monitoring, an employer may rely upon objective or historical data, conducted under substantially similar workplace conditions, to demonstrate that the action level and excursion limit are not exceeded.

ENVIRON Corporation was retained by the Resilient Floor Covering Institute (RFCI) and Armstrong World Industries, Inc. (Armstrong) to design and carry out a study of worker exposures to asbestos during and after maintenance of asbestos-containing resilient floor tiles pursuant to work practices recommended by RFCI and Armstrong for all resilient floor tiles. The maintenance work practices apply to all resilient floor tiles, whether or not they contain asbestos ("Recommended Work Practices", see Appendix A).

Maintenance performed on the floor tiles consisted of three types of procedures assumed to be from least to most aggressive: spray buffing, wet scrubbing, and wet stripping followed by refinishing. This report presents an analysis of fiber exposures to maintenance personnel during and after the maintenance of floor tiles pursuant to the Recommended Work Practices. Based on a total of 8 exposure measurements for maintenance personnel at four sites, the average TWA was 0.025 f/cc, one-fourth of the OSHA action level, for all types of floor tile maintenance. The average of the four excursion level samples was 0.13 f/cc, approximately one-eighth of the excursion limit.

Even though floor tile maintenance is not an abatement activity under the provision of the regulations (40 CFR 763) implementing the Asbestos Hazard Emergency Response Act, ENVIRON also conducted "clearance" sampling to determine the residual fiber levels following completion of the maintenance activity. Samples were taken according to the

On July 20, 1990, OSHA proposed to lower the PEL to 0.1 f/cc (55 CFR 29722).

"clearance" sampling protocols specified in Appendix A to subpart E of 40 CFR 763. For the two stripping and refinishing operations. neither set of "inside" samples exceeded the criterion for "clearance" of 70 s/sq mm by transmission electron microscopy (TEM), with averages of less than 18 and 31.6 s/sq mm for the two sites.

Based on the uniformly low occupational exposure levels, no additional floor tile maintenance studies were deemed necessary. Therefore, this study shows that OSHA's action level and excursion limit for exposure to asbestos fibers are not exceeded when performing floor tile maintenance activities in accordance with the Recommended Work Practices. Consequently, an employer should be able to rely upon these exposure results as historical data in lieu of conducting initial monitoring to satisfy the monitoring requirements of the OSHA standard (29 CFR 1910.1001(d)(2)(ii)) for maintenance of resilient floor tiles performed in accordance with Recommended Work Practices.

II. INTRODUCTION

In the past year, reports regarding potential exposures to asbestos fibers from the maintenance of asbestos-containing resilient floor tiles have been presented in the popular media.[2,3] Examination of the studies upon which those reports are based has revealed that appropriate floor maintenance procedures were not followed, adequate scientific control over the experimental methods was not exercised, and misunderstandings existed regarding the applicable regulatory requirements that bear upon control of occupational exposures and exposures to asbestos-containing materials. To provide a better evaluation of the potential exposure to airborne asbestos and other types of fibers when recommended maintenance procedures are followed, the Resilient Floor Covering Institute and Armstrong World Industries, Inc. requested ENVIRON Corporation to design and conduct a scientifically valid study of exposures to fibers during maintenance of asbestos-containing resilient floor tiles. Such tiles, although no longer manufactured, are installed in homes, institutions, and commercial or industrial establishments.

The sponsors have developed specific work practices recommended for floor maintenance that are to be used whether or not resilient floor tiles contain asbestos (see Appendix A). They also specifically recommend against very aggressive maintenance techniques that are no more effective than the recommended techniques but carry a greater potential for adversely affecting the appearance of the resilient floor tiles.

With the assistance of Industrial Health, Incorporated (which sampled air in the test areas before, during, and after maintenance) and the R. J. Lee Group, Inc. (which analyzed the samples for asbestos and other fibers), ENVIRON has designed and conducted experiments on maintenance of asbestos-containing floor tiles according to the manufacturers' recommended work practices. The design of the studies and the results available to date are discussed in the following sections; details of the sampling procedures and results of the fiber analyses for the individual sites studied are provided in a companion report.[4]

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[2] A.F. Meyer and Associates, Inc. (Meyer). 1989. Untitled report on study at Sligo Middle School, Montgomery County Maryland, performed for WRC-TV. McLean, VA: A.F. Meyer and Associates.

[3] Atlantic Environmental Incorporated (Atlantic). 1989. Untitled report of study at Ironia School, Ironia, NJ. for Randolph Board of Education. Dover, NJ: Atlantic Environmental Incorporated.

[4] ENVIRON Corporation (ENVIRON). 1990. Supporting data for evaluation of exposures to airborne fibers during maintenance of asbestos-containing resilient floor tiles using recommended work practices. Arlington, VA: ENVIRON.

III. FLOOR TILE MAINTENANCE

ENVIRON's study design included the three principal types of maintenance performed routinely on resilient floor tiles: spray buffing, wet scrubbing, and wet stripping followed by refinishing.

Floors showing only moderate wear and soiling on a buffable finish can be buffed with a floor machine equipped with a low-abrasion pad (equivalent to the 3M red pad). Such floors are first sprayed with a small amount of a buffing solution (diluted floor finish). Buffing continues only until the surface soiling is removed.

Floors with somewhat more wear and soiling are candidates for wet scrubbing. The floor is first mopped with a dilute floor scrubbing solution, and then scrubbed with a low-speed (170-300 rpm) floor machine equipped with a moderately abrasive pad (equivalent to the 3M blue or green pads). This process removes some of the original finish but still does not penetrate to the bare tiles.

Severely worn floors are wet-stripped with a low-speed floor machine before being refinished. The process is very similar to scrubbing, except that a stripping solution is used and the time spent on each section of floor is longer. The objective is to remove the existing finish without adversely affecting the appearance of the underlying tile. If a sealer is used under the finish, stripping may be complete when the finish is removed but the sealer is still intact. The floor manufacturers specifically recommend against using the most abrasive pads (equivalent to 3M pads color-coded brown or black) when stripping any resilient floor tiles, including those containing asbestos. Once the floor is stripped, several coats of finish are mopped on, each being allowed to dry before the next coat is applied. The finishes today typically contain synthetic metal-cross-linked polymers.

Of the three types of procedures, spray buffing was assumed to be least aggressive and wet stripping most aggressive.

IV. REGULATORY FRAMEWORK

A. Federal Standards

At the federal level, three major regulatory structures govern in-place asbestos-containing materials.

The Occupational Safety and Health Administration (OSHA) regulates worker exposures to asbestos in the manufacturing and construction industries. Floor maintenance involving asbestos-containing tiles is subject to the general industry standard.[5] The standard specifies that exposures to fibers should not exceed a Permissible Exposure Limit of 0.2 fibers per cubic centimeter (f/cc), expressed as an 8-hour time weighted average (TWA).[6] They should also not exceed an Excursion Limit of 1.0 f/cc over any 30-minute period. If these limits are exceeded, then various worker protection requirements are triggered (e.g., the use of respirators and the establishment of controlled areas). If worker exposures are expected to exceed an Action Level of 0.1 f/cc as a TWA, then initial monitoring requirements for the job are triggered. Compliance with all of the OSHA requirements is measured by phase-contrast microscopy, which records all particles with fiber-like morphology (greater than 5 μm in length and having an aspect ratio greater than 3 to 1), whether or not they are in fact asbestos, as long as asbestos can be assumed to be present.

The National Emissions Standard for Hazardous Air Pollutants (NESHAP)[7] for asbestos is administered by the Environmental Protection Agency (EPA) and applies to renovation and demolition activities involving friable asbestos-containing material (ACM). This standard requires notification and certain procedures to be followed (e.g., wetting the work area, preventing "visible emissions") during renovations and demolitions of friable ACM. It is not expressed in terms of any measurement of ambient air quality near the affected operations. EPA has indicated that resilient floor tile, as manufactured, is not friable,[8] and it remains nonfriable when proper maintenance procedures are followed. When

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[5] 29 CFR 1910.1001.

[6] On July 20, 1990, OSHA proposed to lower the PEL to 0.1 f/cc (55 CFR 29722).

[7] 40 CFR 61, Subpart M.

[8] Farmer, J.R., J.S. Seitz, and M.S. Alushin. 1990. Memorandum on "Clarification of EPA NESHAP Policy - Nonfriable ACM." February 23.

following the recommended work practices for floor maintenance, therefore, the asbestos NESHAP would not apply to maintenance of floor tiles.

EPA also administers the Asbestos Hazard Emergency Response Act (AHERA) that covers asbestos in schools; the implementing regulations[9] establish "clearance" monitoring following the cleaning of an area that has been subject to a "response action" involving ACM. Response actions entail abatement of friable ACM by removal, encapsulation, or enclosure.

Clearance monitoring, intended to measure the effectiveness of cleanup after a response action, entails use of transmission electron microscopy (TEM) and counts all asbestos fibers or structures containing fibers greater than 0.5 μm in length and with an aspect ratio exceeding 5 to 1. In addition to individual fibers, structures include bundles, clusters, and matrixes. Clearance testing is designed to determine whether air in an enclosed area that has undergone a cleanup following a response action has statistically significantly elevated levels of asbestos structures in comparison to air in nearby areas not affected by the response action; it is not a health-based or risk-based concept. An area in a school previously subject to a response action is considered clear under AHERA if the TEM counts averaged over five samples inside the area after the response action show no more than 70 structures per square millimeter (s/sq mm) on the filters (when at least 1200 liters of air are sampled). If the samples do not pass that test, which is based on the chance of finding some fibers even on presumably "blank" filters, they may still pass if their average is not statistically different (by a specified test, the "Z test") from the average of five samples taken outside the area where the response action took place. For defined small AHERA response actions, clearance can also be obtained if samples analyzed by PCM do not exceed 0.01 f/cc.

Because properly conducted floor tile maintenance is not an abatement and because the tile remains nonfriable, maintenance is not a response action under AHERA and therefore does not require clearance monitoring in schools or other regulated buildings. Thus, the only federal asbestos regulations that may apply to proper floor tile maintenance would be those of the OSHA asbestos standard for the construction industry. The EPA requirements under the asbestos NESHAP and the AHERA regulations (including clearance monitoring) are not applicable to proper maintenance of resilient floor tiles. For this reason, ENVIRON designed the current study to determine whether worker exposures exceeded the OSHA Action Level or Excursion Limit by PCM. Although clearance monitoring is not required by EPA regulations, ENVIRON also tested the residual levels of asbestos in rooms following

[9] 40 CFR 763.

proper stripping operations to determine whether they exceeded the "clearance" criterion of 70 s/sq mm by TEM. This testing was performed only because several of the studies of floor maintenance reported in the media used "clearance"-type testing.

B. State and Local Standards

Most state and local regulations deal with requirements for abatement of friable ACM (i.e., its remediation or removal) and with the qualifications of persons who can perform such abatements. Because intact resilient floor tiles are not friable and because floor maintenance is not an abatement activity, such regulations do not apply to proper floor maintenance.

V. STUDY DESIGN

In the expectation that stripping and refinishing would be the most aggressive operation. ENVIRON designed an initial study that featured sampling and analysis of fiber levels in three stripping operations, two buffing operations, and one scrubbing operation as an intermediate case (see protocol, Appendix B). In each case, the size of the work area was selected to ensure that a substantial portion of an 8-hour day could be monitored, so that time-weighting with asbestos-free exposures would have relatively little effect. If either of the latter two operations showed fiber counts higher than the stripping operations, additional studies could be recommended. Similarly, if any of the results suggested that any of the OSHA criteria might be exceeded under certain conditions within the recommended work practices for maintenance, additional tests could be recommended.

In all three types of operations, maintenance was performed by independent maintenance contractors, not by employees of the sponsors. Although the work areas were thoroughly cleaned prior to maintenance to minimize sources of asbestos unrelated to the maintenance, the floors were not specially prepared and were typical of floors requiring maintenance. The maintenance operations were carried out according to the recommended work practices (Appendix A). Table 1 shows the characteristics of the maintenance operations.

TABLE 1

Characteristics of Maintenance Operations

Type of Operation	Machine Speed (rpm)	Pad (3M Code)	Solution[a]
Buffing	360	Red	Over Drive
Scrubbing	220	Green	Sundance
Stripping	≤220	Green	Colonel Cutter

[a]Butcher product name

Worker exposures were monitored by placing personal samplers on two workers in each operation. (Some operations, particularly buffing, can be performed by one worker, but are sometimes performed by two.) Two companion samplers were placed on each worker, one with a filter designed for PCM analysis and one designed for TEM analysis. The protocol (see Appendix B) called for analysis of the PCM filter in all cases, but analysis of the TEM filter only if the PCM results exceeded the relevant OSHA criterion (0.1 f/cc for 8-hr TWA; 1.0 f/cc for 30-min excursion sample). Because occupational exposures are regulated by OSHA according to PCM results, the TEM measurements are not directly relevant. However, in floor maintenance where many non-asbestos fiber sources can be present, an elevated PCM reading is not necessarily indicative of elevated exposures to asbestos. The companion personal TEM samples were reserved only to determine whether any elevated PCM count observed was truly due to asbestos. To determine whether other sources of fibers were present in the maintenance area, a pair of overnight area samples was collected prior to maintenance. To determine whether other sources of fibers outside the area were present during the maintenance activities, a pair of peripheral area samples was collected concurrent with the maintenance. If an outside source of asbestos was suspected (e.g., demolition activity nearby), a pair of outside samples could be collected concurrent with the maintenance. Again, the companion TEM area samples were to be analyzed only if the PCM readings were elevated.

In the stripping operations, "clearance"-type samples were collected in response to the media reports, not because they were required by any federal or other regulation. The samples were collected in a fashion consistent with AHERA methodology,[10] to characterize any residual levels of fibers following completion of the stripping operation. Although not required in everyday stripping operations, critical polyethylene barriers were erected over openings to the maintenance area for test purposes only, to isolate the "inside" and "outside" samples. This practice also maximized the retention of any fibers inside the area and represented a worst case. "Aggressive" sampling, as set forth in the AHERA protocols and featuring use of a leaf blower to mobilize fibers on the floors and walls and use of a fan to keep fibers aloft, was used inside the area both before and after the stripping operations. A third set of samples was collected after maintenance outside the area, without aggressive techniques. In each of the three cases, five samples randomly distributed over the area were collected. A set of three blank filters was also submitted with each job. To conserve resources, the analysis proceeded in typical AHERA fashion: first, the five inside samples

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[10] 40 CFR 763, Appendix A to Subpart E

collected after maintenance were examined; if they passed the 70 s/sq mm test, no further analysis was undertaken. If they failed the test, the remaining samples were analyzed in the following order until the results were explained: blanks, outside samples, and pre-maintenance samples.

Examination of the studies on which the earlier media reports were based, coupled with previous experience by ENVIRON and IHI suggested that extreme care would need to be exercised to eliminate sources of fibers unrelated to the maintenance activities and potentially confounding the results. The protocol calls for use of areas in which no other significant sources of fibers, especially asbestos fibers, are suspected to be present. In particular, many buildings with resilient floor tiles containing asbestos also have ceilings made of asbestos-containing materials such as acoustical plaster or acoustical tiles. Even in areas free of such materials, furnishings such as rugs and drapes can be significant sources of non-asbestos fibers that could register as fibers with PCM analysis. The selection process therefore attempted to exclude areas with suspect materials. It also featured extensive precleaning of the areas prior to overnight monitoring and subsequent maintenance activities to remove any fibers due to other activities preceding the maintenance but, as stated above, no other special preparations of the floor.

Finally, the ENVIRON team determined the asbestos content of the tiles at each site. It is known that asbestos content of tiles varied over the period they were manufactured. Therefore, ENVIRON specified that tiles must contain at least 10% asbestos, assured by positive identification of tile type or by bulk sampling. To avoid questions about positive identification, the tile was always bulk sampled, and some sites were rejected because the nominal asbestos content could not be confirmed. Confirmation was accomplished in as many as three stages: polarized light microscopy (PLM), which is least able to distinguish asbestos, was used first; if PLM did not reveal 10% asbestos, scanning electron microscopy (SEM) or x-ray diffraction analysis (XRD) was used. If none of these techniques could confirm the nominal content, the site was rejected.

VI. RESULTS

To date, two qualifying sites have been monitored for wet stripping and refinishing operations and one each for wet scrubbing and spray buffing. All of the sites are in Pennsylvania near Armstrong facilities in Lancaster, and include three churches and one sporting club. Individual reports prepared by IHI covering the site description and a detailed presentation of the sampling procedures and findings can be found in the companion report,[1] as can the results of the fiber analyses conducted by R. J. Lee.

The results from the four tests are summarized in Table 2.

None of the samples of worker exposure exceeded the OSHA criteria (0.1 f/cc as an 8-hr TWA; 1.0 f/cc as a 30-min Excursion Limit) by PCM analysis. Therefore, none of the TEM samples was analyzed and the levels seen prior to maintenance or on the periphery of the area are irrelevant. The highest TWA by PCM was 0.0416 f/cc, less than half the OSHA action level, for a worker performing stripping and refinishing. The highest TWA for scrubbing was 0.0365 f/cc, and the highest for buffing was 0.0197 f/cc. Thus, the general trend expected was seen. However, some of the stripping measurements were below those for scrubbing. Overall, the average TWA for all types of maintenance was 0.0248, one-fourth of the OSHA action level (eight measurements). The highest excursion level by PCM was 0.2313 f/cc, less than one-fourth of the OSHA excursion limit. The average of the four excursion samples was 0.1302 f/cc, approximately one-eighth of the excursion limit.

For the two stripping and refinishing operations monitored after completion of maintenance by TEM for "clearance," neither set of "inside" samples exceeded the criterion of 70 s/sq mm established in ENVIRON's protocol by analogy to the AHERA procedure. The church showing the lower worker exposures also showed the lower TEM values, which averaged less than 18 s/sq mm. The other church showed values averaging less than 31.6 s/sq mm. Neither of these results is considered statistically different than filter background, and so it was not necessary to analyze blanks, "outside" samples, or premaintenance samples.

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[1] ENVIRON Corporation (ENVIRON). 1990. Supporting data for evaluation of exposures to airborne fibers during maintenance of asbestos-containing resilient floor tiles using recommended work practices. Arlington, VA: ENVIRON.

TABLE 2

Summary of Exposures to Fibers During Maintenance of Asbestos-Containing Resilient Floor Tiles

Site[a]	Procedure	Level (PCM, f/cc)	8-hr TWA (PCM, f/cc)	Excursion (PCM, f/cc)	"Clearance" (TEM, s/q mm)	Tile Content[b] (% Asbestos)
CLC	Wet Stripping & Refinishing	0.0139 0.0187	0.0149 0.0197	0.0641	< 18.0	20
MCB	Spray Buffing	0.0213 0.0210	0.0138 0.0138	0.0593		10
CFG	Wet Scrubbing	0.0372 0.0241	0.0365 0.0237	0.1661		10
SJC	Wet Stripping & Refinishing	0.0353 0.0435	0.0343 0.0416	0.2313	<31.6	10

[a] CLC = Covenant Lutheran Church (more than 8-hr samples)
MCB = Mountville Church of the Brethren
CFG = Columbia Fish & Game
SJC = St. Joseph's Catholic Church

[b] Maximum of reported values

Although the original protocol called for two additional sites to be monitored (one spray buffing operation and one stripping operation), ENVIRON and the sponsors found it difficult to find sites that met all the criteria of the protocol. In particular, it was difficult to find sites in which the floor tile contained substantial amounts of asbestos while no other sources of asbestos were present. Buildings that were finished when asbestos content in tiles was relatively high also were likely to feature asbestos-containing ceiling materials or other asbestos-containing materials. To provide useful information on exposures to fibers during floor tile maintenance as early as possible, the sponsors decided to suspend further sampling after the completion of four site studies.

One stripping operation not included in the above summary was conducted before the protocol had been fully implemented. When the IHI and ENVIRON monitoring team arrived on the scene, the ceiling in the maintenance area was identified as an acoustical plaster of unknown composition. Rather than abort the monitoring, as the final protocol would have required, the monitoring of this site proceeded pending evaluation of the ceiling material; samples of the ceiling material were collected in addition to the usual bulk samples of tile. When the samples were analyzed, the ceiling was found to contain up to 25% asbestos by PLM analysis, featuring fiber lengths similar to those in the floor tile. As this ceiling material could well have been disturbed by the aggressive sampling procedures and to a lesser extent by the maintenance and monitoring activities, it was not surprising to find that all three sets of "clearance"-type samples showed elevated counts of short fibers by TEM analysis. To test this hypothesis, a second monitoring of the church was conducted a short time later, *without* aggressive techniques. All three sets of samples--inside the area, immediately outside the area, and remote--passed the 70 s/sq mm test in this second monitoring series. As the protocol had clearly been violated for this site, its results are not included in this report. It should be noted, however, that the PCM counts for the workers were among the lowest recorded, averaging 0.0180 f/cc as a TWA and 0.0604 as an excursion level, thus supporting the assumption that aggressive sampling may have been responsible for the elevated postmaintenance results. Reports from IHI and R. J. Lee regarding this unacceptable site are included in the companion report.[12]

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[12] ENVIRON Corporation (ENVIRON). 1990. Supporting data for evaluation of exposures to airborne fibers during maintenance of asbestos-containing resilient floor tiles using recommended work practices. Arlington, VA: ENVIRON

VII. CONCLUSIONS

Based on this analysis of available results from monitoring of resilient floor tile maintenance activities for exposures to asbestos and other fibers, ENVIRON concludes that exposures to fibers experienced by workers conducting resilient floor tile maintenance according to work practices recommended by the sponsors did not exceed the OSHA action level or excursion limit from the general industry asbestos standard for protection of workers. Although federal standards promulgated by EPA are not applicable to floor maintenance and clearance monitoring is not required, the ENVIRON criterion based on the EPA AHERA "clearance" criterion was also not exceeded when maintenance was carried out according to the recommended work practices. This finding implies that there were negligible residual fiber levels in the areas after maintenance.

Non-conforming work practices were not monitored in this study and conclusions regarding them cannot be reached. Furthermore, comparison of the results in this report to those reported elsewhere suggests that anomalously high fiber counts can be obtained and incorrectly ascribed to floor maintenance if extreme care is not exercised in excluding other possible sources of asbestos and other fibers.

APPENDIX A

Recommended Work Pracuces for Maintenance of Floor Tiles

APPENDIX A-1

Recommended Work Practices for Maintenance of Floor Tiles

Resilient Floor Covering Institute (February 1990)

MAINTENANCE OF VINYL COMPOSITION (WITH OR WITHOUT ASBESTOS) AND ASPHALT TILE FLOORS

RESILIENT FLOOR COVERING INSTITUTE

966 Hungerford Drive • Suite 12-B
Rockville, MD 20850

STANDARD MAINTENANCE

CAUTION:

DO NOT DRY BUFF, SPRAY BUFF OR BURNISH VINYL COMPOSITION (WITH OR WITHOUT ASBESTOS) OR ASPHALT FLOOR TILE WITHOUT PRIOR APPLICATION OF A METAL CROSS-LINKED ACRYLIC FINISH WHICH IS RESISTANT TO NEUTRAL CLEANERS. DO NOT DRY STRIP UNDER ANY CONDITIONS.

WHEN WASHING, WAXING OR STRIPPING TILE FLOORS, TRAFFIC SHOULD BE EXCLUDED FROM THE AREA BECAUSE WET FLOOR SURFACES ARE USUALLY SLIPPERY. THE USE OF IMPROPER WAXES AND FINISHES CAN CAUSE PROBLEMS SUCH AS SLIPPERINESS AND DIRT ACCUMULATION.

GENERAL

Other than sweeping or mopping, cleaning of tile floors must always be performed by keeping the surface wet with a neutral liquid floor cleaner. Buffing or burnishing of these floor tiles shall be performed only after three to five coats of a metal cross-linked acrylic finish has been applied to the surface of the tile. The use of a sealer prior to application of floor finish is optional. In addition, removal of finish shall always be performed by keeping the surface wet at all times during the stripping procedure using a liquid stripper solution.

The least abrasive stripping or burnishing pads and brushes recommended for each specific operation shall be used to maintain the floor tile. Pads are color coded to indicate their proper use, with manufacturers generally using the following color code:

- Polishing (least abrasion)
  - White or equivalent
- Buffing (low abrasion)
  - Tan or red or equivalent
- Scrubbing/Stripping (moderate abrasion)
  - Blue or green or equivalent

The most abrasive pads, brown and black pads or equivalent, are not recommended for use on resilient flooring.

GRIT CONTROL

Preventing abrasive dirt from being tracked onto the surface of a flooring is crucial to prolong the life of the flooring. The use of walk-off mats at entrances to buildings is an effective way to help prevent scratches and stains caused by tracked-in materials from outside the building. Non-staining mats are recommended and should be the type that remove deposits from shoe soles and allow the particles to fall below the surface of the mat so they can't be tracked on to the flooring with subsequent traffic. Mats should be cleaned on a regular basis consistent with need.

NEW FLOORS

Allow sufficient time after installation (at least one week) for the tile to adhere tightly to the subfloor before scrubbing or initial maintenance. In the interim, maintain with a non-oily dust mop or a clean soft hair push broom. In heavier traffic areas, such as building entrances and cafeterias, damp mopping may also be necessary. Spots of adhesive can be removed by rubbing with a synthetic pad dampened with a *mild liquid* detergent. Rinse area thoroughly with clean water and dry.

INITIAL MAINTENANCE

After a week, clean with a non-oily dust mop or a clean soft hair broom to remove all loose debris. Using a neutral liquid floor cleaner as recommended by the flooring manufacturer, scrub the floor with a commercial scrubbing machine of 170-250 rpm capability equipped with a moderately abrasive scrubbing pad (blue or green pad or equivalent) or brush. Brushes are recommended for flooring that have embossed surfaces. Keep flooring wet at all times during the scrubbing procedure but do not flood the floor. Remove gummy matter or spots of adhesive residue with a putty knife and stubborn spots with a synthetic pad dipped in detergent. Pick up cleaning solution with a mop or wet vacuum.

Some manufacturers of liquid floor cleaners claim rinsing is not necessary after washing a floor. However, in order to thoroughly remove the washing solution from a floor, it is best to rinse the floor with clean water after washing followed by use of a wet pickup vacuum or damp mop.

Note: Automatic scrubbing machines are available and perform washing, rinsing and pickup in one operation and are recommended for very large areas.

APPLYING FINISH

After the flooring has been cleaned, apply three to five coats of a good quality metal cross-linked liquid acrylic finish that is resistant to water spills and is non-removable by a neutral floor cleaner. The use of sealers on new flooring prior to application of finish is optional depending on the finish being used. Allow sufficient time for thorough drying of each coat of finish before applying additional coats. Apply finish with an applicator as recommended by the manufacturer.

SCRUBBING A FINISHED FLOOR

Follow instructions as found under initial maintenance using a *neutral* floor cleaner and a scrubbing machine of 170-250 rpm capability equipped with a moderately abrasive scrubbing pad (blue/green pad or equivalent) or brush. Remember to keep the floor surface *wet* with the cleaning solution at all times while machine scrubbing. Avoid flooding the floor. Remove the cleaning solution from the floor with a mop or wet vacuum. Rinse with clean water and dry.

RESTORING GLOSS TO A FINISHED FLOOR

After a *finished* floor is cleaned with a neutral floor cleaner, rinsed and dried, it may be buffed or burnished to restore gloss using a low abrasive pad (tan or red pad or equivalent). In high traffic areas, a sparse application of a diluted liquid finish may be sprayed on the floor and buffed while wet until glossy. The manufacturer of the finish should be contacted to provide information relating to type of spray buffing solution, and maximum rpm buffer recommended for spray buffing.

CAUTION: ***DO NOT DRY BUFF, SPRAY BUFF OR BURNISH AN UNFINISHED FLOOR OR A FLOOR WHERE THE PROTECTIVE FLOOR FINISH IS THIN OR HAS BEEN WORN OFF.*** **THIS WILL BE APPARENT IN AREAS OF HIGH TRAFFIC. SUCH AREAS SHOULD BE RECOATED PERIODICALLY.**

STRIPPING OFF OLD FINISH

Complete removal of a finish from the surface of the flooring is required when dirt and discoloration can no longer be removed when cleaned with a neutral floor cleaner. Too many coats of finish may cause discoloration and will require complete removal in order to restore the original appearance of the floor covering. Stripping should not be done more often than is absolutely necessary.

Vacuum or sweep to remove loose debris. To strip or remove finish, use a finish or stripping solution recommended by the manufacturer of the finish. Apply the stripping solution to 10'x10' section of the floor at a time. Allow to soak for a few minutes before scrubbing. Scrub the floor with a scrubbing machine of 170-[illegible]0 rpm capability equipped with a moderately abrasive stripping pad or brush, such as a blue or green pad or equivalent. (See Note on Page 4). **Keep the floor wet with stripping solution at all times during the scrubbing procedure.** Pick up scrubbing solution with a mop or wet vacuum, rinse and dry.

CAUTION: ***DO NOT DRY STRIP FLOOR FINISH UNDER ANY CONDITIONS.*** **THE USE OF THE MOST ABRASIVE PADS, (BROWN AND BLACK PADS OR EQUIVALENT) ARE NOT RECOMMENDED IN ANY BUFFING, SCRUBBING, BURNISHING OR STRIPPING OPERATION INVOLVING RESILIENT FLOORING.**

Continue removing finish in this manner in remaining areas of floor. After entire floor has been treated in this manner, inspect for areas where finish has not been removed. Repeat procedure if necessary.

After finish has been completely removed apply three to five coats of floor finish as recommended in Applying Finish Section in this document.

NOTE: Special finishes are available for use where qualities such as high resistance to slip and static dissipative electrical resistance are required. Follow the manufacturers recommendations to apply and maintain these finishes.

OLD FLOOR COVERING

Follow directions found under "Stripping Off Old Finish" (above) to prepare the surface for application of new finish. Then follow application instructions, cleaning and gloss restoration of finished floors specified earlier in this document.

NOTE:

IN INTERIM GUIDANCE DATED JANUARY 25, 1990, THE U.S. ENVIRONMENTAL PROTECTION AGENCY RECOMMENDS THAT THE SCRUBBING MACHINE OPERATE AT 175-190 RPM WHEN STRIPPING ASBESTOS-CONTAINING FLOOR COVERINGS. ON JULY 20, 1990, THE U.S. OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION ("OSHA") PROPOSED THAT THE SCRUBBING MACHINE OPERATE AT 190 RPM OR LESS, ALTHOUGH THIS PROPOSAL IS NOT FINAL. HOWEVER, RFCI HAS CONDUCTED MAINTENANCE TESTS USING SCRUBBING MACHINE SPEEDS OF UP TO 220 RPM, WHICH SHOW EXPOSURE MEASUREMENTS SUBSTANTIALLY BELOW APPLICABLE OSHA EXPOSURE REQUIREMENTS WHEN THE ABOVE MAINTENANCE WORK PRACTICES ARE FOLLOWED.

RESILIENT FLOOR COVERING INSTITUTE

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This publication replaces prior editions of these maintenance procedures. Future editions of these procedures may be issued to replace this publication.

Revised April 1983
Revised April 1987
Revised August [illegible]

APPENDIX A-2

Recommended Work Practices for Maintenance of Floor Tiles

Armstrong World Industries, Inc. (March 1990)

Armstrong

Commercial Resilient Flooring Maintenance Recommendations

General Maintenance Information

A good maintenance program helps insure a long, attractive life for commercial resilient flooring. Walk-off mats, sweeping, mopping, polishing, and buffing protect more than just the floor—they protect the building owner's investment as well.

To insure that maintenance is considered early in the specification process—as part of the initial investment—Armstrong has developed this commercial resilient flooring maintenance reference guide. It discusses a variety of maintenance techniques—including do's and don'ts—and offers insight into problems that every specifier, building owner, and maintenance staff must address regularly.

Early awareness of required maintenance procedures can be useful in selecting the proper floor for the space and protecting the owner's investment. Refer to the individual maintenance tip sheets located in the inside back cover of this folder for recommended maintenance procedures for specific Armstrong commercial floors.

Grit Control

Controlling grit is crucial to prolonging the attractive appearance of any floor. The best way to control grit is simply by using walk-off mats.

Recommended mats have a high friction open surface designed to knock grit particles from the bottoms of shoes and then trap the particles.

Ideally, mats should be used at every entrance and should be at least as wide as the doorway and approximately 8'-12' long.

And don't forget — mats have to be cleaned too. They should be shaken and/or hosed off thoroughly and frequently. AND be sure to select a mat with a backing that won't stain the floor.

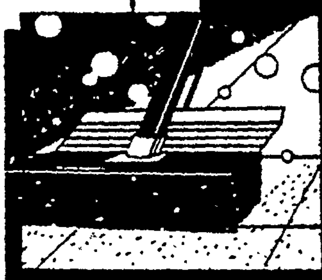
Walk-off mats won't eliminate gritty dirt completely. Fine dust particles (which are [illegible]) will still find their way into interior floors. Regular vacuuming, sweeping and dust mopping will help control this type of grit.

Dust mopping is the most cost-effective method. Using a treated mop (non-oily) is the best procedure. Mop heads are washable and reusable.

Floor Cleaning

Cleaning a floor can range in thoroughness from a simple damp mopping to a complete stripping.

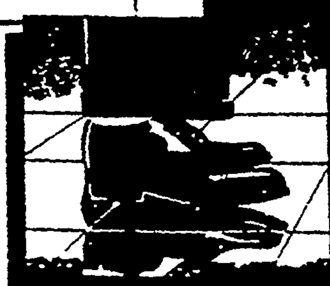
Damp mopping is appropriate for cleaning up dust and dirt or to remove soil. The detergent solution must be changed frequently to eliminate redepositing of dirt on the floor. This procedure can minimize the need for more time-consuming maintenance procedures.



Wet scrubbing is a must when heavy soiling is a problem. It requires application of a nonstripping cleaning solution followed by scrubbing and rinsing of the floor. This procedure uses either a single-disc floor machine and wet vac or an automatic floor machine. (Red, blue, or green pad)

The automatic floor machine is totally self-contained, so it applies solution, scrubs the floor, and takes up the dirty solution all at one time. It is available in several sizes and can be fitted with pads or brushes. The single-disc machine requires separate equipment for each of the washing steps.

Floor Polishing



Floors are polished for three reasons:

1. Protection
2. Appearance
3. Ease of Maintenance

Today, the best polish for protecting and enhancing many commercial vinyl floors is a high-quality metal cross-linked acrylic floor polish.

Available from virtually any janitorial supply house, these polishes contain various percent solids levels, most commonly 18% - 22%. They are preferred because of their durability and resistance to detergent solutions (except stripping solutions). But they are easy to remove when stripping is desired.

A *minimum* protective layer (3 - 5 relatively thin coats) is required. The level of polish is best maintained by spray buffing or burnishing (dry buffing). Heavy-traffic areas will require periodic supplementary coats. This protective layer keeps spills, scuffs, and potential stains from reaching the flooring beneath.

A variety of cross-linked acrylic floor polishes are available. The ideal polish would combine durability, buffability, and easy removal.

"No-Wax" Commercial Maintenance

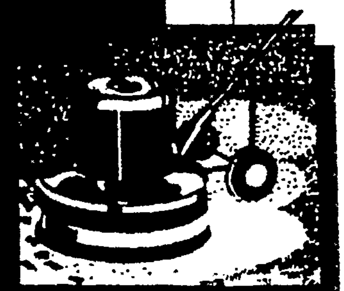
Very few commercial floors can be recommended for no-wax maintenance. The no-wax process generally relies on buffing the surface of the floor to temperatures almost at the melting point. As the vinyl softens, small surface scratches and irregularities are smoothed, leaving the floor shiny. But softening allows detergent residue and dirt particles to become imbedded in the surface. With time, the floor can become discolored in such a way that it cannot be easily cleaned.

Sealing

Sealing is optional. However, if the polish manufacturer recommends use of a sealer, his recommendation should be followed.

Stripping

Stripping is the removal of all dirt and old polish from the floor, exposing the original surface. Use of a strong, highly alkaline detergent solution followed by scrubbing with a moderately (green) abrasive pad or brush is the usual procedure. There are also mop-on stripping solutions which do not require machine scrubbing. The use of these high solvent content strippers (no rinse/no scrub) is not recommended on tile floors less than two years old because they may affect the adhesive system. The soil solution is picked up with a wet vac or mop and the floor is thoroughly rinsed. This process is repeated until all of the old polish is removed. Do *NOT* perform dry stripping.



Stripping is the most labor intensive and, therefore, the most expensive floor maintenance procedure. It should not be done more often than is absolutely necessary. A well-trained maintenance staff using good quality equipment and products on a regular schedule can significantly reduce the need for stripping.

Typical Problems and Causes

Streaks	■ too much or too little floor polish applied in one coat ■ dirty mop used to apply polish ■ inadequate drying time allowed between coats
Floor Polish Powdering	■ acrylic type polish applied over wax type polish ■ floor not thoroughly rinsed after stripping ■ dirty mop used to apply polish ■ surface of polish dried too quickly ■ inadequate [illegible] control ■ [illegible] polish
Traffic Lane Whitening	■ dark floors enhance contrast between the floor and normal white scratches ■ dark floors used in heavy traffic areas and not adequately maintained
[illegible] Sticking	■ [illegible] polishing ■ furniture left in place while polish applied NOTE: [illegible]
Lost Gloss	■ excessive alkaline moisture permeating through tile from concrete subfloor ■ installation of floor over suspended concrete pan construction where the moisture has been sealed in by the use of an incorrect concrete curing compound
Rapid Black Marking	■ little or no protective polish ■ polish being removed through the use of alkaline cleaners ■ overly abrasive floor machine pads and brushes ■ poor quality brush
Bleeding of Brightly Colored Vinyl Composition Tile	■ too little floor polish ■ cleaning/stripping solutions too aggressive ■ colored pigments removed by abrasion from coarse stripping or scrubbing pads

Maintenance Glossary

Automatic Floor Machine

A self-contained, single- or multiple-disc floor machine that dispenses cleaning solution, scrubs the floor, and takes up the spent solution, leaving a dry floor. Available in a variety of sizes; they can be equipped with pads or brushes.

Buffing/Burnishing of Polishes or Finishes

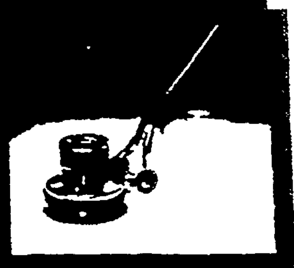
The process of making the polish or finish smooth and glossy by friction. Care must be taken to combine the proper pads or brushes with the proper machine speed and the recommended polish or finish to produce the desired result. The rpm of buffing machines and the selection of pads should be as recommended by polish/finish manufacturer.

Finish

The final (semipermanent) protective coating. The term "finish" is often used interchangeably with "polish" and "wax."

Floor Machine

A single disc machine that can be equipped with either pads or brushes and can be used for both scrubbing and buffing (170 - 300 rpm).



Floor-Machine Brush

A circular brush with bristles of varying stiffness and abrasiveness, depending on whether it's to be used for buffing, scrubbing, or stripping. Bristles are made of natural fibers or grit-impregnated nylon.

Sealer

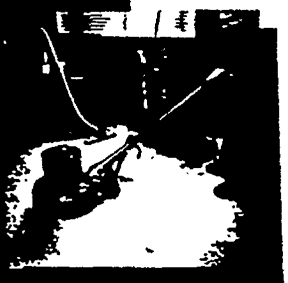
(for resilient floors) A medium to low percent solids, metal cross linked acrylic sealer used on very porous floors to help smooth out the surface prior to the application of floor polish. If polish manufacturer recommends the use of a sealer as part of their maintenance program, it should be used.

Spray-Buffing

The application and buffing of a dilute floor polish or a specially formulated spray-buffing compound. This procedure is especially useful in high-traffic areas. The liquid is sprayed on the floor and then immediately buffed with a floor machine, using a tan or red pad or buffing brush, until it is dry. This helps reduce the need for stripping by protecting the base coat of polish.

Stripper

A strong, generally highly alkaline detergent designed specifically for the removal of floor polish.

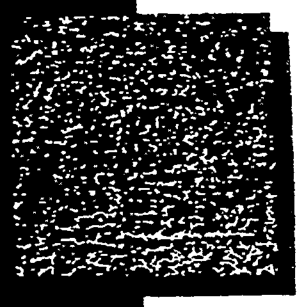


Ultra-High-Speed Buffer

A buffer (usually single-disc) that operates 1100–2000 + rpm. The machine does not ride on the buffing disc (natural fiber or white) or brush, and is operated in a push-pull method instead of sweeping motion. These buffers are powered by electric motors or propane-fueled engines. They allow for quick buffing and burnishing, helping to cut labor costs. They should be operated only by properly trained personnel.

Walk-Off Mats

A sheet of material placed at building entrances to remove gritty dirt from shoes. Good mats should also trap dirt, so it can't be picked up by subsequent traffic. The mats should be as wide as the doorway and ideally 8'–12' long.



Wax

A natural or synthetic substance that is physically and chemically similar to beeswax. Many years ago beeswax was the major constituent of floor polish and is still available in that form today for certain uses. Today, wax is mainly used as a minor constituent of metal cross-linked acrylic polish. Wax is frequently used interchangeably with the terms polish and finish.

Wet Vac

A vacuum cleaner that picks up water. It's particularly useful when wet scrubbing or stripping a floor.

Armstrong

Floor Machine Pad

A nonwoven nylon, polyester or natural fiber disc up to 1" thick with grit particles of various types and sizes bonded to the surface of the intertwined fibers. The coarseness of the pad determines its use: least coarse for buffing, medium coarse for scrubbing/stripping. Pads are color coded to designate their use. For example, manufacturers generally use the following color code:

Natural Fiber – Burnishing

White – Polishing

Tan, Red – Buffing (least coarse)

Blue, Green – Scrubbing, stripping (medium coarse)

Brown, Black – Not recommended for use on any Armstrong resilient flooring

High Speed Buffer

A single disc buffer designed to operate in the 300–1100 rpm range for the purpose of buffing and spray buffing. (Some machines are available that operate in the 1100–2000+ rpm range — see section on ultra high speed buffers.)

Metal Cross-Linked Acrylic Polish

An acrylic emulsion type polish that incorporates metallic salts (usually zinc). When dry, ionic cross links are formed between the polymer chains, giving the acrylic film added toughness and resistance to neutral detergents.

Neutral Cleaner

A mild detergent that does not contain any strongly alkaline materials. It is designed to remove soil, not floor polish.

Polish

A temporary protective coating which usually increases gloss.

Armstrong

Standard Excelon® and Premium Series

Commercial Vinyl Composition Tile

M A I N T E N A N C E   T I P S

Smart maintenance programs consist of thorough dirt and grit control, removal of spills and stains, and protection of the floor surface.*

Walk-off mats, sweeping, mopping, and vacuuming all help in the control of loose dirt and grit. Damp-mopping, spot-cleaning, and washing will remove most spills and stains. And polishing will give the floor a protective coating which can be periodically refurbished or removed when necessary.

Regular adherence to this type of program will assure a longer, more attractive life for the floor. Recognized quality name products should be used to insure consistency of performance.

*NOTE: Armstrong Excelon® SDT Static Dissipative Tile and Step Master™ Excelon Slip-Retardant Tile require specific maintenance procedures. Please refer to their tip sheets.

A. Initial Maintenance After Installation

1. Sweep or vacuum thoroughly.

2. Do not wash, scrub, or strip the floor for at least four to five days after installation. This is to prevent excess moisture from interfering with the adhesive bond and/or seam treatments. The floor may be cleaned after installation by damp-mopping with a very dilute neutral detergent solution, carefully scrubbing black marks and excessive soil.

3. As a temporary measure, apply a minimum of two coats of high quality, metal cross-linked, acrylic floor polish to protect the floor [illegible] regular maintenance procedures can be started.

B. Preparation for Commercial Traffic

1. Scrub the floor using a neutral detergent and a floor machine of 170-250 rpm capability equipped with a scrub brush or a scrubbing pad (3M blue or equal).

However, if the floor is badly soiled and scratched, strip it using the same procedure but substituting a stripping detergent.
NOTE: The use of high solvent content strippers (no-rinse/no-scrub) is not recommended on tile floors less than two years old.

2. Thoroughly rinse and allow to dry.
NOTE: Do not flood the floor with rinse water, scrubbing, or stripping solutions.

3. After the floor has been thoroughly stripped, rinsed, and dried, apply three to five coats of high quality, metal cross-linked, acrylic floor polish. The use of sealers is optional but may be recommended by the polish manufacturer. Allow at least 30 minutes' drying time between applications. Do not allow traffic on the floor for the length of time specified by the polish manufacturer.

C. Continuing Regular Maintenance

1. Sweep or dust-mop frequently. Use walk-off mats that are as wide as the doorway and long enough to trap dirt before feet reach the resilient floor. Clean the walk-off mats frequently.

2. Damp-mop the floor as appearance requires. Use a dilute, neutral-detergent solution. A light scrubbing with an automatic floor machine may also be performed.

3. After damp-mopping or light scrubbing, the floor may be spray-buffed or burnished (dry-buffed) to restore gloss.

a. To spray-buff, a dilute floor polish (7% to 8% solids) or a spray-buffing compound is sprayed onto the floor. Before the liquid can dry, it is buffed with a floor machine of 170 to 1100 rpm equipped with a buffing pad or brush. A thin, protective, glossy film remains after buffing the liquid dry. This procedure allows the base coat of polish to be protected, reducing the need for stripping. Severe traffic areas may require extra coats of polish on a more frequent basis.

b. Ultra-high-speed burnishing, utilizing a machine of 900 to 2000 rpm capacity, allows a large area to be buffed in a short period of time. This is a dry procedure done on a floor coated with a good base of polish specifically formulated for burnishing. Reapplications of polish are needed to maintain the base of polish. Operators of ultra-high-speed floor machines should be well-trained. Careless or improper use of these machines can result in severe and expensive damage to the floor.

D. Stripping

1. Use of good quality maintenance products and regular adherence to a quality maintenance program will greatly reduce the need for stripping. Stripping should be done only when necessary.

2. Procedures for stripping are outlined under Preparation for Commercial Traffic Part 1. This procedure should not be performed within the first four to five days after installation.

F-8664-10/89J

Quantification of Fiber Releases for Various Floor Tile Removal Methods

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Jerry Lauderdale,[C] *Kathy Schosek,*[B] *and Ronald F. Dodson*[B]

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The risk of human exposure from asbestos-containing material is directly related to the condition of the material, custodial/maintenance activities, and the methods used to reduce the potential exposure to workers, bystander employees, and occupants of the area containing the asbestos. Many consider floor tile to be nonfriable, which is in accordance with the National Emission Standards for Hazardous Air Pollutants regulations, although there is some documentation of fiber releases from deterioration of such asbestos-containing materials during polishing, removal, or routine walking, due to the friction generated by such activities. This study evaluates several commonly used procedures for removal of floor tile and quantifies the fibers released during those procedures using data obtained by analyses from phase contrast microscopy and analytical transmission electron microscopy. These data document that fibers are released when floor tile is broken and/or abraded during removal procedures. Fiber levels vary with the aggressiveness of the procedures. A considerable percentage of the asbestos fibers identified by the analytical transmission electron microscopy methods specified in the Asbestos Hazard Emergency Response Act are below the size that can be detected by phase contrast microscopy and which are also the most easily respired due to their physical characteristics. CROSSMAN, JR., R.N.; WILLIAMS, JR., M.G.; LAUDERDALE, J.; SCHOSEK, K.; DODSON, R.F.: QUANTIFICATION OF FIBER RELEASES FOR VARIOUS FLOOR TILE REMOVAL METHODS. APPL. OCCUP. ENVIRON. HYG. 11(9):1113–1124; 1996.

The risk of human exposures from asbestos-containing building materials is considered to be directly related to the condition of the material, degree of friability of the material, the asbestos content (percent), and the fiber size distribution within the product. An effective management strategy for reducing the potential of exposure must therefore include a physical inspection made by an accredited inspector to evaluate factors such as air movement, accessibility, vibration, and potential for disturbance based on the type of material (surfacing, thermal, miscellaneous).[1,2]

Floor tile, which is classified as miscellaneous material, poses a particular challenge for proper management since any asbestos is often finely dispersed within the matrix, and thus difficult to assess as to percentage by standard techniques using polarized light microscopy (PLM). Many floor tiles do contain asbestos, usually chrysotile, at levels up to 25 percent, but which may be reported as 1 percent or less by PLM analysis.[3–5] Therefore, asbestos fibers, because of their potentially thin diameters, require analytical transmission electron microscopy (ATEM) as the method of choice for accurate quantitation in air samples and some bulk materials.[6] This is particularly important in chrysotile-containing products where many fibrils below the limit of detection by light microscopy may become airborne and thus inhalable.[7] While it may be considered that the asbestos fibers in products such as floor tiles are bound and not easily released unless broken or crushed, Sebastien *et al.*, found that even under normal conditions of weathering, asbestos fibers were released into the environment.[8]

Although levels of asbestos in public buildings may usually be low, elevated levels of airborne asbestos can be expected when asbestos-containing material (ACM), including floor tile, is in poor condition or is disturbed by occupants and maintenance activities.[9] The Environmental Protection Agency (EPA) has reported asbestos fiber release from floor tile spray buffing operations in 12 of 17 schools in New Jersey.[10] The Occupational Safety and Health Administration (OSHA)[11] requires polishing of asbestos-containing floor tile to be conducted using least abrasive pads and polishers operating at 300 rpm or less.[11]

Limited numbers of other studies have been carried out to ascertain what fiber release occurs when asbestos-containing floor tiles are removed by procedures not utilizing negative pressure containment and wet methods as required under the Asbestos Hazard Emergency Response Act (AHERA)[12] for asbestos abatement in public schools. Unfortunately, these data are usually collected for personal exposure compliance purposes and not as part of a protocol in a scientific project. The published data often fail to describe condition, age, type of material, asbestos type and content, sampling information (volume and collection rate), filter pore size, and analysis protocols.

The EPA has published a guidance advisory[3] specifying that floor tile should be analyzed by ATEM, if it is reported to contain 1 percent or less asbestos by PLM. The OSHA regulation 1926.1101[11] places all floor tile installed in 1980 or earlier in the presumed ACM category, unless rebutted by a bulk sample analysis by a technically feasible method. However, a final rule to phase out distribution of vinyl asbestos tile (VAT) in the United States was declared invalid by the U.S. Court of Appeals in New Orleans; therefore, the manufacture, distribution, and importation of VAT are not restricted.[13]

The issue of potential exposure from the removal of floor tiles in public buildings can be addressed by either total containment procedures or through one of several other procedures, such as the suggested work practices published by the Resilient Floor Covering Institute (RFCI).[14] When federal or state regulations permit, selection of the removal technique is left up to building owners or their consultants. The decision may be made on the perception that total containment procedures are the most costly, without considering the potential health risk and liability risk. Total containment controls emissions and residue, while noncontainment may result in exposure to workers during the project and to occupants through reentrainment by subsequent activities.

The authors established a joint research investigation with the Texas Department of Health, which was designed to assess fiber release during floor tile removal in public buildings by a series of available procedures, monitored by phase contrast (light) microscopy (PCM) and ATEM. These data were quantified to compare the merits of each method, as well as the level of fibers detected by PCM versus ATEM in actual work place environments.

The Texas Asbestos Health Protection Rules, September 1994, §295.36,[15] provide an exemption from licensing and registration for persons removing resilient floor covering materials in public buildings, if those persons received training in an 8-hour course covering the elements in the document titled, *Recommended Work Practices for the Removal of Resilient Floor Coverings*, published by the RFCI in 1990.[14]

Methods

Study Design

The following general criteria were established for all field investigations during this study:

1. Locations for investigative procedures were evaluated by a licensed asbestos inspector to rule out the potential for asbestos contamination caused by friable and/or damaged ACM in the work areas. No sites were used which had any friable ACM or damaged ACM present in the area.
2. Each site was cleaned by high efficiency particulate air (HEPA) vacuum and/or wet wiping prior to the collection of baseline samples and the beginning of any work that was part of the test procedures. The baseline air samples were collected and analyzed by PCM (NIOSH 7400, Rev. 3,A rules) and ATEM.[2,16]
3. Bulk samples of floor tile and mastic were analyzed by PLM.[17]
4. Bulk samples of floor tile were analyzed by ATEM via the Chatfield Method.[18]
5. Each work site had critical barriers installed and was under a differential pressure of −0.02 inches water column. Two of the sites had polyethylene wall covering while the third site had full inverted containment consisting of a single layer of 4 mil polyethylene on the walls and ceiling. (The type of containment will be noted under specific procedures.) All work sites had a minimum of four air changes per hour within the critical barriers. During each specific procedure, the work area within the negative pressure enclosure was sealed using double flap doors taped closed so there was no air circulation by suction or discharge from negative air machines. The air flow was checked using smoke tubes, and there was no detectable flow observed. The exception for this is the full AHERA[2] procedure investigation, which was conducted with no restriction of flow through the work area. All locations had decontamination facilities.[11,19,20]
6. Three air samples were collected in the work area involved during each procedure. These were analyzed by PCM and ATEM. The relative location in each area was the same.
7. Outside samples were taken at negative air unit discharges and areas outside containment and were analyzed by both PCM and ATEM using the procedures cited in item 2 above.
8. Following the completion of the procedures being evaluated, each area was cleaned by HEPA vacuum/wet wiping and samples for clearance analysis were collected by aggressive methods.[2] These samples were also analyzed by PCM and ATEM.
9. After clearance was achieved, all remaining polyethylene was removed and disposed of as ACM and the areas were made available for reoccupancy following final cleaning.
10. All area air samples were collected on 0.45 μm pore size, mixed cellulose ester (MCE) filters with backup pads in 25-mm diameter conducting cassettes with 50-mm extension cowls. Staplex high volume pumps were used to collect the samples. The flow rates were 1 L/min to less than 10 L/min. Flow rates were checked at the start and end of each sampling period using an Asbestos Analytics rotameter, which was calibrated using a bubble burette as a primary standard.
11. All workers were EPA Model Accreditation Plan (MAP)[21] accredited and were experienced in asbestos abatement. The same workers were used at both sites of the urban school district and were employees of the school district. The workers conducting the procedures at the third site were furnished by another licensed asbestos contractor.
12. The Texas Department of Health is not an OSHA[11] enforcement agency and personal samples were not a part of this study. Personal samples were collected by the employer of the workers.

Abatement Methods

Removal of floor tile at the first site, designated as Room 10 (Figure 1), was conducted under AHERA[2] rules. This site, located inside a middle school building of a large urban school district, contained approximately 1000 square feet of floor tile, which was "flooded" each morning for 3 days preceding the removal. Gross removal was conducted using amended water and hand spud bars* to release the tiles from the floor. The 9 × 9 floor tiles had been installed 20 to 25 years before onto a concrete floor and were securely attached. Consequently, removal of the tiles required a great amount of force, which resulted in breakage of the tiles into many small pieces.

*A spud bar is a steel shaft approximately 2 inches in diameter, with a tapered, sharp end to work under the floor tile. Hand power may be used or the bar may be inserted in a pneumatic power unit, which causes the bar to operate in a hammerlike mode.

FIGURE 1. Urban middle school, room 10, AHERA removal.

There were three patterns of tile in Room 10. The predominant pattern was light blue-gray in color and occupied approximately 95 percent of the floor area in the room. Analysis by PLM of this tile showed an asbestos content of 4 to 6 percent; ATEM analysis found the amount of asbestos to be considerably higher, 16 to 23 percent. No asbestos was detected by ATEM analysis of the other two tile patterns. (See Table 1 for analytical results.)

The second site consisted of two rooms of an administrative building, which had previously been used as an elementary school, of the same urban school district. Room A (Figure 2) was approximately 1200 square feet and Room B was approximately 900 square feet. During this procedure, workers wore full personal protective equipment, which included Type C supplied air respirators. Personal samples were taken by the contractor in accordance with 40 CFR 763, Subpart G, Worker Protection.[20]

In Room A, floor tiles were removed initially using a hand-powered spud bar. Later, due to the difficulty in releasing the tile from the concrete floor, the pneumatic powered spud bar was used.

FIGURE 2. Urban administrative building, room A, dry pneumatic spud bar removal.

FIGURE 3. Commercial building, room 8, dry ice removal.

In Room B, floor tile was initially removed dry, using hand-held scrapers in accordance with the RFCI[14] work practices. This method for removal was extremely slow, and sufficient force to remove all pieces of the tile from the floor was not possible. Because the floor tiles were so firmly attached to the concrete floor, the procedures were changed and pneumatic powered spud bars were utilized for two sampling periods. Use of both the hand-held scraper and the pneumatic powered spud bar resulted in many very small sized pieces of detached floor tile. (Analytical results are in Table 2.)

The third location was in an unoccupied commercial building in East Texas, which contained approximately 1500 square feet. After this area was precleaned, critical barriers were erected, a single inverted polyethylene containment was erected for the walls and the ceiling, and differential pressure was established for the area. Work areas were separated and isolated from the air flow from the rest of the contained area by taped, double-flap doors. The approximate square footage of each work area was 175 to 220 square feet. At this site, methods for the removal of floor tile included heating, dry ice,

FIGURE 4. Commercial building, room 9 RFCI dry-hand-held scraper.

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11(9) SEPTEMBER 1996

TABLE 1. Floor Tile Removal by AHERA Regulations Urban Middle School, Room 10

Bulk Sample Analysis of Three Patterns of 9 × 9 Floor Tiles

ID	Description	PLM	ATEM
1	Tan tile	None detected	None detected
	Black mastic	None detected	—
2	Light blue-gray tile	4–6% Chrysotile	16–23% Chrysotile
	Black mastic	1–2% Chrysotile	—
3	Dark/light green tile	None detected	<1% Chrysotile
	Yellow mastic	Insufficient sample	—

Baseline air samples

ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
B-1	Inside containment	750.5	0.046	0.012	0.012	<0.006
B-2	Inside containment	750.5	0.057	0.006	0.006	<0.006
B-3	Inside containment	918.3	0.056	0.026	0.020	0.006

AHERA Procedure

ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
A-1	Inside containment	741.0	0.042	0.24	0.22	0.025
A-2	Inside containment	731.5	0.022	0.13	0.12	0.012
A-3	Inside containment	950.0	0.027	0.093	0.087	0.006
A-4	Outside hallway	630.0	0.062	—	—	—

Clearance (Samples for comparison were collected within two feet of the contractor's clearance samples and reported as follows)

ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
C-1	Inside containment	1630.0	0.19	0.011	0.008	0.003
C-2	Inside containment	1610.0	0.22	0.009	0.009	<0.003
C-3	Inside containment	1590.0	0.21	0.006	0.006	<0.003
C-4	Outside containment	1470.0	0.34	—	—	—

NOTE: More than 12 hours elapsed between the completion of removal and the collection of the "clearance" samples.

and hand-held scraper RFCI[14] work practices. Removal of mastic was accomplished by amended water/long-handled floor scraper and Abatix 007 mastic remover (Table 3).

Following is a description for work in each of the areas where the investigation was conducted at the third location:

Room 7: Floor tile was removed by heating the surface with hand-held propane torches to make it pliable. Many of the tiles did not readily release from the floor and were broken during their removal from the floor with hand-held scrapers. (See Table 3A for analytical results.)

Mastic was removed after a settling period by RFCI[14] work practices, using amended water to wet the mastic and a long-handled floor scraper to peel the ridges down so that the floor would be suitable for installation of a new tile floor. A HEPA wet vacuum was used to pick up the residue and the floor was mopped to clean it. (See Table 3B for analytical results.)

Room 8: The floor tile in this room (Figure 3) was removed by dry ice cooling to release the dry tiles and/or mastic. A 2-inch thick layer of dry ice was placed in an approximately 2 × 5 foot movable frame, with a polyethylene bottom. The dry ice was left at each location for approximately 3 to 4 minutes. Measurements of carbon dioxide (CO_2) levels were made using a Dräger pump and direct indicating CO_2 tubes about 2 feet above the floor and above the frame. The highest level of CO_2 measured at this location was approximately 2500 ppm. The level of CO_2 found in the worker breathing zone was approximately 1000 ppm. The CO_2 level decreased rapidly as one moved a greater distance above the floor and from the frame. (See Table 3C for analytical results.)

Room 9: The floor tile in Room 9 (Figure 4) was removed using the hand-held scrapers in accordance with the RFCI[14] recommended work practices. (See Table 3D for analytical results.)

TABLE 2. Floor Tile Removal by Dry Hand Spud Bar, Dry Pneumatic Spud Bar, and Dry Hand-held Scraper (RFCI),[14] Administrative Building in an Urban School District

Bulk Sample Analysis of Three Patterns of 9 × 9 Floor Tiles

ID	Description	PLM	ATEM
A	Red Tile	10–15% Chrysolite	24–29% Chrysolite
	Black Mastic	5–7% Chrysolite	—
B	Gray Tile	10–15% Chrysolite	24–36% Chrysolite
	Black Mastic	3–5% Chrysolite	—
C	Brown Tile	7–10% Chrysolite	23–34% Chrysolite
	Black Mastic	2–4% Chrysolite	—

Baseline Air Sample (collected only in Room B due to activity in Room A)

ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
1-A	Rm. B, NW quarter	1479	0.042	0.003	0.003	<0.003

Room A—Dry Hand Spud Bar

ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
2-D	SW third	292	0.021	0.74	0.63	0.11
2-E	S middle	322	0.040	1.2	0.98	0.20
2-F	N middle	284	0.062	1.3	1.1	0.16

Room A—Dry Pneumatic Spud Bar (Day 1)

ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
2-I	SW third	248	0.079	6.4	5.7	0.70
2-J	S middle	228	0.12	6.0	5.4	0.57
2-K	N middle	204	0.12	8.3	7.6	0.73

Bulk Sample Analysis of Three Patterns of 9 × 9 Floor Tiles

ID	Description	PLM	ATEM
A	Red Tile	10–15% Chrysolite	24–29% Chrysolite
	Black Mastic	5–7% Chrysolite	—
B	Gray Tile	10–15% Chrysolite	24–36% Chrysolite
	Black Mastic	3–5% Chrysolite	—
C	Brown Tile	7–10% Chrysolite	23–34% Chrysolite
	Black Mastic	2–4% Chrysolite	—

Baseline Air Sample (collected only in Room B due to activity in Room A)

ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
1-A	Rm. B, NW quarter	1479	0.042	0.003	0.003	<0.003

(continued)

Table 2. Continued

Room A—Dry Hand Spud Bar

ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
2-D	SW third	292	0.021	0.74	0.63	0.11
2-E	S middle	322	0.040	1.2	0.98	0.20
2-F	N middle	284	0.062	1.3	1.1	0.16

Room A—Dry Pneumatic Spud Bar (Day 1)

ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
2-I	SW third	248	0.079	6.4	5.7	0.70
2-J	S middle	228	0.12	6.0	5.4	0.57
2-K	N middle	204	0.12	8.3	7.6	0.73

Room A—Dry Pneumatic Spud Bar (Day 2)

ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
3-D	S middle	446	0.082		Not analyzed/overloaded	
3-E	N middle	483	0.11		Not analyzed/overloaded	
3-F	SW third	446	0.14		Not analyzed/overloaded	

Room B—Dry Hand-held Scraper (RFCI Work Practices[14])

ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
2-A	W middle	760	0.032	1.3	1.3	0.066
2-B	NW quarter	929	Torn	—	—	—
2-C	E middle	890	0.033	1.0	0.97	0.046

Room B—Dry Pneumatic Spud Bar (Day 1)

ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
2-L	W middle	70	0.088		Volume too low	
2-M	NW quarter	70	0.074		Volume too low	
2-N	E middle	70	0.074		Volume too low	

Room B—Dry Pneumatic Spud Bar (Day 2)

ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
3-A	E middle.	437	0.11		Not analyzed/overloaded	
3-B	NW quarter	446	0.092		Not analyzed/overloaded	
3-C	W middle	469	0.093		Not analyzed/overloaded	
3-I	E middle	582	0.094		Not analyzed/overloaded	
3-J	NW quarter	582	0.048		Not analyzed/overloaded	
3-K	W middle	582	0.059		Not analyzed/overloaded	

NOTE: The containment area was cleared by the owner upon completion of all work that disturbed ACM. No samples were collected as part of this study.

TABLE 3. Floor Tile Removal By Propane Torch Heat, Hand-held Scraper (RFCI),[14] Dry Ice, and Mastic Removal by Abatix 007 or Amended Water (RFCI),[14] Commercial Building in East Texas

Bulk Sample Analysis of Two Patterns of 9 × 9 Floor Tiles[A]

ID	Description	PLM	ATEM
1A	Tan tile	4–6% Chrysolite	13–18% Chrysolite
	Black mastic	ND	—
2A	Tan/Brown mottled tile	7–10% Chrysolite	20–27% Chrysolite
	Black mastic	2–4% Chrysolite	—

Baseline Air Samples[B]

ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
C101	Room 9	918	0.029	0.030	0.020	0.010
C102	Room 7	828	0.037	0.039	0.028	0.011
C103	Room 2	828	0.026	0.022	0.017	0.005

Floor Tile Removal Applying Heat with Hand-held Propane Torch[C]

ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
C211	Room 7	739	0.022	0.60	0.38	0.22
C212	Room 7	850	0.006	0.52	0.34	0.18
C213	Room 7	892	0.011	0.25	0.12	0.13

Mastic Removal with Amended Water and Extended-handle Floor Scraper (RFCI Work Practices[14])

ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
C301	Room 7	522	0.035	0.34	0.13	0.21
C302	Room 7	540	0.027	0.26	0.15	0.11
C303	Room 7	552	0.027	0.18	0.083	0.099

Floor Tile Removal Using Dry Ice[D]

ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
C208	Room 8	666	0.024	0.36	0.25	0.11
C209	Room 8	703	0.019	0.31	0.23	0.071
C210	Room 8	760	0.024	0.19	0.15	0.036

Dry Hand-held Scraper (RFCI Work Practices[14])

ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
C104	Room 9			—Pump Stopped—		
C105	Room 9	522	0.17	1.3	0.63	0.67
C106	Room 9	509	0.15	0.96	0.51	0.45

(continued)

Table 3. Continued

Mastic Removal Using Abatix 007 Mastic Remover						
ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
C203	Room 9	1840	0.054	0.30	0.20	0.10
C204	Room 9	1890	0.052	0.52	0.42	0.10
C205	Room 9	1950	0.048	0.32	0.22	0.10
Clearance Samples for Commercial Building in East Texas						
ID	Description	VOL (L)	PCM (f/cc)	ATEM total (st/cc)	ATEM >0.5 (st/cc)	ATEM ≥5 (st/cc)
C401	Room 7	1187	<0.004	<0.005	<0.005	<0.005
C402	Room 8	1187	<0.004	<0.005	<0.005	<0.005
C403	Room 11	1345	<0.004	0.004	0.004	<0.004
C404	Room 1	1100	<0.004	0.016	0.010	0.006
C405	Room 3	1288	<0.004	<0.004	<0.004	<0.004

[A]These types were mixed throughout the building area.
[B]Baseline samples were taken after the area was cleaned and the containment was erected. The floor was being walked on as these samples were taken.
[C]There was little breakage. The laboratory report noted altered structures probably caused by the heat.
[D]Cold was applied 3 to 4 minutes in each location. Some floor tile breakage occurred from insufficient release, or perhaps from brittleness due to the cold. This was usually limited to 2 to 4 pieces when breakage occurred.

Following removal of the floor tile and a settling period, the mastic was removed using Abatix 007 mastic remover. The area was then hand-rubbed with the least abrasive buffer pad to loosen it and the residue picked up using a squeegee. Final cleaning was done by mopping. (See Table 3E for analytical results.)

Analytical Procedures

BULK SAMPLE ANALYSIS. Bulk sample analyses were conducted using both PLM and ATEM. The PLM procedure was performed as described in 40 CFR 763, Subpart F, Appendix A.[17] The ATEM analysis was done in accordance with the procedure of Chatfield.[18]

For the PLM procedure, random portions of the floor tiles were dissected into small fragments while being examined for obvious asbestos fibers. These fragments were dissolved in a small amount of 1.550 n_D dispersion oil by gentle heating, visible fiber bundles were removed and placed in fresh 1.550 n_D oil and a large quantity of fresh oil was added to the remaining dispersed sample. The sample was analyzed using magnifications ranging from ×7 to ×400. Asbestos was identified based on morphology (frequently as chopped fragments), color and pleochroism, refractive indices, birefringence, extinction characteristics, and sign of elongation. Quantitation was by estimation from models of known composition and results were reported as area percent.

For the ATEM analysis, 100- to 500-mg samples were shaved from the floor tiles, which were then weighed. These samples were ashed in a muffle furnace at 480° ± 5°C. for at least 12 hours and weighed again. The ash was then dispersed in 2 ml of 6N HC1. When effervescence ceased, the residue was collected on a preweighed 0.2-μm polycarbonate filter, where it was rinsed with distilled water, oven dried, and weighed. The residue was resuspended in a known volume of water and 3 μl of the suspension were transferred to formvar-coated grids. After drying, the proportion of asbestos in the residue was visually estimated at ×16,000 and the upper and lower weight percents (±10%) were calculated and reported for asbestos, organic material and calcite and dolomite.

PHASE-CONTRAST MICROSCOPY. Phase-contrast microscopy following NIOSH 7400 Revision 3, May 15, 1989 was used to analyze representative portions of the 0.45-μm mixed cellulose ester filters for later comparison with ATEM. Quadrants of the filters were collapsed with acetone vapor, mounted in 1.460 n_D oil, and coverslipped. The quadrants were analyzed at ×400 and fibers greater than 5-μm long, with aspect ratios equal to or greater than 3, were counted using the NIOSH 7400 A rules. Results were reported as fibers per cc.

ANALYTICAL TRANSMISSION ELECTRON MICROSCOPY. Electron microscopy counts were obtained on the above filters, using the AHERA counting protocol described in 40 CFR 763, Subpart E, Appendix A[2] or EPA Level II analysis.[16] In brief, upon arrival in the lab, portions of the filters were collapsed on glass slides with acetone vapor and plasma etched until 10 percent of the surface was removed. They were carbon coated in a vacuum evaporator and small squares were placed on calibrated 200 mesh grids. The MCE plastic was removed in an acetone condensation washer. The samples were examined in an ATEM at a screen magnification of ×16,000 for asbestos fibers. Five 200 mesh grid squares were analyzed on each of two grids. The AHERA[2] protocol was used for the clearance samples. To be counted, a structure had to have a 5 to 1 aspect ratio or greater and be at least 0.5 μm long or greater. Selected area electron diffraction (SAED) and energy dispersive X-ray analysis (EDXRA) were used to confirm all asbestos structures. EDXRA alone was used to confirm nonasbestos. The structures were categorized as fibers, bundles,

TABLE 4. Data Summary

Removal Procedures	PCM f/cc			ATEM total st/cc		
	Mean	Standard Deviation	Geometric Mean	Mean	Standard Deviation	Geometric Mean
AHERA	.030	.010	.029	0.15	0.078	0.14
Dry hand spud bar	.041	.021	.037	1.1	0.30	1.0
Dry pneumatic spud bar (Room A)	.11	.024	.10	6.9	1.2	6.8
Dry pneumatic spud bar (all cases)	.092	.025	.089	I*	I*	I*
RFCI dry hand scraper (all cases)	.096	.0073	.096	1.2	0.23	1.1
Dry ice	.022	.0029	.022	0.28	0.086	0.27
Propane torch	.013	.0082	.011	0.46	0.18	0.43
Abatix 007 mastic remover	.051	.0031	.051	0.38	0.12	0.37
Wet mastic scraper	.030	.0046	.029	0.26	0.08	0.25

*ATEM data incomplete.

clusters, or matrices according to AHERA. Results were recorded as asbestos structures greater than or equal to 0.5 μm to less than 5 μm, or greater than or equal to 5 μm in length per cc and as total asbestos structures per cc.

A second ATEM method, known as EPA Level II, was published by Yamate *et al.*[16] This method was used to analyze all samples, except the clearance samples. The samples were collected and the filters prepared as in the AHERA[2] protocol. Asbestos structures were counted at $\times$16,000 and were classified as above. SAED and EDXRA were used to identify the structures. The data were made to conform to the AHERA counting rules[2] and were reported using the AHERA guidelines.[2]

All samples for electron microscopy were prepared by the direct method, as outlined above.

A one-way analysis of variance (ANOVA), associated with a Tukey Studentized Range Test, was performed on the ATEM $\log_{10}$ transformed data. The post hoc experiment-wise error rate, representing the probability of at least one falsely declared significant difference, was controlled at 5 percent for the 21 pair-wise comparisons of the seven treatment means.

Analytical Results—Synopsis

Representative floor tiles from each site were analyzed by PLM and ATEM. The only asbestos present was chrysotile, and the concentrations ranged from "none detected" to as high as 10 to 15 percent by PLM and 24 to 36 percent by ATEM, both percentages coming from the same tile. The average percent difference between the two analytical procedures was 194 percent, with ATEM always giving the higher results. Only chrysotile was found in the mastics, and it ranged in concentration from "none detected" to 5 to 7 percent by PLM.

Of the various removal procedures tested, the propane torch method produced the lowest concentration of airborne fibers per cc, which averaged 0.013 by PCM (see Table 4 and Figure 5). The RFCI[14] hand-held scraper (Room 9) produced the highest average concentration, with 0.16 fibers per cc (See "Analytical Results by Site" and Figure 4).

FIGURE 5. ATEM micrograph showing a chrysotile bundle (arrow) visible by PCM. Source was the urban administrative building, room B, dry pneumatic spud bar procedure. Bar = 1 μm.

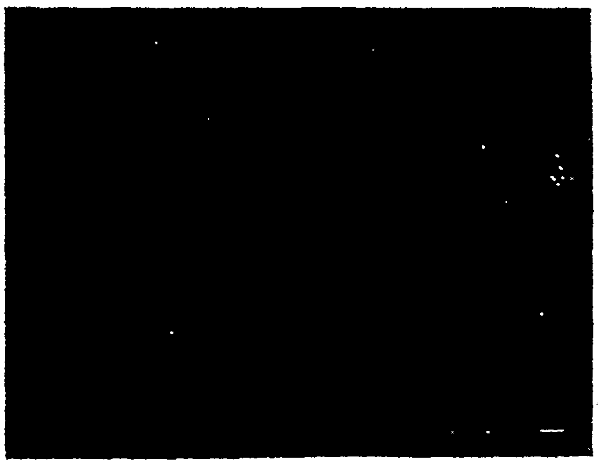

FIGURE 6. ATEM micrograph of chrysotile fibers seen only by electron microscopy. Source was the East Texas commercial building Abatix 007 mastic procedure. Bar = 1 μm.

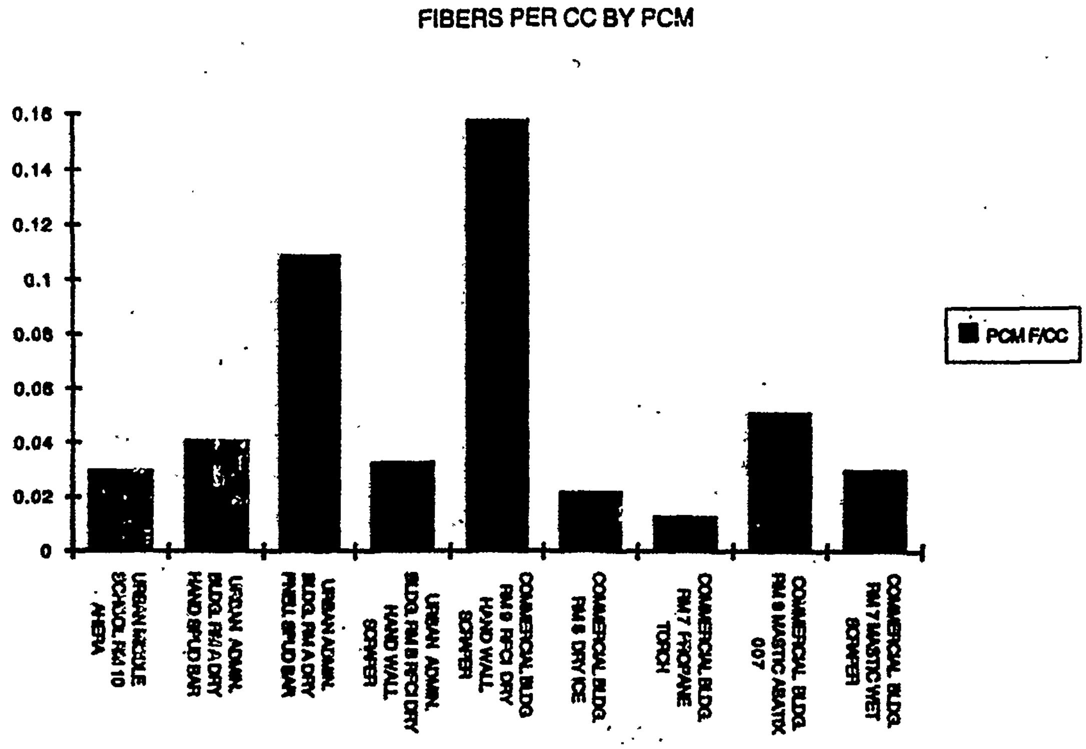

FIGURE 7. Fibers per cc by PCM.

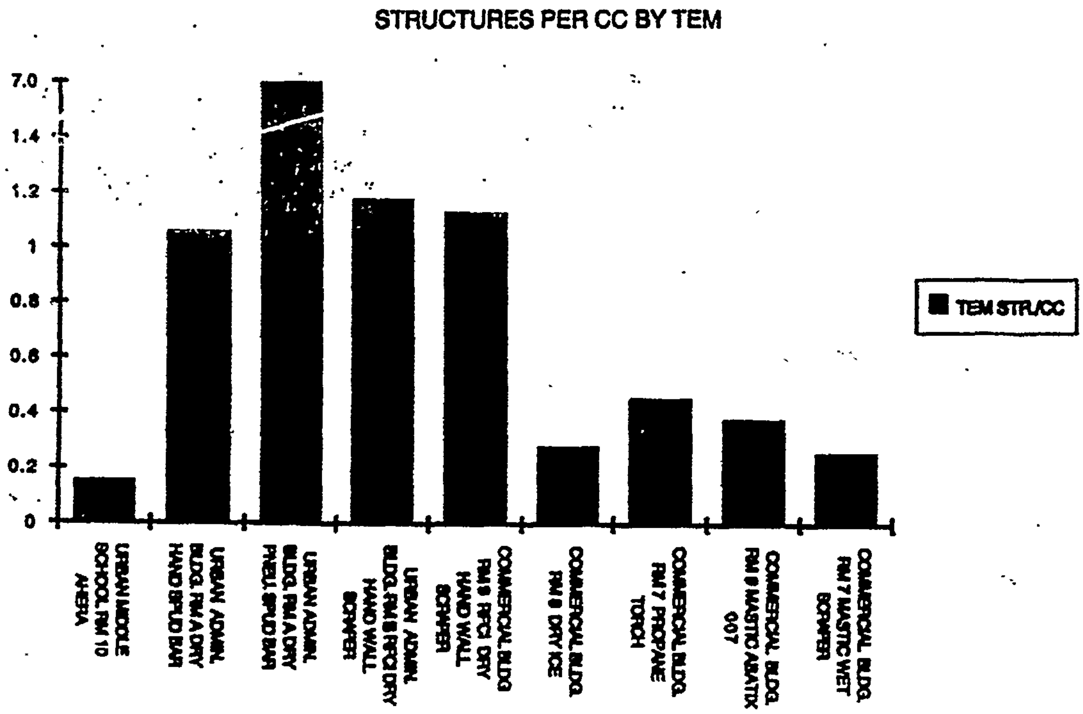

FIGURE 8. Structures per cc by TEM.

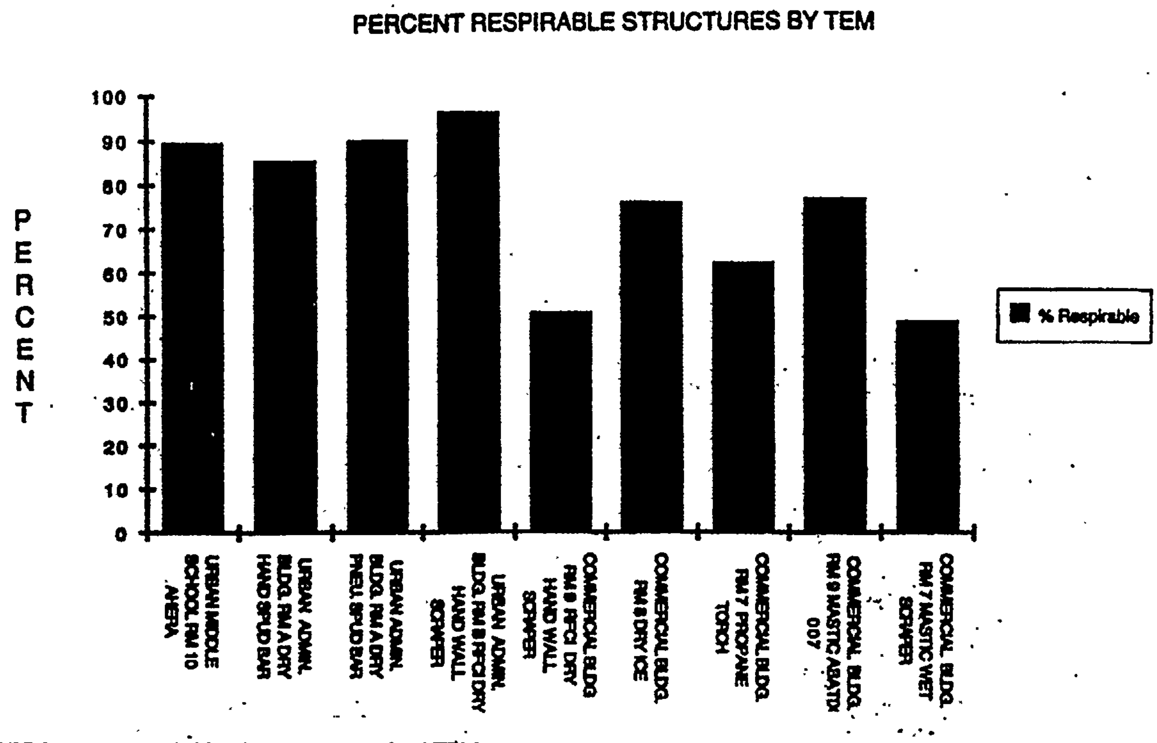

FIGURE 9. Percent respirable asbestos structures by ATEM.

ATEM results indicated the AHERA[2] procedure generated the least number of asbestos structures per cc, with an average of 0.15 (see Table 4 and Figure 6). This concentration was significantly lower than that for all other floor tile removal procedures except for the dry ice. The greatest concentrations, averaging 6.9 structures per cc, were produced by the dry-pneumatic spud bar. These concentrations were significantly higher than those for all other removal procedures. The average percent difference between the PCM and ATEM counts for the various floor tile removal procedures was 2840 percent, and the ATEM counts were always the higher. (See Table 4.)

The ATEM results also provided insight into the type and size of asbestos structures that were produced by the various removal procedures tested (Figures 7 and 8). The most common structures were fibers and matrices, many of which were respirable. Two amphibole fibers were identified during the electron microscopy analyses of the air samples; however, this was not considered to be a significant finding. The average percentage of respirable asbestos structures generated by each method is illustrated in Figure 9. The dry-hand-held scraper and the dry-pneumatic spud bar produced the highest percentages, 96.5 and 90.2, respectively, but all of the removal procedures produced at least 48.9 percent or greater respirable structures.

The above percentages represent conservatively low estimates of the respirable fractions because the AHERA[2] counting rules require lengths to be recorded in two categories: those structures greater than or equal to 0.5 μm to less than 5 μm and those greater than or equal to 5 μm. Diameters are not recorded. Therefore, all clusters and matrices greater than or equal to 5 μm in length were considered nonrespirable, even though some may have been respirable. All fibers and bundles were considered respirable.

Discussion

The techniques used in this study are those presently recommended and/or applied in floor tile removal. The data from the present studies confirm that asbestos fibers are released in appreciable numbers during application of each of the techniques. The AHERA procedure resulted in the least generation of asbestos-containing dust. Seven of 28 samples taken during dry procedures exceeded 0.1 f/cc by PCM analysis. Two of these samples were collected during dry removal by RFCI[14] hand-held scraper procedures and were reported as greater than 0.1 f/cc by PCM analysis. Three of four samples collected during dry removal by the RFCI[14] hand-held scraper method were reported greater than 1 str/cc by ATEM. Two of three samples collected during dry removal by hand spud bar were reported greater than 1 str/cc by ATEM.

While the purpose of this study was not focused on evaluation of potential health effects associated with these activities, it is obvious that a considerable fraction of the asbestos dust is of a respirable size. This point was documented by ATEM analysis of air samples in which the majority of freed fibers were too small to be detectable by the light microscope. Furthermore, any remaining nonrespirable, settled asbestos-containing particulates can be reduced to a respirable size by foot traffic or maintenance activities and can spread throughout the building.

Conclusion

Economic considerations have been used to justify decisions for floor tile removal by techniques other than full containment. These decisions frequently do not take into account either the potential exposure to workers and occupants, or the risk of contaminating the area of removal and other adjacent areas. The expense of training and compliance with OSHA[11] and MAP[21] requirements is often a significant consideration. However, while consideration of these costs is important, the data from the present study suggest that potentially respirable dust is created during floor tile removal and thus exposures occur for the workers and potentially others. Arguments made to the contrary and supported by PCM analysis are shown to be suspect by companion ATEM analysis.

Prudent judgements based on available knowledge, should be used when addressing floor tile removal procedures. The following recommendations are made to aid industrial hygienists and asbestos project designers:

1. Analyze all floor tile by ATEM bulk methods when reported 1 percent or less by PLM. Assuming asbestos at greater than 1 percent is always an option.
2. Conduct floor tile removals using a negative pressure enclosure, with polyethylene (1 layer) on walls and ceiling.
3. Use wet methods for floor tile removal.
4. Following cleanup and visual inspection, apply lock-down and allow to dry and settle.
5. Collect clearance samples by aggressive methods in accordance with 40 CFR 763, Subpart E.[2]
6. Analyze clearance samples by ATEM in accordance with 40 CFR 763, Subpart E.[2]

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APPENDIX B

Protocol for Sampling and Analysis

APPENDIX B
Protocol for Sampling and Analysis

Objectives:
The objectives of the proposed studies are to:

- Determine whether asbestos exposures to maintenance personnel meet the OSHA action level of 0.1 f/cc and excursion limit of 1 f/cc during recommended maintenance activities on asbestos-containing floor tiles. The exposure should be determined as a time-weighted average of measurements using the OSHA Reference Method for phase-contrast microscopy.

- Determine whether asbestos concentrations following maintenance of asbestos-containing floor tiles are significantly elevated. The criteria for elevation are:

  1) The concentration of asbestos on filters, as determined by the 40 CFR Part 763, Appendix A method[1] for transmission electron microscopy, is greater than 70 s/sq mm <u>and</u>

  2) The concentration on the filters is statistically higher inside the area maintained than it is outside the area maintained.

Maintenance Activities:
The maintenance activities to be monitored are:

- Spray Buffing: Typical maintenance of modestly soiled/worn finish. Least likely of the activities to release fibers. Two sites will be selected for monitoring of spray buffing.

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[1] This method is specified because it provides a sensitive method for determining asbestos concentrations at very low levels and because its highly specific instructions for sample collection assure comparability of results among tests of the maintenance activities.

- Scrubbing: Typical maintenance of moderately soiled/worn finish. Intermediate likelihood of releasing fibers. One site will be selected for monitoring of scrubbing.

- Stripping/Refinishing: Typical maintenance of heavily soiled/worn finish. Entails removal of old finish and replacement by new finish to begin cycle anew. Most likely of the activities to generate fibers. Three sites will be selected for monitoring of stripping/refinishing.

Responsibilities:

Armstrong World Industries and members of the Resilient Floor Covering Institute (RFCI) will be responsible for identifying sites and designating a host company for each site.

The host company will be responsible for sampling bulk materials if necessary; obtaining necessary permissions; providing maintenance personnel (preferably from outside the company); providing a floor machine and pads or brushes of the appropriate types; providing treated dust mops and washed wet mops; coordinating work schedules with the maintenance personnel, the monitoring group, and any observers; and arranging for refreshments.

The maintenance personnel are responsible for supplying any stripping, scrubbing, or buffing solutions and any finishes for completion of the stripping/refinishing studies.

ENVIRON Corporation is responsible for overall study design and analysis, and for coordination of the activities of the sampling and analysis subcontractors.

As subcontractor to ENVIRON, Industrial Health Incorporated (IHI) will conduct all sampling activities other than the initial collection of bulk samples in connection with site identification. IHI will also have analyzed bulk samples of the floor tiles by polarized light microscopy and scanning electron microscopy.

As subcontractor to ENVIRON, The R. J. Lee Group will analyze all other samples, including bulk samples by polarized light microscopy (PLM), air samples by phase contrast microscopy (PCM), and air samples by transmission electron microscopy (TEM).

Selection of Sites:

Potential sites identified by Armstrong and RFCI will be examined to determine the condition of the finish for assignment to one of the three maintenance categories above. Floors must be vinyl-asbestos floor tile or asphalt-asbestos floor tile with asbestos content greater than 10%. If the tile cannot be confirmed as containing more than 10% asbestos by positive visual identification, a bulk sample of tile must be assayed by PLM to verify asbestos content before the test is scheduled. Areas should not contain any suspected sources of asbestos other than the floor tiles. If suspect material is identified, bulk samples may be obtained for PLM analysis. Areas should also not contain any significant sources of non-asbestos fibers, such as carpets. Areas must be selected to ensure that a reasonable fraction of a work day can be monitored. For stripping, a room the size of a large classroom (e.g., 500 sq ft) should be sufficient. For buffing, an area the size of a large cafeteria would be preferred. The scrubbing test should be conducted in an area of intermediate size.

Preparation of Area:

Prior to the beginning of the test, heating and air conditioning vents as well as windows and doors should be covered with plastic to reduce air exchange with the rest of the building. Next, the entire area should be thoroughly cleaned to reduce the possibility that pre-existing fibrous material, whether asbestos or not, would contribute to the sampling results. The floor should by HEPA-vacuumed and other dusty areas cleaned. (One door may be provided with overlapping plastic to allow entrance and exist.) Following cleaning, aggressive monitoring of baseline conditions according to the procedures outlined in 40 CFR Part 763, Appendix A should be conducted to verify the completeness of cleaning. As specified later in this protocol, these samples will be analyzed only if necessary. Afterwards, a pair of baseline samples (see description below) should be taken overnight to establish quiescent fiber levels in the area prior to the maintenance activities. These baseline samples need not be analyzed if worker exposures do not exceed the OSHA action level.

Preparation of Equipment:

All equipment and supplies should be prepared to minimize their potential contributions to fiber levels. The floor machine and pads or brushes should be new or pre-cleaned. Wet mops should have been washed and dried more than once to reduce linting. Dust mops should be treated to ensure maximum capture of dust. Any water to be used in connection with mopping, buffing, scrubbing, and stripping operations should be distilled.

Maintenance Activities:

Buffing, scrubbing, and stripping should be conducted according to the procedures described in Appendix A. Any variation from the range of conditions specified in Appendix A should be avoided. Any deviations should be noted by observers from the host company, ENVIRON, and IHI.

Sampling:

All six maintenance activities should be monitored for worker exposures. Except for the excursion sample, pairs of samples should be collected in each case, one for analysis by PCM according to the OSHA Reference Method and one of analysis by TEM according to the method in 40 CFR Part 763, Appendix A. The following samples should be collected:

- A pair of overnight baseline samples should be collected inside the area following area preparation but before maintenance activities begin.
- A pair of samples should be collected in the breathing zone of each maintenance worker. The sampling pumps should remain on during the entire maintenance period, including initial mopping and final cleanup prior to removal of the plastic barriers.
- A 30-minute sample for PCM analysis should also be collected during an aggressive part of the maintenance activities to compare with the OSHA excursion limits.
- A pair of samples should be collected well removed from the sampling area, but not necessarily outdoors, to determine the overall background level of asbestos fibers in the general vicinity. The pump should remain on at least during the entire duration of the maintenance activities.
- Two blank filters should be submitted for analysis by PCM with each set of samples.

In addition, four bulk samples of the tile should be collected. Three will be analyzed by PLM by R.J. Lee. The fourth will be analyzed by PLM and TEM by a laboratory to be selected by IHI.

All of the stripping/refinishing operations should be monitored before the operations begin and after the operations are complete to determine whether asbestos concentrations are elevated as a result of maintenance activities. Samples should be collected according to procedures specified in 40 CFR Part 763, Appendix A:

- Aggressive sampling methods should be employed inside the area. The area should be swept with a minimum 1-hp leaf blower prior to the initiation of sampling. One or more fans pointing toward the ceiling should be operated during the monitoring. A fan should be supplied for each 10,000 cu ft of worksite volume.

- Five samples should be collected for TEM analysis inside the area both before all operations commence and after they are finished. The locations for the filters should be selected randomly in the area. Assuming the filters will be 25 mm in diameter, the sampling volumes should be 1200 liters. Any deviation should be toward the higher side.

- Another five samples should be collected outside the area that are representative of air entering the work site. Again, random placement is desired.

- Two field blanks and one sealed blank should be submitted for analysis.

Asbestos Analysis:

Initially, only the samples collected for PCM analysis should be processed. One section of the filter should be analyzed by PCM (OSHA Reference Method). The samples collected for TEM analysis should not be analyzed unless worker exposures exceed the OSHA action level, in which case the samples should be analyzed to determine the fraction of qualifying structures that are actually asbestos. TEM results should be analyzed by the EPA level II method but defining a qualifying fiber or structure as exceeding a 3:1 aspect ratio instead of 5:1. Results should be reported in the following categories:

1) all visible structures containing qualifying asbestos fibers with lengths between 0.5 and up to but not including 5 μm.

2) all visible structures containing qualifying asbestos fibers with lengths 5 μm and greater.

3) total of 1) and 2)

4) all qualifying structures 5 μm and greater in length and greater than 0.25 μm in width that contain asbestos fibers

5) all qualifying structures 5 μm and greater in length and greater than 0.25 μm in width that contain asbestos fibers

6) if a substantial number of amphibole structures are detected, results will also distinguish between chrysotile only and total asbestos structure counts.

For the samples collected initially and following completion of the stripping/refinishing tests, analysis should proceed by the strategy and methods outlined in 40 CFR Part 763, Appendix A. Qualifying fibers should be equal to or greater than 5:1 aspect ratio.

- First, the five samples from inside the maintenance area should be examined. If the arithmetic mean density of asbestos structures on the filters is less than or equal to 70 s/sq mm, then the analysis can be terminated.

- If the above measurements exceed 70 s/sq mm, then the blank filters should be analyzed to assure that they do not exceed 70 s/sq mm and explain the earlier results.

- Presuming the blanks pass, the outside samples should be analyzed to assure that they do not explain the results for the inside results.

- Finally, if the outside samples do not explain the results, the samples taken before the maintenance activities began should be analyzed to determine whether initial conditions inside the area might explain the results.

Scientific Analysis and Interpretation:

Methods from 40 CFR Part 763, Appendix A, will have been used in the development of the TEM data to ensure sensitivity and comparability. However, it must be emphasized that the clearance standard described in the Asbestos-Containing Materials in Schools Rule under the Asbestos Hazard Emergency Response Act (AHERA) applies to response actions and is not applicable to maintenance activities involving non-friable materials such as floor tiles.

Following completion of the sampling and laboratory analyses, the data should be analyzed statistically and the results compared with various criteria. For the worker exposures as measured by PCM, the results may be compared to the OSHA action level of 0.1 f/cc and excursion limit of 1 f/cc. For the post-maintenance measurements, the asbestos concentrations will be considered elevated only if they exceed 70 s/sq mm and the samples from inside the area are statistically higher than those from outside the area.

Health and Safety Issues:

The A. F. Meyer study, although weak in many respects, does provide some evidence that 8-hour TWA asbestos exposures of maintenance workers will not approach, let alone exceed, the OSHA action level. Therefore no respiratory protection is required for maintenance personnel. Because the fiber levels during aggressive sampling have not been measured previously during the first such test and thereafter if required by the results obtained, the industrial hygiene personnel conducting the aggressive practices will wear respiratory protection and protective clothing. Normal precautions for preventing electrical hazards in wet conditions (e.g., use of a ground-fault interrupter for the floor machine), preventing slipping on wet floors, and preventing injuries from rotating machinery should be implemented.

APPENDIX A

Maintenance Procedures

1. STRIPPING AND REFINISH OF FLOOR

Equipment and Materials

MACHINE: Any size, but limiting the speed to no more than 500 RPM -- 150-300 RPM preferred.

PAD = 3M Green or equivalent

Stripping Solution

Standard stripping solution, using the manufacturer's recommended dilution for heavy-duty stripping.

Procedure

- Dry mop floor with treated dust mop.
- Thoroughly and uniformly wet floor with stripping solution. (DO NOT FLOOD)
- Allow solution to soak for amount of time recommended by manufacturer.
- Strip with machine and pad at the rate of 25 sq ft per 5 minutes (2 hrs).
- Remove residual stripping solution with wet vacuum equipped with floor tool.

RINSING

Procedure

- Using a mop, thoroughly and uniformly wet the floor with clear water and remove with wet vacuum.
- Rinse and vacuum second time.
- Damp mop entire floor.
- Allow to dry.

- Apply four uniform coats of metal-crosslinked finish. (Allow sufficient drying times between coats.) (Finish should be 20% ± 2% solids.) 3-4 hours

2. SPRAY BUFFING

Dry mop with treated dust mop.

Spray buff floor using available equipment incorporating 3M Red or equivalent pad and standard spray buffing solution according to manufacturer's recommendations. Record manufacturer, model number, and RPM of equipment used; also record composition or name of spray buff solution.

Dust mop floor to pick up dust generated during spray-buffing.

3. SCRUBBING

Follow procedure No. 1 with the following exceptions:

Substitute a scrubbing solution for the stripping solution specified.

Reduce the amount of soak time to that recommended by manufacturer, generally about two minutes.

Scrub at the rate of 50 sq ft per 5 minutes (1 hr).

Rinse only once.

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