ANALYSIS OF MEASUREMENTS OF AIRBORNE FIBERS DURING REMOVAL OF RESILIENT FLOOR TILES USING RECOMMENDED WORK PRACTICES

Prepared for

Resilient Floor Covering Institute
Rockville, MD

Armstrong World Industries, Inc.
Lancaster, PA

The Flintkote Company
San Francisco, CA

GAF Corporation
Wayne, NJ

Prepared by

ENVIRON Corporation
Washington, DC

December 13, 1988

PREFACE

This report was prepared under the direction of Grover Wrenn by Stephen Brown and Anson Keller. Michael Larsen of Larsen Environmental Associates consulted with ENVIRON on the evaluation and analysis of the information provided in a report by Fowler Associates.

C O N T E N T S

I. EXECUTIVE SUMMARY

I. EXECUTIVE SUMMARY

Some types of resilient floor tiles manufactured in the past contained asbestos fibers in a vinyl or asphalt matrix. Removal of this type of floor tile in an occupational setting (e.g., prior to installation of new resilient floor coverings) is subject to the general provisions of asbestos standards set by the United States Occupational Safety and Health Administration (OSHA) for the construction industry (29 CFR 1926.58). These standards require employers to assure that worker exposures to asbestos do not exceed the permissible exposure limit of 0.2 fibers per cubic centimeter (f/cc) air for an 8-hour time-weighted average (TWA) or the excursion limit of 1 f/cc over a 30-minute period.

The OSHA asbestos standards require initial monitoring of employee exposure at the start of a job to establish that neither the action level (0.1 f/cc for an 8-hour time-weighted average) nor the excursion limit (1.0 f/cc over 30 minutes) is exceeded. The standards also provide that an employer may rely upon objective or historical data to demonstrate that the action level and excursion limit will not be exceeded.

This report presents an analysis of fiber exposures to floor mechanics and supervisory personnel during floor tile removal conducted pursuant to work practices recommended by the Resilient Floor Covering Institute and by Armstrong World Industries ("Recommended Work Practices"). Based on a total of 21 exposures measured according to procedures specified by OSHA, the average TWA is approximately 0.031 f/cc. The 95% upper confidence limit for all removal operations is approximately 0.09 f/cc, also below the action level. Evaluation of the samples by transmission electron microscopy (TEM) revealed that most of the fibers counted were not asbestos. Although these measurements were undertaken before the need for compliance with an excursion limit was established, calculating the highest possible 30-minute exposure showed, with 95% confidence, that the excursion limit also would not be

exceeded. Consequently, these tests should constitute objective data that the action level and excursion limit will not be exceeded when the Recommended Work Practices are followed.

II. INTRODUCTION

II. INTRODUCTION

Resilient floor tiles are the preferred flooring material in many commercial and residential applications. The tile matrix is frequently reinforced with some type of fibrous filler material. The fibers are dispersed in a vinyl or asphalt matrix that binds them into the tile, thus minimizing the potential for their release during installation, use, and removal of resilient floor tiles.

Some types of floor tiles manufactured in the past contained chrysotile asbestos. Other fibrous materials have now been substituted for asbestos. Vinyl-asbestos tiles and asphalt tiles were the most common varieties of asbestos-containing resilient floor tiles. Some of the asphaltic ("cutback") adhesives used to install floor tile in the past also contained asbestos.

When new resilient floor coverings are installed, removal of old floor tiles may be necessary. If the old tiles and adhesives contain asbestos, the floor mechanics who remove the tiles and their supervisors are potentially exposed to airborne asbestos fibers. Accordingly, the removal process in an occupational setting is a workplace activity subject to the regulations of the United States Occupational Safety and Health Administration (OSHA) that limit workplace exposures to asbestos. As explained further in Section III, OSHA has issued two standards regulating occupational exposures to asbestos, one for general industry and one for the construction industry.

Floor tile removal is one of the many activities that are properly classified under the general heading of "construction." The resilient floor covering manufacturers therefore are interested in demonstrating by objective or historical data that removing floor tile pursuant to the Recommended Work Practices does not lead to worker exposures in excess of either the OSHA action level of 0.1 f/cc as an 8-hour time-weighted average or the OSHA excursion limit of 1 f/cc over a 30-minute

period. Such findings would obviate the requirement for initial monitoring of worker exposure at each job site.

Toward this goal, the industry has undertaken a study conducted by Fowler Associates to determine the magnitude of worker exposure to asbestos when resilient floor tiles are removed in accordance with the Recommended Work Practices. The sampling conducted by Fowler Associates and the subsequent fiber counting procedures conducted with phase-contrast microscopy by Chatfield Technical Consulting were in accordance with the methods and procedures specified by OSHA. ENVIRON Corporation has analyzed the resulting data and demonstrated that exposures to asbestos during tile removal following the Recommended Work Practices are lower, often substantially lower, than the OHSA action level of 0.1 f/cc. Although no 30-minute exposures were monitored, the same data imply that the excursion limit of 1.0 f/cc would also not be exceeded. This report summarizes the measurements and the analyses that led to these conclusions.

III. REGULATORY FRAMEWORK

III. REGULATORY FRAMEWORK

In 1972, OSHA promulgated a 6(b) standard dealing with occupational exposures to asbestos for all industries covered by the Act. On June 20, 1986 and September 14, 1988, OSHA issued revised standards relating to occupational exposures to asbestos. OSHA issued two revised standards for employee exposure to asbestos, one applicable to general industry (29 CFR 1910.1001) and one applicable to the construction industry (29 CFR 1926.58). The 1972 standard had mandated a 10 f/cc "ceiling" limit as well as a 2 f/cc time weighted average (TWA) permissible exposure limit (PEL). The present standards reduced, among other things, the permissible exposure limit to 0.2 f/cc as an 8 hour time-weighted average (TWA) and set an excursion limit of 1 f/cc average over a sampling period of 30 minutes. OSHA has also set an action level of 0.1 f/cc calculated as an 8-hour time-weighted average (29 CFR 1926.58(b)). Although the general industry standard is similar, references below will be to the construction standard only, because removal of resilient floor tiles is a construction activity.

The standard for the construction industry requires that each employer, who has a workplace or work operation covered by the standard, perform initial monitoring to determine the airborne concentrations of asbestos to which employees may be exposed (29 CFR 1926.58(f)(2)(i)). When the action level of 0.1 f/cc is exceeded, the employer must continue to perform initial monitoring at the initiation of subsequent new asbestos jobs. Employee training and medical surveillance are also required when exposures exceed the action level. When the PEL of 0.2 f/cc is exceeded, the employer must establish a regulated area that must be demarcated and to which access must be

---

*Many relevant data sets are expressed in units of fibers per milliliter (f/ml), which are equivalent to f/cc.

limited to authorized persons supplied with respirators (29 CFR 1926.58(e)). Certain other conditions also apply to a regulated area. When the results of continued periodic monitoring reveal that employee exposures, by statistically reliable measurements, are below the action level, monitoring of the affected employees may be discontinued (29 CFR 1926.58(f)(4)). OSHA also provided two exceptions to the requirement for initial monitoring: 1) where objective data demonstrate that employee exposures are below the action level and/or excursion limit (29 CFR 1926.58(f)(2)(ii)) and 2) where the employer has a certain type of historical monitoring data (29 CFR 1926.58(f)(2)(iii)). The regulation states, in pertinent part:

> (2) Initial Monitoring:
>
> (i) Each employer who has a workplace or work operation covered by this standard, except as provided for in paragraphs (f)(2)(ii) and (f)(2)(iii) of this section, shall perform initial monitoring at the initiation of each asbestos, tremolite, anthophyllite, or actinolite job to accurately determine the airborne concentrations of asbestos, tremolite, anthophyllite, or actinolite to which employees may be exposed.
>
> (ii) The employer may demonstrate that employee exposures are below that action level and/or excursion limit by means of objective data demonstrating that the product or material containing asbestos, tremolite, anthophylite, actinolite, or a combination of these minerals cannot release airborne fibers in concentrations exceeding the action level and/or excursion limit under those work conditions having the greatest potential for releasing asbestos, tremolite, anthophylite, or actinolite.
>
> (iii) Where the employer has monitored each asbestos, tremolite, anthophylite, or actinolite job for the TWA, and where he has monitored after March 14, 1988, for the excursion limit, and the data were obtained during work operations conducted under workplace conditions closely resembling the processes, type of material, control methods, work practices, and environmental conditions used and prevailing in the employer's current operations, the employer may rely on such earlier monitoring results to satisfy the requirements of paragraph (f)(2)(i) of this section. (29 CFR 1926.58(f)(2))

Very little substantive guidance was given by OSHA in its 1986 amendment of the objective data exception to the initial monitoring rquirement. However, the preamble to the recent amendment dealing with the excursion limit does give some indication of what OSHA anticipates by way of objective data. OSHA stated:

> "Objective data" is limited to information demonstrating that a particular product or material containing asbestos or a specific process, operation, or activity involving asbestos, cannot release fibers in concentrations above either the action level or Eleven [sic: excursion limit even] under worst-case release conditions. Objective data can be obtained from an industry-wide study, from manufacturers of asbestos-containing products or materials, or from laboratory test results of an asbestos containing product. For the employer who relies upon an industry-wide study, the data he uses must be obtained under workplace conditions closely resembling the processes, type of material, control methods, work practices, and environmental conditions used and prevailing in the employer's current operations. Sampling and anlytical procedures must conform to NIOSH and/or OSHA approved methods The following three examples illustrate how an employer may use "objective data" to avoid the burden of initial monitoring.
>
> In the automotive brake and clutch repair industry (the largest group of exposed workers), OSHA has determined that employers can successfully reduce their employees' exposures to asbestos to below the EL by employing the enclosed cylinder/HEPA vacuum system method as described in Appendix F to § 1910.1001. This determination is based on evidence in the rulemaking record (NIOSH Report 32.4, Ex. 84-263). The effectiveness of the vacuum/enclosure is dependent upon the mechanic being adequately trained so that he/she can perform the manufacturer's recommended sequence of steps with care and skill. OSHA therefore believes that employers in the brake and clutch repair industry will be able to avail themselves of exemption from initial monitoring in this amended standard if they conscientiously employ the enclosed cylinder/HEPA vacuum system.
>
> In construction, where certain operations are short-term, intermittent in nature and generate peak exposures, data show that the use of shrouded tools may limit peak exposures to below the EL. An example of a detailed study, which can be used as objective data in lieu of exposure monitoring, is Ex. 84-279. This study by the A/C Pipe Producers Association shows that under certain conditions (e.g., experienced workmen, properly maintained equipment, strict adherence to recommended work practices), cutting and machining A/C pressure and sewer pipe, using wet methods and a shrouded Doty tool, will limit exposures to below 0.5 f/cc.

> Small-scale, short-duration maintenance or renovation activities where the use of glove bags and wet methods are capable of keeping employee exposures to asbestos below the 0.1 f/cc action level and 1 f/cc EL is another situation where objective data could be used to obviate the need for exposure monitoring. The success of glove bag asbestos removal operations relies heavily on the use of workers specially trained in asbestos abatement working under well controlled conditions. Generally, two persons are required to perform removal especially with the use of heavy bags or in elevated locations. Diligence on the part of management and employees is essential for minimizing contamination. Appendix G to § 1926.58 (51 FR 22785)--"Work Practices and Engineering Controls for Small-Scale, Short Duration Asbestos Renovation and Maintenance Activities", provides requirements for glove-bag procedures which, when followed by employers, will satisfy the requirements for relying on "objective data" to be relieved from monitoring duties. (53 Fed. Reg. 35621-35622, September 14, 1988)

As we point out below, the data relied upon in this report more than meet the quality and amount of data OSHA has previously found acceptable as objective or historical data, such as data dealing with brake and clutch repair, shrouded tools, and glove bags. For example, the brake and clutch repair exemption appears to rely upon only two samples, while the analysis here takes into account exposure measurements from 10 different asbestos-removal operations. The glove bag exemption appears to rely solely on a theoretical argument, while the removal data analyzed here are quantitative and supported by a variety of auxiliary data indicating that the exposures reported are very likely to be higher than actual exposures to asbestos fibers. Also, like the A/C pipe study accepted by OSHA, the Fowler-Chatfield study is based on a specific work practice recommended for removal of resilient floor tiles.

IV. RECOMMENDED WORK PRACTICES FOR FLOOR TILE REMOVAL

IV. RECOMMENDED WORK PRACTICES FOR FLOOR TILE REMOVAL

In accordance with the regulatory scheme for controlling asbestos exposures potentially resulting from floor tile removal, the current members of the Resilient Floor Covering Institute (RFCI) and Armstrong World Industries, Inc. have developed guidelines for floor tile removal designed to assure compliance with the OSHA standards governing exposure to asbestos. These Recommended Work Practices, which have evolved from earlier recommendations, prohibit sanding or otherwise abrading the tile surface and call for the use of other techniques to facilitate removal of tiles intact. Among these are techniques designed to loosen the floor tile adhesive, for example, by heating the more firmly attached tiles with a hot air blower prior to removal attempts.

Additional protection is provided by advice on practices to follow before and after removal. The floor should be vacuumed before and after removal with a High Efficiency Particulate Air (HEPA) vacuum cleaner or swept/mopped wet; these practices will minimize air entrainment of any asbestos or other fibers that may be present on the floor before the tile is removed. Finally, removed tiles are to be placed carefully in impermeable labeled trash bags at periodic intervals to limit breakage.

Additional details of the Recommended Work Practices are provided in Appendix A, which reproduces the Recommended Work Practices distributed by the Resilient Floor Covering Institute, and Appendix B, which reproduces the Recommended Work Practices distributed by Armstrong World Industries, Inc.

V. AVAILABLE MONITORING INFORMATION

V. AVAILABLE MONITORING INFORMATION

A. The Fowler-Chatfield Study

A comprehensive set of measurements of workplace exposures to asbestos during floor tile removal following the Recommended Work Practices has been carried out by Fowler Associates ("Fowler") with the participation of Chatfield Technical Consulting, Ltd. (Chatfield). Fowler designed and carried out the sampling program, while Chatfield conducted the determination of fiber concentrations with optical and electron microscopy. Their complete results are presented in an extensive report (Fowler 1988 - see attachment) to the sponsors of the work (RFCI, Armstrong World Industries, Inc., the Flintkote Company, and GAF Corporation).

Fowler and his colleagues selected 10 examples of removals of resilient floor tiles containing asbestos. These examples spanned a variety of building types (residential, commercial, institutional), subflooring (wood, concrete), geographic areas, ages of tile installation, types of tile matrix (vinyl, asphalt), thickness of tile, ventilation, area of floor, season, and duration of removal. All installations appeared to have been made with cutback adhesives, the type most likely to contain asbestos. These situations span the most likely types of tile removal conditions.

In each case, the floor mechanics were first instructed for a brief period on the Recommended Work Practices. Personal monitoring of the mechanics was accomplished in the breathing zone at a nominal pump flow rate of 1.5 to 2.5 liters per minute (range: 1.45-3.00) and extended over the entire period of tile removal and floor cleanup, but did not extend to initial preparations, installation of new resilient floor covering not containing asbestos, or other work activities subsequent to the removal itself. In many situations, these other activities will occupy as much or more of the workday than actual tile removal and will entail negligible exposures to asbestos.

The personal monitoring of the mechanics was augmented by personal monitoring of the industrial hygienists, with area monitors "following" the mechanics, and with stationary indoor monitors to establish that supervisory personnel would not have higher exposures than the mechanics and to measure the background levels of asbestos fibers unrelated to tile removal. For all the personal monitoring, two companion samples were collected, one for analysis by phase contrast optical microscopy (PCM) and one for analysis by transmission electron microscopy (TEM). PCM is the required procedure for monitoring employee exposure to asbestos under the OSHA regulations, whereas TEM (with x-ray analysis for crystallographic structure identification) is used to determine the proportion of true asbestos fibers among all fibers meeting the counting rules. Briefly, OSHA requires that any particle longer than 5 microns and having an aspect (length to width) ratio greater than 3 to 1 be counted.

All of the samples collected were analyzed in the laboratories of Chatfield Technical Consulting, using procedures that follow the OSHA guidelines (NIOSH 7400 method) for PCM analysis and EPA guidelines (Yamate method) for TEM analysis. Chatfield also analyzed a number of "blank" samples to allow corrections for asbestos or asbestos-like fibers associated with the collection filters themselves. Finally, Chatfield developed special procedures for TEM analysis of floor tile debris to ensure that the results realistically represented the characteristics of the dust in the air.

OSHA specifies PCM analysis principally for practical reasons of cost and reliability but also because the epidemiologic studies on which its standards are based used PCM or other optical microscopy to describe the exposure levels of the occupational cohorts studied. For any industry in which asbestos fibers are predominant among all particles meeting the counting rules, this choice is most likely to yield appropriate conclusions about the level of asbestos exposures. If the work environment is likely to contain many non-asbestos particles

that meet the counting rules, however, the results of PCM analysis can exaggerate the potential exposure. Chatfield found in the TEM analyses that only a fraction of the particles meeting the PCM counting rules were actually asbestos fibers. Thus, compliance with standards during floor tile removal is likely to provide a greater margin of safety than a similar level of compliance in an industry where most of the fibers can correctly be assumed to be asbestos.

The Fowler studies followed then-current Recommended Work Practices but deviated from the current Recommended Work Practices in that a HEPA vacuum was not used for cleanup. Therefore, the monitors undoubtedly captured preexisting fibers from the cracks between the tiles as well as dust from the ordinary shop vacuum that would not have been captured if the most recent Recommended Work Practices for floor tile removal had been followed. The magnitude of the influence of this difference on the fiber counts cannot currently be estimated, but it is certain that the Fowler-Chatfield data represent exposures greater than those that would be expected had a HEPA vacuum been used as recommended, i.e., a worst case.

Fowler presents statistical analyses of both the PCM and TEM data from the "follower" and stationary area monitors as well as from the personal monitors. The area monitoring results show similar but generally lower concentrations in comparison with the personal monitoring results. The comparison of PCM with TEM counts can be used to demonstrate that the PCM counts are probably overestimates of the true asbestos concentrations. Only the PCM results for personal monitoring are offered as objective data showing compliance with the OSHA standards, however, again to portray worst-case conditions.

Fowler's raw data from the mechanics' personal monitoring are presented in Table 1. Note that these data have not been adjusted for blanks or background concentrations, nor have 8-hr time-weighted averages been computed. These adjustments are discussed in Chapter VI. This tabulation does, however,

Table 1

SUMMARY OF PERSONAL MONITORING RESULTS
FOR FLOOR MECHANICS DURING REMOVAL
OF ASBESTOS-CONTAINING FLOOR TILES
PURSUANT TO RECOMMENDED WORK PRACTICES

Site No.	Concentration (f/cc) PCM	TEM (asbestos)	Duration (minutes)	Comments
1	0.036	0.003	380	
	0.011	0.0031	321	
2	0.052	<0.0032	346	No asbestos by TEM
	0.026	0.0056	348	
3	0.23	0.0144	127	
	0.091	0.0404	130	
	0.11	0.0097	132	
4	0.051	0.016	137	
	0.035	<0.018	118	No asbestos by TEM
5	0.20	0.026	101	
	0.15	<0.012	101	No asbestos by TEM
6	0.058	<0.013	79	No asbestos by TEM
	0.18	<0.017	79	No asbestos by TEM
	0.075	0.024	90	
	0.063	<0.016	88	No asbestos by TEM
	0.18	0.021	52	
	0.091	0.025	54	
7	0.023	0.019	275	
	0.33	<0.0063	272	No asbestos by TEM*
8	0.093	0.0097	141	
	0.096	0.0075	157	
9	0.054	<0.0065	198	No asbestos by TEM
	0.034	<0.0064	197	No asbestos by TEM
10	0.076	0.0066	191	
	0.041	0.0065	194	

*Only sample for which PCM results could exceed the 30-minute Excursion Limit of 1 f/cc

indicate that 1) the TEM counts are uniformly below the PCM counts, often by a factor of ten or more, and 2) in about a third of the cases, no asbestos at all was detected by TEM.

Fowler also placed personal monitors on the industrial hygienists who were observing the removal operations. Their exposures should be reasonably representative of supervisory personnel and can provide additional evidence about exposures of workers during floor tile removal. The 16 sets of data for these personnel are shown in Table 2. Again, TEM exposure are well below PCM results and no asbestos is seen in almost half the samples.

B. Other Studies

Several other investigators have studied asbestos release from floor tiles. Most of these investigations are not relevant to the characterization of exposures to floor mechanics removing resilient floor tiles according to the Recommended Work Practices, however. Some of them involve maintenance of existing tile floors, some involve preparation of old floors by sanding instead of removal, and some involve installation of new tiles containing asbestos. Of the studies involving removal of old floor tiles, most do not follow the Recommended Work Practices or do not provide detail sufficient to determine whether the Recommended Work Practices were followed. Of the studies located, only two other than the Fowler-Chatfield study had direct relevance to asbestos exposures during floor tile removal, each following earlier versions of the Recommended Work Practices. Both are much more limited than the Fowler-Chatfield study, but both support its findings.

The importance of following Recommended Work Practices during floor tile removal is underscored by the known characteristics of air quality in buildings. Typical residential and commercial buildings contain significant quantities of fibers that are not asbestos but that could be

Table 2

SUMMARY OF PERSONAL MONITORING RESULTS
FOR INDUSTRIAL HYGIENISTS DURING REMOVAL
OF ASBESTOS-CONTAINING FLOOR TILES
PURSUANT TO RECOMMENDED WORK PRACTICES

Site No.	Concentration (f/cc) PCM	TEM (asbestos)	Duration (minutes)	Comments
1	0.0097	0.0088	337	
	0.0071	0.0043	266	
2	0.0079	0.0032	312	
	0.0089	0.0058	342	
3+4	0.10	<0.0140	123	No asbestos by TEM
5	0.13	<0.013	101	No asbestos by TEM
	0.11	<0.012	101	No asbestos by TEM
6	0.048	<0.012	166	No asbestos by TEM
	0.037	<0.0062	209	No asbestos by TEM
7	0.020	0.0040	268	
	0.013	0.0061	346	
8	0.034	0.0090	148	
	0.095	0.011	130	
9	0.023	<0.0073	186	No asbestos by TEM
	0.020	0.0066	196	
10	0.020	<0.0065	193	No asbestos by TEM

counted as asbestos under the procedures required by OSHA for measuring workplace concentrations of asbestos. Even a "clean" tile floor may present many types of fibers, including those from textiles, fibrous glass, mineral wool, and paper, in addition to any asbestos fibers that may be present. As discussed further in section VI-C, many of these fibers could be falsely identified as asbestos fibers under the requirements to count all geometrically qualifying structures under the phase-contrast optical microscope, independent of their chemical or mineralogical classifications. Other mineral fillers in the tile matrix can also mimic asbestos fibers with optical counting procedures, thereby yielding misleading results.

Lundgren et al. (1988) studied asbestos exposures from installation, maintenance, and removal of vinyl-asbestos floor tile pursuant to the then-current Recommended Work Practices. In the removal study, the protocol was very similar to that of the Fowler-Chatfield study with the following exceptions:

1) The floor was swept and damp-mopped two hours prior to tile removal.

2) No cleanup vacuuming was described.

3) A part of the flooring was removed with a "cold" technique involving dry ice, previously recommended by RFCI as an alternative work practice.

4) Companion samples were assayed by scanning electron microscopy (SEM) instead of TEM.

Lundgren et al. reported PCM fiber counts ranging from 0.033 to 0.139 f/cc. Although blanks and background samples were analyzed, it is not clear from the report whether the reported counts have been adjusted. No time-weighted averages were computed (the time for removal ranged from 30 minutes for the cold removal to 45 minutes for the hot removal). These measurements are quite comparable to Fowler's results by PCM. When only asbestos fibers were counted by SEM, the results

ranged from 0.0005 to 0.0056 f/cc, also quite comparable to but generally lower than Fowler's TEM results for asbestos fibers.

In an older study, Walcott and Warrick (1979) investigated asbestos concentrations during installation, use, maintenance, and removal of vinyl asbestos floor tile pursuant to the then-current Recommended Work Practices. The removal techniques were similar to the hot air blower technique described by Lundgren et al. (1988), but the cleanup procedures before or after removal were not described. The analysis was conducted with an older version of the NIOSH technique (P&CAM-239), without any experimental confirmation of asbestos composition. However, the microscopist visually estimated that 10% of the fibers were asbestos, a finding consistent with Fowler's observations. With these techniques, the reported total fiber concentrations during the removal operations ranged from 0.062 to 0.147 f/cc unadjusted for blanks, background, or time-weighted average. The estimated asbestos fiber concentrations were 0.006 to 0.015 f/cc. Walcott and Warrick also reported a time-weighted average for asbestos fibers in the samples. Their results are also consistent with those of Fowler (1988).

VI. ANALYSIS OF AVAILABLE OBJECTIVE INFORMATION

VI. ANALYSIS OF AVAILABLE OBJECTIVE INFORMATION

A. Interpretation of Monitoring Data

Fibers of asbestos and many other materials are found in virtually every type of environment, including all the types of structures where asbestos-containing resilient floor tiles might be removed. Many of these fibers would qualify under the geometrical counting rules of the OSHA standard, independent of their composition or origin. These fibers are not attributable to floor tile removal activities and should not be counted against compliance with the action level. Thus, it is important to know the background concentration of qualifying fibers in interpreting the monitoring results in a tile-removal study such as conducted by Fowler (1988).

Similarly, some of the filters used in the personal monitors are made of materials that can be contaminated with fibers of asbestos or other substances. These, too, are not attributable to the flooring-removal activities and should not be counted against the action level. Thus, it is also important to know what fiber concentrations would be found from counting a filter that had never been exposed to the work environment, i.e., a blank.

Accordingly, Fowler's results must be corrected for the fiber counts on blanks and those from samples of background air in the vicinity of the monitored workplace. The procedure is as follows:

- The raw fiber counts (f/sq mm) are reduced by the fiber counts on the blanks. The latter are computed for each batch of filters (in this case, for Sites 1 & 2, 3 & 4, 5 & 6, 7, and 8, 9, & 10).

- The air concentrations are computed by multiplying the adjusted fiber counts by the area of the filter exposed (385 sq mm; 106 sq mm of the 491 sq mm total filter area is shielded by the sampling cassette) and dividing by the volume of air sampled.

- The background concentrations are computed in a similar way and then subtracted from the adjusted concentrations site-by-site to yield the net concentrations attributable to tile removal.

A further adjustment is necessary to account for the fact that flooring-removal activities and the corresponding monitoring did not extend over a full 8-hour workday. Floor mechanics typically proceed to install new flooring following tile removal, or return to their home shop. These activities do not involve occupational exposures to asbestos. Consequently, the time-weighted-average (TWA) concentrations are lower than the adjusted measured concentrations by a factor of T/480, where T is the sampling time, in minutes, and 480 is the number of minutes in an 8-hour day. The sampling times were reported in Table 1.

Fowler and Chatfield conducted their studies before monitoring for the Excursion Limit was discussed. Therefore, no short-term (30-minute) measurements were made. However, a maximum 30-minute concentration can be estimated by multiplying the net concentration by the sampling duration in minutes and dividing by 30.

The original concentrations reported by Fowler, the net concentrations after adjustments for blanks and background, the final adjusted TWA concentrations, and the maximum 30-minute concentrations for the floor mechanics and industrial hygienists are summarized in Tables 3 and 4, respectively. A fuller description of the Fowler-Chatfield data and their interpretation appears in Appendix C.

Table 3

ADJUSTED PERSONAL MONITORING RESULTS
FOR FLOOR MECHANICS DURING REMOVAL
OF ASBESTOS-CONTAINING FLOOR TILES
PURSUANT TO RECOMMENDED WORK PRACTICES
(All data are PCM f/cc)

	Concentrations			
Site No.	Reported	Net	8-hr TWA	30-min Max.
1	0.036	0.0326	0.0258	0.413
	0.011	0.0073	0.0049	0.079
2	0.052	0.0481	0.0347	0.555
	0.026	0.0224	0.0162	0.260
3	0.23	0.1971	0.0522	0.834
	0.091	0.0553	0.0150	0.240
	0.11	0.0791	0.0217	0.348
4	0.051	0.0270	0.0077	0.123
	0.035	0.0106	0.0026	0.042
5	0.20	0.1842	0.0388	0.620
	0.15	0.1366	0.0288	0.460
6	0.058	0.0520		0.137
	0.18	0.0686	0.0398 *	0.206
	0.075	0.1698		0.294
	0.063	0.1730		0.456
	0.18	0.0506	0.0483 *	0.166
	0.091	0.0843		0.152
7	0.023	0.0217	0.0124	0.199
	0.33	0.3295	0.1867	2.988**
8	0.093	0.0810	0.0238	0.381
	0.096	0.0840	0.0275	0.440
9	0.054	0.0383	0.0158	0.253
	0.034	0.0192	0.0079	0.126
10	0.076	0.0655	0.0261	0.417
	0.041	0.0309	0.0125	0.200

* These values are the TWAs for the three sampling periods combined for this job.

**The companion sample showed no asbestos by TEM; furthermore, this value is grossly inconsistent with the sample for the other mechanic on the job and with other measurements, and is therefore suspect.

Table 4

ADJUSTED PERSONAL MONITORING RESULTS
FOR INDUSTRIAL HYGIENISTS DURING REMOVAL
OF ASBESTOS-CONTAINING FLOOR TILES
PURSUANT TO RECOMMENDED WORK PRACTICES

(All data are PCM f/cc)

	Concentrations			
Site No.	Reported	Net	8-hr TWA	30-min Max.
1	0.0097	0.0060	0.0042	0.067
	0.0071	0.0027	0.0015	0.024
2	0.0079	0.0039	0.0025	0.041
	0.0089	0.0053	0.0038	0.060
3	0.10	0.0658	0.0169	0.270
5	0.13	0.1153	0.0243	0.388
	0.11	0.0951	0.0200	0.320
6	0.048	0.0426	0.0147	0.236
	0.037	0.0331	0.0144	0.231
7	0.020	0.0183	0.0102	0.164
	0.013	0.0331	0.0239	0.382
8	0.034	0.0226	0.0070	0.112
	0.095	0.0833	0.0226	0.361
9	0.023	0.0074	0.0029	0.046
	0.020	0.0047	0.0019	0.031
10	0.020	0.0097	0.0039	0.063

B. Statistical Analysis

In gross terms, all the adjusted TWA concentrations shown in Table 3 are below the action level of 0.1 f/cc except for one value, 0.187 f/cc, reported for the second mechanic at Site 7. As indicated in the footnote to the table, this value is suspect because it is grossly higher than the sample for the other mechanic and for other monitors and because no asbestos fibers were identified in the companion TEM analysis. It may be due, for example, to a puff of dust from the vacuum cleaner. Nevertheless, it is included in the statistical analysis following, to assure a worst-case analysis.

The six mechanics' samples from Site 6 contribute to only 2 TWA concentrations, because three samples were collected for each mechanic. Therefore, a total of 21 measurements of mechanics' exposures are available for analysis. The cumulative frequency distribution for these measurements is presented in Figure 1. Its arithmetic mean is 0.0309 f/cc and its geometric mean is 0.0204 f/cc. If it is assumed that the distribution is normal in the logarithm of the concentration, as it appears from the plot, then the calculated 95th percentile confidence limit is 0.0924 f/cc. If the outlier point (0.1867 f/cc) had been excluded, the arithmetic mean would have fallen to 0.0231 f/cc, the geometric mean to 0.0183 f/cc, and the 95th percentile confidence limit to 0.0698 f/cc.

The corresponding arithmetic and geometric means for the industrial hygienists' exposures, which can serve as surrogates for supervisors' exposures, are 0.0109 and 0.0074 f/cc, respectively. The highest TWA for these samples was 0.0243 f/cc. These statistics clearly show that workers other than the floor mechanics would experience lower exposures than the mechanics; the statistical analysis for the mechanics represents a worst case.

Given that the estimated 30-minute concentrations are maximum values, no elaborate statistical analysis is warranted. For the floor mechanics, only one of the 25 measurements could have produced a concentration over 1.0 f/cc

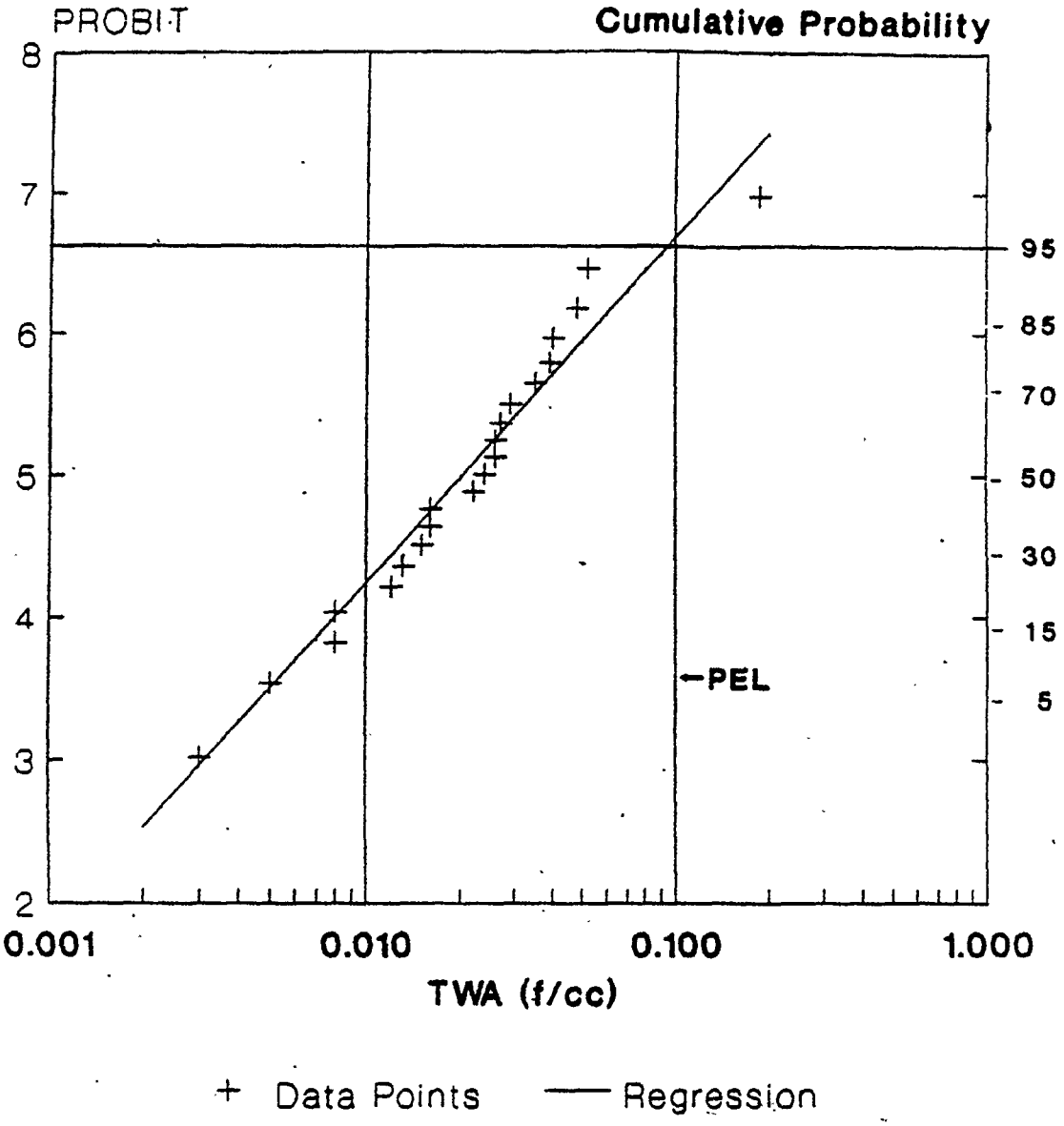


Figure 1. Distribution of Floor Mechanics' Exposures to Fibers as Measured by Phase-Contrast Microscopy. Regression is for a log-normal probability distribution fitted to the data.

averaged over 30-minutes. This measurement was for the same sample that contains no asbestos by TEM and appears to be an outlier in the statistical analysis for the TWAs. Thus, 96% of the values are below 1.0 f/cc. The arithmetic and geometric means of the estimated maximum values for the floor mechanics are 0.416 and 0.278 f/cc, respectively. For the industrial hygienists, they are 0.175 and 0.119 f/cc. These results confirm the finding of OSHA that "there appears to be virtually no possibility that the excursion limit would be exceeded if the recommendations of the Resilient Floor Covering Institute were followed." (53 Fed. Reg. 35614, September 14, 1988)

This analysis demonstrates that initial monitoring of a tile removal job is highly unlikely to show fiber counts in excess of the action limit of 0.1 f/cc or the excursion limit of 1 f/cc. There is no indication whatsoever that the Permissible Exposure Limit of 0.2 f/cc would be exceeded.

C. Reliability of the Conclusions

In the Fowler-Chatfield study, the number of samples is sufficient to give adequate statistical precision and the experimental design is consistent with OSHA-recommended monitoring requirements and in most respects with the current Recommended Work Practices.

Several features of the sampling program and its analysis assure that a worst case has been evaluated with respect to the current Recommended Work Practices. First is the use of phase contrast microscopy, which cannot discriminate between asbestos fibers and other structures of similar morphology. In general industry studies where the presence of asbestos is suspected, or in asbestos-abatement activities covered under the construction industry standards, it can reasonably be assumed that most qualifying structures counted by PCM are asbestos. In floor tile removal, both an a-priori consideration of the nature of the activity and the TEM/PCM comparisons presented in Table 1 and Appendix C confirm that asbestos fibers constitute a small fraction of the fibers counted by PCM in most samples

collected during tile removal. The arithmetic mean ratio of asbestos to all fibers for the floor mechanics is 15.1%; the geometric mean is 10.2%. If the sampling results were to be adjusted to reflect the difference in asbestos content between tile removal and true asbestos-contaminated workplaces, the 95% upper confidence limit on the TWA would fall far short of the action level.

Second, the Fowler-Chatfield data were collected without the use of a HEPA vacuum for cleanup, which is required by the current Recommended Work Practices. The use of an ordinary shop vacuum cleaner not only is less efficient at collecting fibers, but actually serves as a source of dust, some of which may be fibrous.

Third, the highest recorded 8-hour TWA was included in the analysis, even though considerable evidence indicates that it is an outlier. Exclusion of this data point would have yielded a considerably lower 95% upper confidence limit for the TWA.

Finally, only the exposures of mechanics were included in the base statistical analysis. Inclusion of the hygienists' exposures (as surrogates for supervisors' exposures) would also have lowered the 95% upper confidence limit on the TWA.

VII. CONCLUSIONS

VII. CONCLUSIONS

This report was commissioned to determine whether routine initial monitoring is necessary when resilient floor tiles are removed according to Recommended Work Practices. According to the OSHA asbestos standard, initial monitoring would not be required if neither the action level of 0.1 f/cc (8-hr TWA) or the excursion limit of 1.0 f/cc (30-min average) is expected to be exceeded, based on objective or historical data. OSHA has not issued precise definitions of acceptable objective or historical data, but examples of exclusions from the initial monitoring requirement suggest that demonstration of the statistical unlikelihood of exceedance should be sufficient.

ENVIRON's analysis of the Fowler (1988) data presented in section VI clearly meet this test. The 95% upper confidence limit on the individual measurements of exposures to floor mechanics is approximately 0.09 f/cc and below the action level. Also, it is extremely unlikely that the same mechanic would be exposed near the action level day after day, and the mean exposure of approximately 0.031 f/cc is a better representation of the expected results of initial monitoring.

Similarly, the 30-minute concentrations are more than 95% sure to be below 1.0 f/cc. Using the conservative assumption that all the fibers counted during a sampling period were concentrated in a 30-minute period, the mechanics exposures could have averaged at most 0.416 f/cc.

Moreover, the analysis presented here is a worst case because 1) only 10-15% (on average) of the fibers counted by PCM have been confirmed as asbestos, 2) a HEPA vacuum cleaner was not used for the Fowler-Chatfield studies, 3) a likely outlier data point was left in the analysis, and 4) only the exposures of floor mechanics, not those of supervisor-surrogates, were included in the analysis. Results from other studies conducted under conditions resembling the Recommended Work Practices, while limited, are also consistent with the Fowler-Chatfield data.

Therefore, ENVIRON believes that the analysis of the Fowler-Chatfield study provides objective data to support a determination that employee exposure to asbestos during removal of resilient floor tiles does not exceed the action level or excursion limit if the Recommended Work Practices are followed.

REFERENCES

REFERENCES

Fowler Associates. 1988. Final Reprt on Industrial Hygiene Survey of Asbestos Exposures During Resilient Floor Tile Removals Pursuant to Recommended Work Practices at 10 Resilient Floor Tile Removal Sites. Mountain View, CA: Fowler Associates.

Lundgren, D.A., R.W. Vanderpool, and B.Y.H. Liu. 1988. Asbestos Fiber Concentrations Resulting from the Installation, Maintenance and Removal of Vinyl-Asbestos Floor Tile. Presently unpublished report prepared for Armstrong World Industries, Inc.

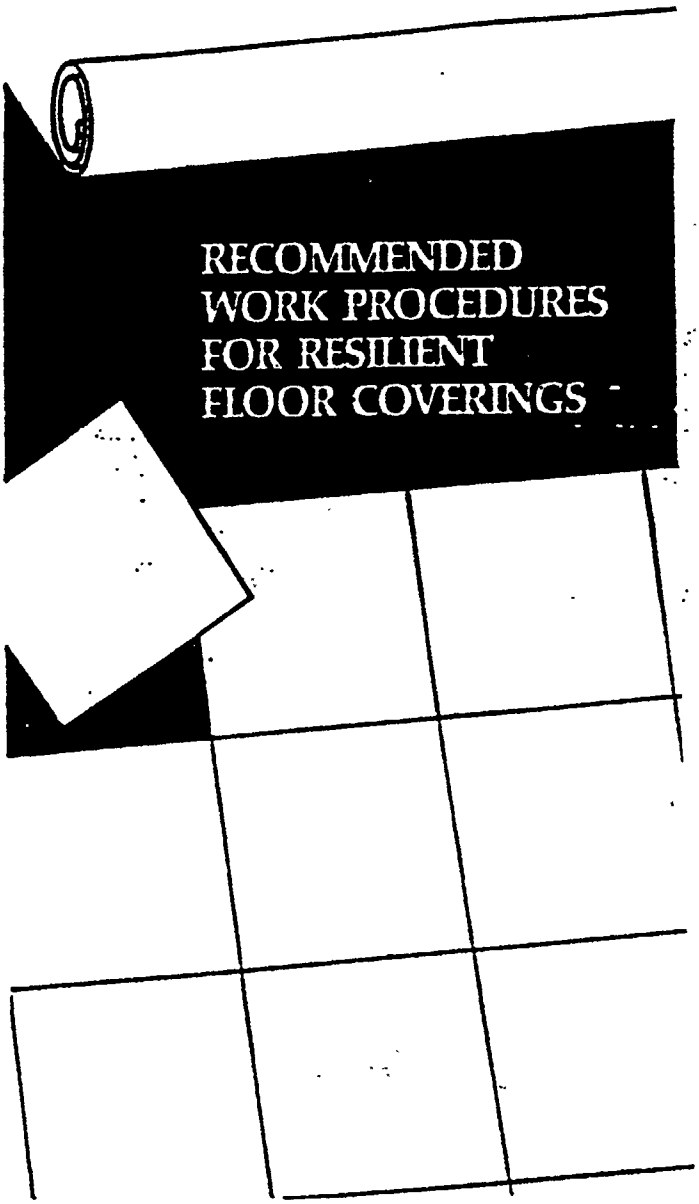
Walcott, R., and J. Warrick. 1979. Monitoring for Airborne Asbestos Fibers: Vinyl Asbestos Floor Tile. SRI Project 7988. Washington, DC: SRI International.

0103a:12/13/88:6:slb:SB

APPENDIXES

APPENDIX A
CURRENT RECOMMENDED WORK PRACTICES
RESILIENT FLOOR COVERING INSTITUTE

RECOMMENDED WORK PROCEDURES FOR RESILIENT FLOOR COVERINGS



Issued by
Resilient Floor Covering Institute
966 Hungerford Dr., Suite 12-B
Rockville, MD 20850

RFCI-WP-1900
Revised 1987

Reprinted by Permission

RECOMMENDED WORK PROCEDURES FOR RESILIENT FLOOR COVERINGS

WARNING

Do Not Sand Existing Resilient Flooring, Backing, Or Lining Felt. These Products May Contain Asbestos Fibers That Are Not Readily Identifiable. Sanding Of Asbestos Containing Material Can Place Fine Particles Of Asbestos In The Air. These Asbestos Particles If Inhaled May Cause Serious Bodily Harm. Smoking Greatly Increases The Risk Of Serious Bodily Harm.

CONTENTS

Issued by
Resilient Floor Covering Institute
966 Hungerford Dr., Suite 12-B
Rockville, MD 20850

IMPORTANT INFORMATION FOR INSTALLERS OF RESILIENT FLOOR COVERINGS

Introduction

The member companies of the Resilient Floor Covering Institute are manufacturers of the following forms of Resilient Floor Coverings:

1. **Sheet Vinyl.**
2. **Vinyl Floor Tile.**

While today these products do not contain asbestos, it is possible that in the past some of these products, including asphalt tile, may have contained asbestos fibers which were firmly encapsulated in the products to provide durability and adaptability.

The Resilient Floor Covering Institute is providing this booklet of recommended work practices for installing or removing resilient floors so that you may proceed with this work in the safest possible way.

There are several general rules to follow:

1. Unless absolutely positive beyond any doubt that the floor is a *non*-asbestos product, assume it contains asbestos and treat it in the manner prescribed in this pamphlet for a floor containing asbestos.
2. It is preferred to install a new floor over a floor which contains asbestos rather than to remove that floor. This can be done by several methods—new underlayment, use of leveling compounds, following installation procedures recommended by the floor covering manufacturer.
3. Never sand any resilient floor or its backing to remove them from the floor.
4. All sweeping must be done wet.
5. All scraping must be done wet.
6. Material removed must be placed in heavy-duty polyethylene bags at least 6 mils thick, properly labeled, and disposed of in an authorized land fill.

WHAT ABOUT ASBESTOS?

In the past decade much attention has been focused on the relationship between exposure to asbestos fibers and respiratory ailments. It has been determined that inhalation of free airborne asbestos fibers may be injurious to health. However, the asbestos fibers contained in the above types of resilient floor coverings are *not free*, but firmly encapsulated or *locked in* the product during the manufacturing process. Asbestos contained therein will not become airborne during the lifetime of the product when these products are used and maintained as recommended by the manufacturer.*

Recommended Work Procedures

PREPARATION OF FLOORS WITH EXISTING RESILIENT FLOOR COVERINGS TO RECEIVE NEW RESILIENT FLOOR COVERINGS

Follow the installation instructions published by the manufacturer of the new floor covering when a new resilient sheet or tile floor covering is to be installed on a surface presently covered with a resilient floor covering. These instructions will tell you what must be done to the existing surface before the new resilient floor covering can be installed.

Of the four general procedures listed below, Items 1 and 2 are covered by manufacturers' instructions; Items 3 and 4 are covered specifically in this Work Procedures Manual**:

Resilient Floor Covering Installed Over....

1. *The Existing Surface.* Follow the manufacturer's instructions for removing wax, filling in low spots, etc. *Use wet scrubbing. Never sand an existing resilient floor covering.*
2. *New Underlayment.* Install panels on top of the existing surface (wood subfloors only) and apply new floor covering directly over this. Follow the manufacturer's instructions.
3. *Partially Removed Existing Adhered Sheet Vinyl Floor Covering.* See instructions below under heading "Partial Removal of Existing Adhered Sheet Vinyl Floor Covering," page 8.
4. *Completely Removed Existing Resilient Floor Covering*
   (a) *Sheet Vinyl*—See instructions below:
   1. "Complete Removal of an Unadhered (Loose-Lay) or Peripherally Adhered Sheet Vinyl Floor Covering," page 6.
   2. "Complete Removal of an Existing Adhered Sheet Vinyl Floor Covering," page 11.

   (b) *Tile*—See instructions under heading "Complete Removal of an Existing Resilient Tile Floor Covering," page 14.

* See "Monitoring for Airborne Asbestos Fibers Vinyl Asbestos Floor Tile" and "Monitoring for Airborne Asbestos Fibers Sheet Vinyl Floor Covering" report prepared by SRI International, 1978-79. (Available on request from the Resilient Floor Covering Institute, 966 Hungerford Dr., Suite 12-B, Rockville, Md 20850.)

** In case of minor variations, the manufacturer's instructions should be followed.

SHEET VINYL FLOOR COVERING

Preparation of Floors With Existing Sheet Vinyl Floor Covering to Receive a New Resilient Floor Covering

Sheet vinyl floor covering is installed in several ways:

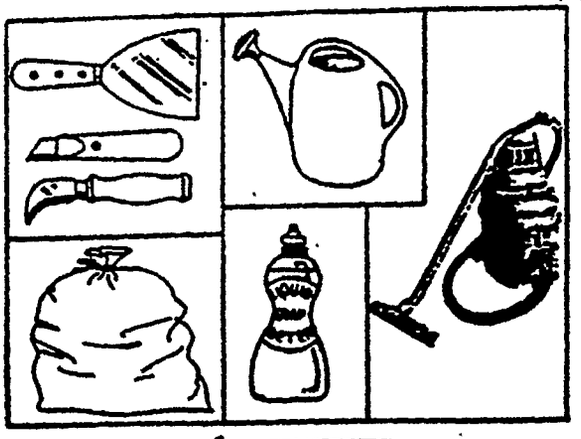
1. Unadhered or Loose-Lay.
2. Adhered or Cemented.
3. Peripherally adhered.

Some resilient floor covering can be installed over existing resilient sheet vinyl floor covering under certain conditions. Be sure to follow the floor covering manufacturer's instructions, regarding the conditions and floor preparation required.

If partial or complete removal of the existing sheet vinyl floor covering is required, the following instructions are to be followed:

Supplies and Tools
(refer Sketch 1.)

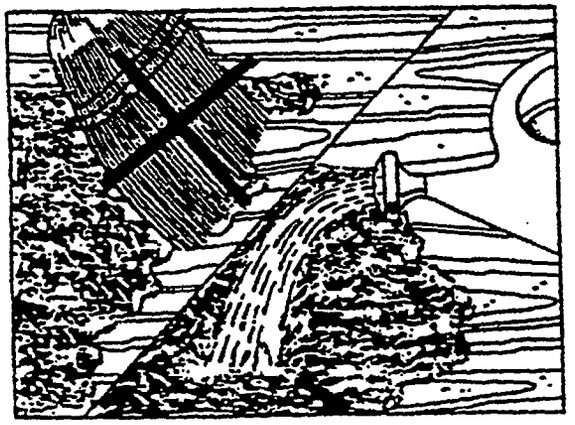
1. Broad, stiff-bladed wall scraper, or floor scraper.
2. Utility or hook knife.
3. Tank type HEPA (High Efficiency Particulate Air) filter vacuum cleaner with disposable dust bag.
4. Large size heavy-duty impermeable trash bags (or closed impermeable containers) with ties, tapes, or string to tie shut, and tags for labeling.
5. Hand sprayer or sprinkling can.
6. Liquid dishwashing detergent or liquid wallpaper remover mixed with water to make a dilute solution (1 oz. liquid in one gallon of water).



WARNING

Sketch 1. *Tools and supplies for sheet removal.*

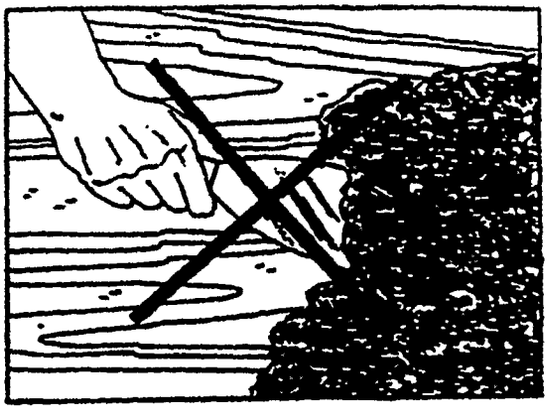
Special Precautions



WARNING

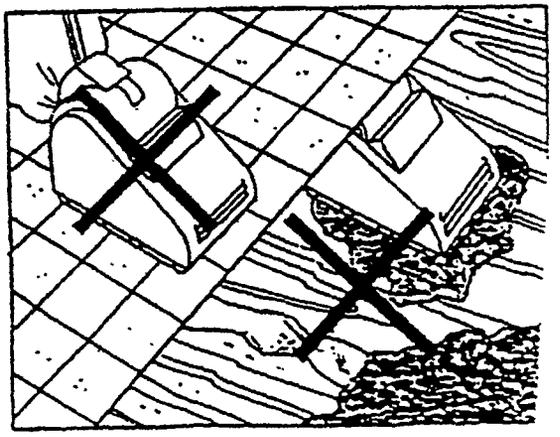
Sketch 2. *Never dry sweep. If unavoidable, use water or other suppressant.*

Special Precautions (Continued)



WARNING

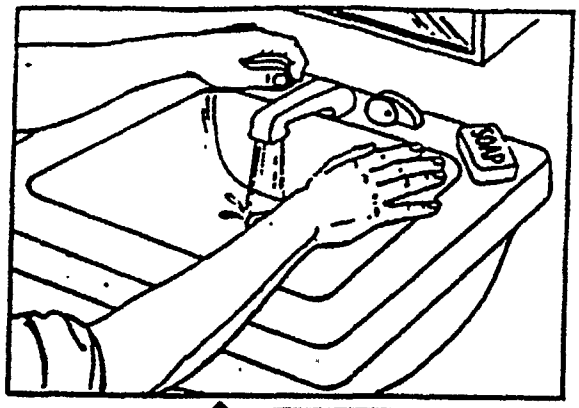
Sketch 3. *Never dry sweep inland even of floor covering.*



WARNING

Sketch 4. *Never sand an existing floor covering; use sand or dry screen residual*

Special Precautions (Continued)



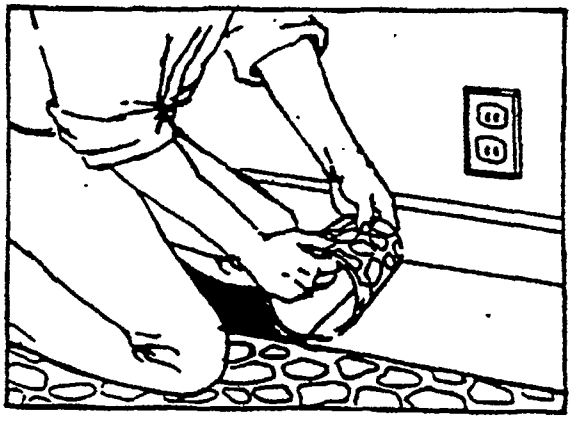
WARNING

Sketch 5. Wash hands before eating and at the end of the work day.

Complete Removal of an Unadhered (Loose-Lay) or Peripherally Adhered Sheet Vinyl Floor Covering

a. Remove any binding strips or other restrictive moldings from doorways, walls, etc.

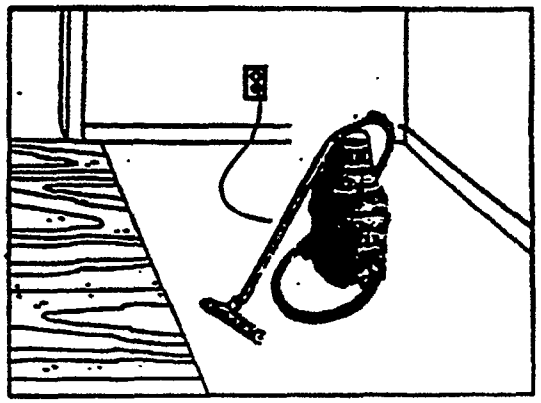
b. Cut a strip the length of the floor and about 18" wide along one wall. Remove this strip, gently turn it over and roll face out into a tight roll (see Sketch 6). Tie or tape securely so it will not unroll. Place it in a heavy-duty impermeable trash bag, or closed impermeable container big enough to accommodate several rolls, for disposal.



Sketch 6. When removing cut strips, roll face out into a tight roll.

c. Clean the exposed floor with a vacuum cleaner positioned so that exhaust air does not blow over the unclean area (see Sketch 7). *DO NOT DRY SWEEP. IF UNAVOIDABLE, USE WATER OR OTHER DUST SUPPRESSANTS.*

d. Repeat the above, cutting, removing, rolling, disposing of one strip at a time and cleaning the newly exposed area immediately until the whole floor covering has been removed and the whole floor vacuumed clean.



WARNING

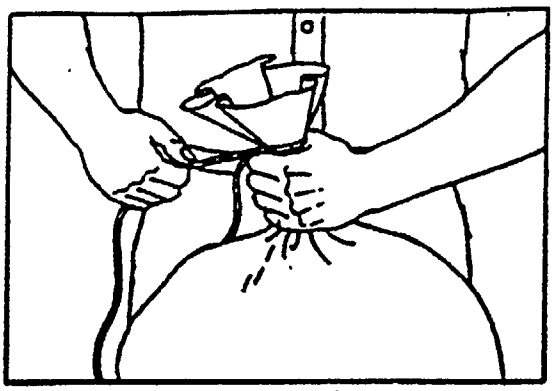
Sketch 7. Position vacuum so that exhaust air does not blow over unclean area. Do not create dust.

e. If seams or door openings have been adhered with double faced tape, remove the tape and place in the heavy-duty impermeable trash bag or closed impermeable container.

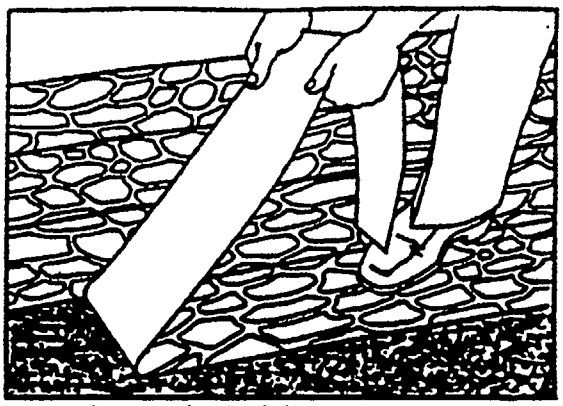
f. If any floor covering areas have been adhered with adhesive and remain stuck to the floor, they should be removed by the wet scraping method explained in page 10. *DO NOT DRY SCRAPE OR SAND.*

g. Carefully remove the dust bag from the cleaner and place it in the trash bag.

h. Close and seal the trash bags tightly for disposal (see Sketch 8). Identify contents with a label stating, "Caution—Contains Asbestos—Dispose in an approved land fill only."



Sketch 8. *Seal trash bags securely for disposal.*



Sketch 9. *Separating top layer from backing.*

l. Install the new resilient floor covering according to the manufacturer's instructions.

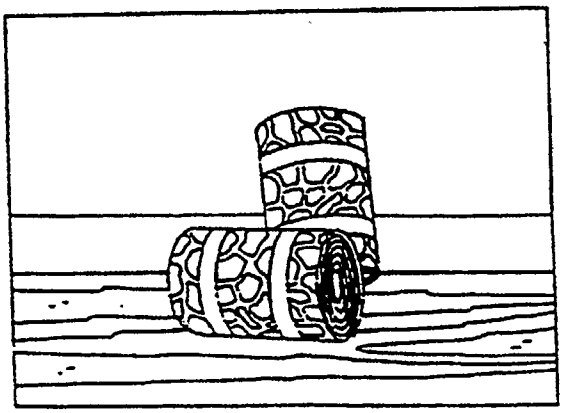
Partial Removal of Existing Adhered Sheet Vinyl Floor Covering

Most felt backed sheet floor coverings can be separated in the backing or felt layer. The felt left on the floor presents a smooth surface on which some new sheet floor coverings can be installed directly. Be sure to follow the manufacturer's instructions. Use the following procedure to partially remove the existing adhered floor covering.

WARNING

Never Sand an Existing Floor Covering

a. Remove any binding strips or other restrictive moldings from doorways, walls, etc.
b. Make a series of parallel cuts 4 to 8 inches apart through the top layers and about halfway through the backing, parallel to the wall.
c. Start at the end of the room farthest from the entrance door and pry up the corner of a strip, separating the backing layer. Pull the top layer back upon itself slowly and evenly at the angle that permits the best separation, and half the backing and the top layers will pull free (see Sketch 9). After it is removed, roll up the strip face out into a tight roll. Tie or tape securely (see Sketch 10) and place in the heavy-duty impermeable trash bag or closed impermeable container for disposal.
d. Each succeeding strip should be removed in the above manner. Avoid walking on the exposed felt as much as possible. Roll up each strip as it is removed and place it in the trash bag or closed container. Close full bags tightly and seal securely for



Sketch 10. *Rolled up strips must be sealed for liquid security.*

disposal. Identify with a label stating, "Caution—contains asbestos. Dispose in an approved land fill only."

e. Occasionally, parts of the top layers will stick to the backing. This can often be eliminated by peeling from the opposite direction. The stiff-bladed scraper will help in stubborn areas.

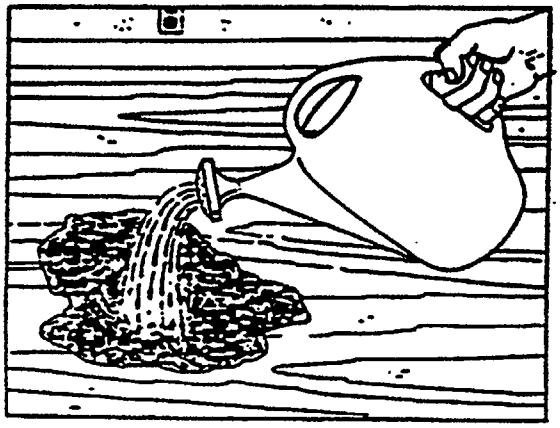
f. Any high spots of felt on the floor can be levelled by wet scraping.

WARNING

Never Sand or Dry Scrape Residual Felt

Wet scraping is done as follows:

1. Pour the detergent solution into the sprayer or sprinkling can.
2. Thoroughly wet the high felt spot with this solution. Wait a few minutes to allow the solution to soak into the felt (see Sketch 11 below).

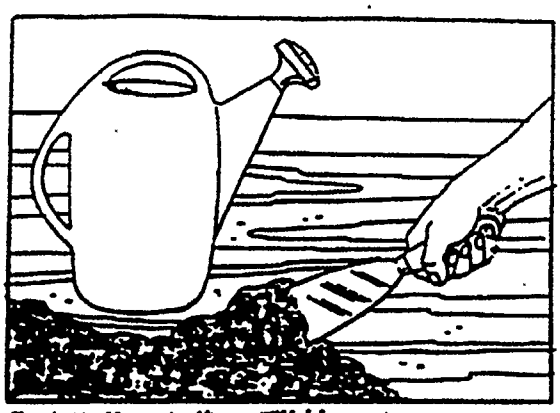


WARNING

Sketch 11. *Do not dry scrape. Thoroughly wet dry felt before removal.*

3. Use the stiff-bladed scraper to remove the excess felt (see Sketch 12). If felt dries out, or dry felt is exposed during scraping, re-wet with more solution.
4. Pick up the larger pieces by hand and place in the trash bag immediately.

g. Non-adhered felt left on the floor can be cut open and re-adhered to the floor with adhesive.



Sketch 12. *After wetting felt, use stiff-bladed scraper to remove.*

h. If small areas of backing pull free from the floor, the depression should be filled with latex patching compound, as recommended by the floor covering manufacturer. Patching compound *must* be troweled to finished smoothness since the area *cannot* be sanded later.

i. Clean the floor with the vacuum cleaner using the metal floor tool. *DO NOT DRY SWEEP WITH A BROOM.* Position the vacuum cleaner so that discharge air does not blow on the felt. Carefully remove the dust bag from the cleaner immediately and place in a heavy-duty impermeable trash bag or closed impermeable container.

j. Close and seal trash bags tightly for disposal. Identify contents with a label: "Caution—contains asbestos. Dispose in a approved land fill only."

k. Do not walk over the felt unnecessarily, as this might scuff the felt and raise dust.

l. Install the new resilient floor covering immediately, following the manufacturer's instructions.

Complete Removal of an Existing Adhered Sheet Vinyl Floor Covering

If complete removal is required, follow these instructions:

WARNING

Never Sand an Existing Floor Covering

a. Remove any binding strips or other restrictive moldings from doorways, walls, etc.
b. Make a series of parallel cuts 4 to 8 inches apart, parallel to a wall.
c. Start at the end of the room farthest from the entrance door, pry up the corner of the first strip, separating the backing layer. Pull the top layer back upon itself slowly and evenly at an angle that permits the best separation, and most of the backing and top layers will pull free (see Sketch 9). Remove this strip, gently turn it over and roll face out into a tight roll. Tie or tape securely (see Sketch 10) and place in a heavy-duty impermeable trash bag or closed impermeable container for disposal.
d. Repeat the above on the next two strips but do not remove anymore than a total of three strips at this time.
e. Remove the felt remaining on the floor in the stripped area by *not scraping.*

WARNING

Never Sand or Dry Scrape Residual Felt

Wet scraping is done as follows:

1. Pour the detergent solution into the sprayer or sprinkling can.
2. Thoroughly wet the residual felt with this solution. Wait a few minutes to allow the solution to soak into the felt (see Sketch 11).
3. Stand on the remaining floor covering (not the felt) and use the stiff-bladed scraper to scrape up the wet felt (see Sketch 13 below).

WARNING

Do Not Scrape Dry Felt

Re-wet the felt if it dries out or if dry felt is exposed during scraping. Pick up the scrapings as they are removed from the floor and place in a heavy-duty impermeable trash bag or closed impermeable container. Scrape *all* felt from this floor area before proceeding further.

Sketch 13. Stand on the remaining floor covering, not the felt, during felt removal.

4. Repeat the above on the next series of strips. Do only *one* three-strip area at a time. Stand on the remaining floor covering or clean floor (do not stand on the felt) to scrape up the felt.
5. Repeat this operation until the felt has been removed from the whole floor. Close full bags tightly, and seal securely for disposal. Identify with a label stating, "Caution—Contains Asbestos. Dispose in an approved land fill only."

f. When the whole floor has been cleaned free of felt, let it dry and vacuum up any dirt using the vacuum cleaner with the metal floor tool. Stand only in vacuumed areas as you proceed across the floor.

WARNING

Do Not Dry Sweep

Position the vacuum cleaner so that the discharge air does not blow on the floor being cleaned.

g. Carefully remove the dust bag from the cleaner and place in a heavy-duty impermeable trash bag or closed impermeable container for later disposal.
h. When the floor is dry, it is ready to have a new resilient floor covering installed. Follow the floor covering manufacturer's instructions.

RESILIENT TILE FLOOR COVERING

Preparation of Floors With Existing Resilient Tiles to Receive New Resilient Floor Covering

Some resilient floor coverings can be installed over existing resilient tile installations. Follow the installation instructions published by the manufacturer of the new floor covering when a new resilient floor covering is to be installed on a surface presently covered with a resilient floor covering. These instructions will tell you what must be done to the existing surface before the new resilient floor covering can be installed.

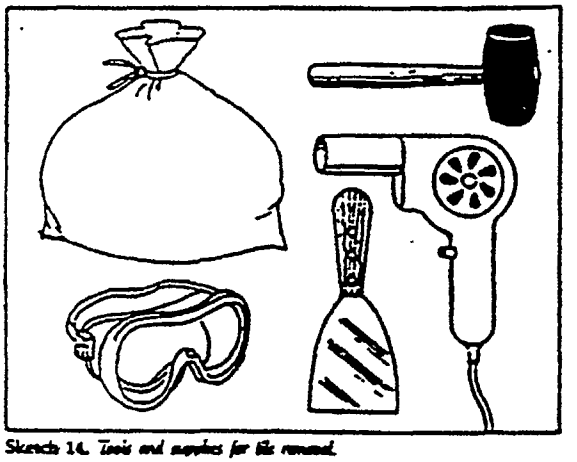
WARNING

Never Sand an Existing Tile Installation (see Sketch 4)

Complete Removal of Existing Resilient Tile Floor Covering

Supplies and Tools (refer Sketch 14)

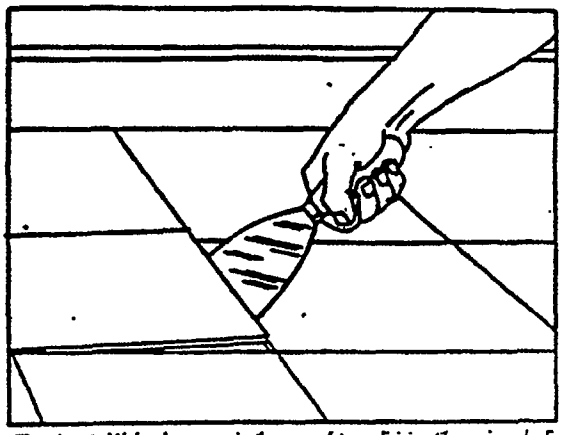
1. Heavy-duty wall scraper with approximately 4" blade and 6" to 8" handle.
2. Hammer.
3. Commercial type hand-held hot air blower.
4. Heavy-duty polyethylene bags at least 6 mils thick (or closed impermeable containers), ties, and labels.



Sketch 14. *Tools and supplies for tile removal.*

Removal Procedure

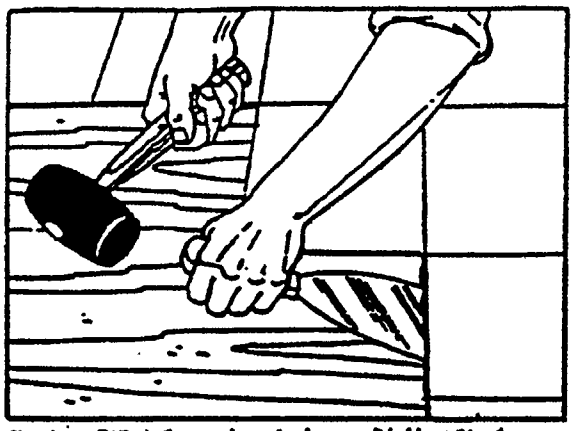
a. Those areas normally exposed to heavy foot traffic patterns usually have tiles adhered the tightest. As a matter of good practice in starting the tile removal, those sections which receive least traffic should be the locations selected for starting the removal of the tile. Since tiles are normally in a 9" × 9" or 12" × 12" dimension, it should be the goal to remove individual tiles as a complete unit.



Sketch 15. *Wedge the scraper in the seam of two adjoining tiles and gradually force tile upward.*

b. Start the removal by carefully wedging the wall scraper in the seam of two adjoining tiles and gradually forcing the edge of one of the tiles up and away from the floor (see Sketch 15). Do not break off pieces of the tile but continue to force the balance of the tile up by working the scraper beneath the tile and exerting both a forward pressure and a twisting action on the blade to promote release of the tile from the adhesive and the floor.

c. When the first tile is removed place it, without breaking it into smaller pieces, in the heavy-duty impermeable trash bag or closed impermeable container which will be used for disposal.



Sketch 16. Difficult tile removal can often be accomplished by striking the scraper handle with a hammer or mallet as shown.

d. With the removal of the first tile accessibility of the other tiles is improved. Force the wall scraper under the exposed edge of another tile and continue to exert a prying twisting force to the scraper as it is moved under the tile until the tile releases from the floor. Again, dispose of the tile, and succeeding tiles, by placing in the heavy-duty bag or closed container without additional breaking.

e. Some tiles will release quite easily while others require varying degrees of force. Where the adhesive is spread heavily or is quite hard, it may prove easier to force the scraper through the tightly adhered areas by striking the scraper handle with a hammer using blows of moderate force while maintaining the scraper at a 25° to 30° angle to the floor (see Sketch 16). Caution: Use safety goggles.

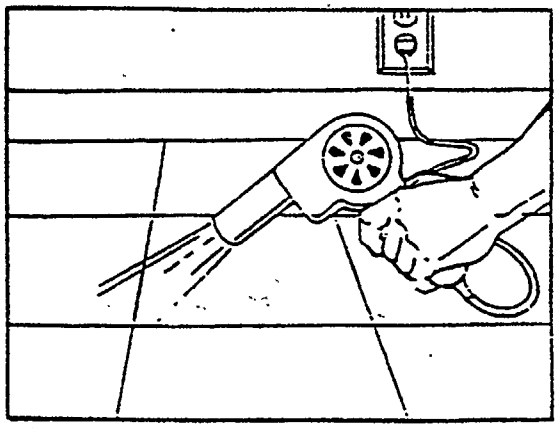
f. If some areas are encountered where even the technique detailed in the previous paragraph proves to be inadequate, the removal procedure can be simplified by thoroughly heating the tile(s) with a hot air blower until the heat penetrates through the tile and softens the adhesive.

NOTE 1: Handle the hot air blower, tiles, and adhesive carefully to avoid personal burns (see Sketch 17 below).

NOTE 2: Do not handle the heated tiles and adhesive without suitable glove protection for the hands.

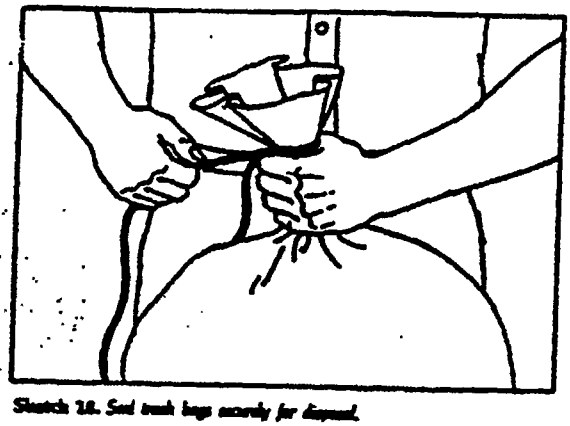
g. As small areas of subfloor are cleared of tile, the adhesive remaining on the floor must be scraped up with the 4" hand scraper until only a thin, smooth film remains. In those areas where deposits are heavy or difficult to scrape, the removal can be expedited by heating with the hot air blower prior to scraping. Deposit scrapings in a heavy-duty impermeable trash bag or closed impermeable container.

h. As indicated in previous paragraphs, tiles should be placed immediately in a heavy-duty impermeable trash bag or closed impermeable container. Do not attempt to break tiles after they are in the bag.



Sketch 17. In very difficult areas, using a hot air blower can simplify tile removal.

i. When all tiles have been removed from the floor and placed in heavy-duty polyethylene bags at least 6 mils thick or closed containers, seal the bags securely for disposal (see Sketch 18 below) and mark: "Caution—Contains Asbestos—Dispose in an approved land fill only."



Sketch 18. Seal trash bags securely for disposal.

WARNING

Do Not Sand Existing Resilient Flooring, Backing, Or Lining Felt. These Products May Contain Asbestos Fibers That Are Not Readily Identifiable. Sanding Of Asbestos Containing Material Can Place Fine Particles Of Asbestos In The Air. These Asbestos Particles If Inhaled May Cause Serious Bodily Harm. Smoking Greatly Increases The Risk Of Serious Bodily Harm.

APPENDIX B
CURRENT RECOMMENDED WORK PRACTICES
ARMSTRONG WORLD INDUTRIES, INC.

Armstrong

Recommended Work Practices for Removal of **Resilient Floor Coverings**

F-5662-366J

Printed in United States of America

It is essential that certain precautions be observed when installing a resilient floor covering or when preparing or removing an existing resilient floor covering. It is the purpose of these Work Practices to provide those precautionary steps necessary to accomplish the work involved.

⚠WARNING STATEMENT:

EXISTING RESILIENT TILE AND SHEET FLOORING, BACKING, OR LINING FELT MAY CONTAIN ASBESTOS FIBERS THAT ARE NOT READILY IDENTIFIABLE. AVOID CREATING DUST. INHALATION OF ASBESTOS DUST MAY CAUSE ASBESTOSIS OR OTHER SERIOUS BODILY HARM. SMOKING GREATLY INCREASES THE RISK OF SERIOUS BODILY HARM.

NOTICE:

Various government agencies have regulations governing the removal of in-place asbestos-containing material. If you contemplate the removal of a resilient floor covering structure that contains (or is assumed to contain) asbestos, you should determine whether such regulations apply.

Important information for installers of resilient floor coverings

What You Should Know About Resilient Floor Coverings

Vinyl-asbestos tile and asphalt tile contain asbestos fibers, as did the backings of many sheet vinyl floorings and lining felts. The presence of the asbestos in these floor products is not readily identifiable.

Recommended Work Practices for Removal of Resilient Floor Coverings

TABLE OF CONTENTS

1. ALTERNATIVES TO REMOVAL OF EXISTING RESILIENT FLOOR COVERINGS

• Installing resilient floor covering over existing resilient floor covering

Removal of the existing resilient floor is the final alternative (see note below). Armstrong recommends that whenever possible you leave the existing resilient floor covering in place and go over the top with your new floor.

Note: Alternatives to the removal of an unsuitable resilient floor or residual felt on a suspended wood floor are the use of an underlayment as a new surface before installing the new Armstrong flooring or going over a single layer of existing resilient flooring with the new layer of resilient flooring.

Contact your local Armstrong dealer for our recommendations or consult Armstrong's brochure F-5061, "Resilient Flooring Installation Recommendations."

When you plan to install a new resilient sheet or tile floor covering over an existing resilient floor covering, follow the installation instructions published by the manufacturer. Those instructions will tell you what must be done to the existing surface before the new resilient floor covering can be installed. Just be sure to remove wax by wet stripping.

⚠WARNING

NEVER SAND AN EXISTING RESILIENT FLOOR COVERING. SEE WARNING STATEMENT INSIDE COVER.

• Installing resilient floor covering over new underlayment

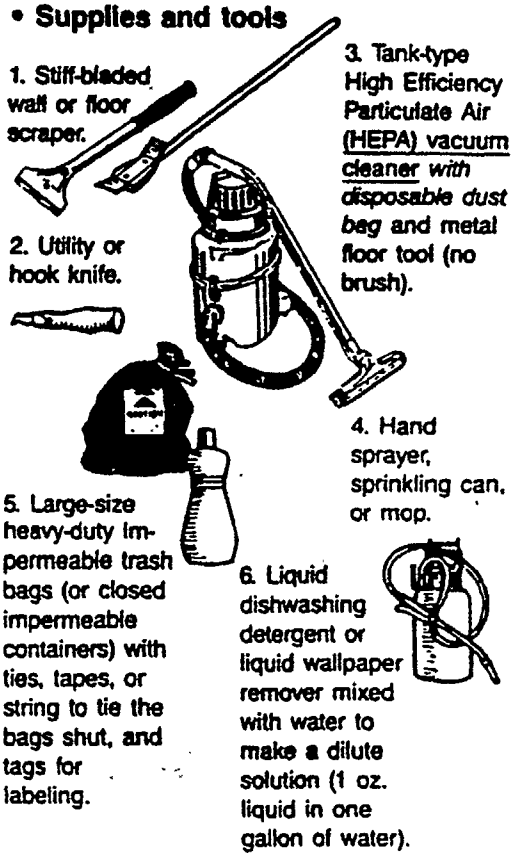
When you install a new floor covering over new underlayment, follow the Armstrong recommendations found in brochure F-5061, "Armstrong Resilient Flooring Installation Recommendations."

2. PARTIAL OR COMPLETE REMOVAL OF EXISTING RESILIENT SHEET FLOORING

⚠WARNING

DO NOT SAND EXISTING RESILIENT TILE AND SHEET FLOORING, BACKING, OR LINING FELT. SEE WARNING STATEMENT INSIDE COVER.

• Supplies and tools



1. Stiff-bladed wall or floor scraper.
2. Utility or hook knife.
3. Tank-type High Efficiency Particulate Air (HEPA) vacuum cleaner *with disposable dust bag* and metal floor tool (no brush).
4. Hand sprayer, sprinkling can, or mop.
5. Large-size heavy-duty impermeable trash bags (or closed impermeable containers) with ties, tapes, or string to tie the bags shut, and tags for labeling.
6. Liquid dishwashing detergent or liquid wallpaper remover mixed with water to make a dilute solution (1 oz. liquid in one gallon of water).

• Partial removal, resilient sheet flooring

Most felt-backed sheet floor coverings can be separated in the backing or felt layer. If the remaining felt presents a smooth surface, some new sheet floor coverings can be installed directly over top of it. Be sure to follow Armstrong's instructions for installation. Use the following procedure to partially remove the existing adhered floor covering.

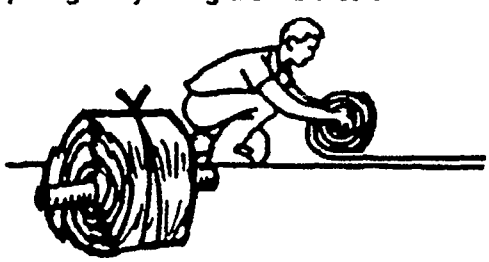
⚠WARNING

NEVER SAND AN EXISTING FLOOR COVERING OR FELT BACKING. SEE WARNING STATEMENT INSIDE COVER.

a. Remove any binding strips or other restrictive moldings from doorways, walls, etc.

b. Make a series of parallel cuts 4" to 8" apart through the top layers and about halfway through the backing, parallel to the wall.

c. Start at the end of the room farthest from the entrance door and pry up the corner of a strip, separating the backing layer. The cut strips should be peeled from the backing by pulling or by rolling around a core



which will control the stripping angle to create a uniform tension (some resilient flooring wear layers may not readily be strippable and may require scraping). Tie or tape the removed material securely and place in the heavy-duty impermeable trash bag or closed impermeable container for disposal.

d. Remove and dispose of each succeeding strip in the above manner. Avoid walking on the exposed felt as much as possible. Close full bags tightly, and seal securely for disposal. Identify with a label stating—"Caution—contains asbestos. Avoid creating dust. Breathing asbestos may cause bodily harm. Dispose in an approved landfill only."

e. Occasionally, parts of the top layers will stick to the backing. This can often be eliminated by peeling from the opposite direction. The stiff-bladed scraper or the use of heat supplied by a source such as a heat gun may aid in the removal or peeling of the wear layer.

⚠WARNING

NEVER SAND OR DRY-SCRAPE RESIDUAL FELT BACKING. SEE WARNING STATEMENT INSIDE COVER.

f. Wet-scraping—any high spots of felt on the floor can be leveled by wet-scraping.

(1) Apply a detergent solution to the felt, and allow it to penetrate for several minutes before scraping. Use only enough solution to keep the top surface of the felt damp. More than one application may be necessary, depending upon the time required for removal.

(2) Use the stiff-bladed scraper to remove the excess felt.

(3) Pick up the larger pieces by hand, and place in the trash bag immediately.

PRECAUTIONS: DO NOT SOAK FELT. EXCESSIVE MOISTURE CAN CAUSE PERMANENT DAMAGE TO WOOD UNDERLAYMENTS. IT IS THE INSTALLER'S RESPONSIBILITY TO USE THE CORRECT AMOUNT OF WETTING SOLUTION TO PREVENT UNDERLAYMENT DAMAGE. A FLOOR THAT HAS BEEN WET-SCRAPED MUST BE ALLOWED TO DRY BEFORE INSTALLING ANY NEW RESILIENT FLOORING.

g. Nonadhered felt left on the floor can be cut open and readhered to the floor with adhesive.

h. Clean the floor with the HEPA vacuum cleaner, using the metal floor tool. Position the vacuum cleaner so that discharge air does not blow on the felt. After vacuuming, used HEPA filters and cleaner bags should be removed carefully and placed in a sealable plastic bag (appropriately labeled) and disposed of as asbestos waste.

⚠WARNING

DO NOT DRY-SWEEP. AVOID CREATING DUST. SEE WARNING STATEMENT INSIDE COVER.

i. Close and seal trash bags tightly for disposal. Identify with a label stating—"Caution—contains asbestos. Avoid creating dust. Breathing asbestos may cause bodily harm. Dispose in an approved landfill only."

j. Do not walk over the felt unnecessarily as this might scuff the felt and raise dust.

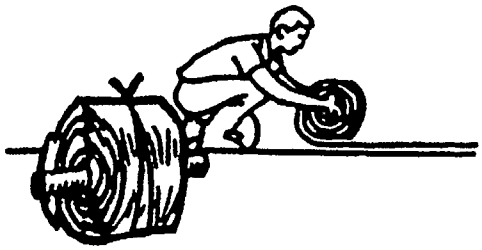
k. If small areas of backing pull free from the floor, the depression should be filled with S-180 Latex Underlayment as recommended by the floor covering manufacturer. Patching compound *must* be trowelled to finished smoothness since the area *cannot* be sanded later.

l. After the underlayment has dried, install the new Armstrong resilient floor covering following recommended instructions.

• Complete removal, unadhered (loose-lay) or peripherally adhered resilient sheet flooring

a. Remove any binding strips or other restrictive moldings from doorways, walls, etc.

b. If flooring is unadhered, cut flooring into strips about 18" wide. Remove these strips by rolling face out into a tight roll. Tie or tape securely so it will not unroll. Place it in a heavy-duty impermeable trash bag or closed impermeable container big enough to accommodate several rolls for disposal.



Use this method for nonbonded areas of peripherally adhered floors. To remove bonded areas, follow instructions under "Complete removal, fully adhered resilient sheet flooring."

c. Clean the exposed floor with a HEPA vacuum cleaner positioned so that exhaust air does not blow over the unclean area.

⚠WARNING

DO NOT DRY-SWEEP. SEE WARNING STATEMENT INSIDE COVER. IF SWEEPING IS UNAVOIDABLE, USE WATER OR OTHER DUST SUPPRESSANTS.

d. Repeat the above, cutting, rolling, and disposing of one strip at a time and cleaning the newly exposed area immediately until the entire floor covering has been removed and the entire floor is vacuumed clean.

e. If any floor covering remains stuck to the floor, it should be removed by the *wet-scraping* method previously explained.

⚠WARNING

DO NOT DRY-SCRAPE OR SAND. SEE WARNING STATEMENT INSIDE COVER. PLACE THE REMOVED FLOOR COVERING IN THE HEAVY-DUTY IMPERMEABLE TRASH BAG OR CLOSED IMPERMEABLE CONTAINER.

f. After vacuuming, used HEPA filters and cleaner bags should be removed carefully and placed in a sealable plastic bag (appropriately labeled) and disposed of as asbestos waste.

g. Close and seal the trash bags tightly for disposal. Identify with a label stating—"Caution—contains asbestos. Avoid creating dust. Breathing asbestos may cause bodily harm. Dispose in an approved landfill only."

h. After the underlayment is dry, install the new Armstrong resilient floor covering according to Armstrong's installation instructions.

• Complete removal, fully adhered resilient sheet flooring

⚠WARNING

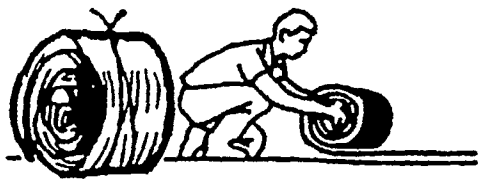
NEVER SAND AN EXISTING RESILIENT FLOOR COVERING OR BACKING. SEE WARNING STATEMENT INSIDE COVER.

• Wear layer removal

a. Remove any binding strips or other restrictive moldings from doorways, walls, etc.

b. Make a series of parallel cuts 4" to 8" apart through the top layers and about halfway through the backing, parallel to the wall.

c. Start at the end of the room farthest from the entrance door and pry up the corner of a strip, separating the backing layer. The cut strips should be peeled from the backing by pulling or by rolling around a core which will control the stripping angle to create a uniform tension (some resilient flooring wear layers may not be readily strippable and may require scraping). Tie or tape the removed material securely and place in the heavy-duty impermeable trash bag or closed impermeable container for disposal.



d. Do only one three-strip area at a time. Stand on the remaining floor covering or clean floor (do not stand on the felt).

⚠WARNING

NEVER SAND OR DRY-SCRAPE RESIDUAL FELT BACKING. AVOID CREATING DUST. SEE WARNING STATEMENT INSIDE COVER.

e. Wet-scraping remaining felt:

(1) Pour the detergent solution into the sprayer or sprinkling can.

(2) Thoroughly wet the residual felt with this solution. Wait a few minutes to allow the solution to soak into the felt.

(3) Stand on the remaining floor covering (not the felt), and use the stiff-bladed scraper to scrape up the wet felt.

(4) Rewet the felt if it dries out or if dry felt is exposed during scraping. Pick up the scrapings as they are removed from the floor and place in a heavy-duty impermeable trash bag or closed impermeable container. Scrape *all* felt from this floor area before proceeding further.

(5) Repeat the above on the next series of strips.

(6) Repeat this operation until the felt has been removed from the whole floor. Close full bags tightly and seal securely for disposal. Identify with a label stating—"Caution—contains asbestos. Avoid creating dust. Breathing asbestos may cause bodily harm. Dispose in an approved landfill only."

(7) When the whole floor has been cleaned free of felt, vacuum up any dirt using the HEPA vacuum cleaner with the metal floor tool and let it dry. Position the vacuum cleaner so that the discharge air does not blow on the floor being cleaned.

⚠WARNING

DO NOT DRY-SWEEP. AVOID CREATING DUST. SEE WARNING STATEMENT INSIDE COVER.

(8) After vacuuming, used HEPA filters and cleaner bags should be removed carefully and placed in a sealable plastic bag (appropriately labeled) and disposed of as asbestos waste.

(9) When the floor is dry, it is ready to have a new resilient floor covering installed. Follow Armstrong's installation instructions.

3. REMOVAL OF RESILIENT TILE

Some resilient floor coverings can be installed over existing resilient tile installations. Follow the Armstrong installation instructions when a new Armstrong resilient floor covering is to be installed on a surface presently covered with a resilient tile floor. These instructions will tell you what must be done to the existing surface before the new resilient floor covering can be installed.

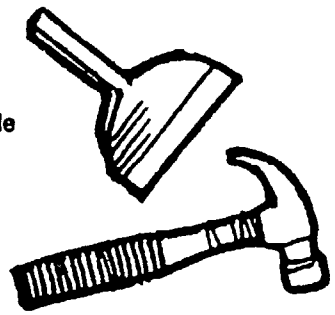
⚠WARNING

NEVER SAND AN EXISTING RESILIENT TILE INSTALLATION. SEE WARNING STATEMENT INSIDE COVER.

• Supplies and tools

1. Heavy-duty scraper with approximately 4" blade and 6" to 8" handle or weighted long-handled floor scraper.

2. Hammer.



3. Commercial-type hand-held hot-air blower.

4. Heavy-duty impermeable trash bags (or closed impermeable containers), ties, and labels.

• Removal Procedure

a. Those areas normally exposed to heavy foot-traffic patterns usually have tiles adhered the tightest. As a matter of good practice in starting the tile removal, select those sections which receive the least traffic. Since tiles are normally in a 9"x9" or 12"x12" dimension, try to remove individual tiles as a complete unit.

b. Start the removal by carefully wedging the scraper in the seam of two adjoining tiles and gradually forcing the edge of one of the tiles up and away from the floor. Do not break off pieces of the tile, but continue to force the balance of the tile up by working the scraper beneath the tile and exerting both a forward pressure and a twisting action on the blade to promote release of the tile from the adhesive and the floor.

c. When the first tile is removed, place it, without breaking it into smaller pieces, in the heavy-duty impermeable trash bag or closed impermeable container which will be used for disposal.

d. With the removal of the first tile, accessibility of other tiles is improved. Force the scraper under the exposed edge of another tile, and continue to exert a prying, twisting force to the scraper as it is moved under the tile until the tile releases from the floor. Again, dispose of the tile and succeeding tiles by placing in the heavy-duty bag or closed container without additional breaking.

e. Some tiles will release quite easily while others require varying degrees of force. Where the adhesive is spread heavily or is quite hard, it may prove easier to force the scraper through the tightly adhered areas by striking the scraper handle with a hammer, using blows of moderate force while maintaining the scraper at a 25° to 30° angle to the floor.

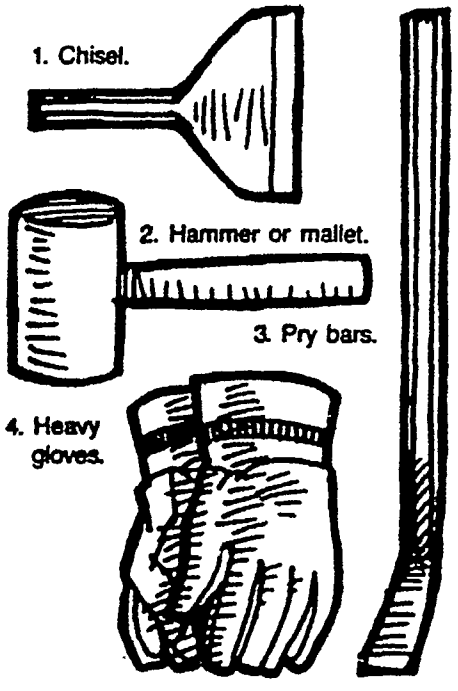
⚠ CAUTION

WEAR SAFETY GLASSES WHEN USING THIS PROCEDURE.

f. If you encounter areas where even the above methods will not remove the tiles, the removal procedure can be simplified by thoroughly heating the tiles with a hot-air blower until the heat penetrates through the tile and softens the adhesive. **NOTE: Handle the hot-air blower carefully to avoid injury. Do not use a blowtorch or open flame. Use caution not to burn or char tile. Use adequate ventilation.**

4. COMPLETE REMOVAL OF WOOD UNDERLAYMENT/EXISTING FLOORING

- **Supplies and tools**



a. Remove any binding strips or other restrictive moldings from doorways, walls, etc.

b. Starting near center of area, locate a joint in the underlayment. Cut through the existing resilient flooring at the underlayment's joints so that one panel can be removed. Drive a chisel into the underlayment joint, using a hammer or mallet. Now use the chisel to pry up the underlayment enough to insert a pry bar and remove the chisel. Slowly and carefully use one or two pry bars to pry up the underlayment panel a little at a time until panel is completely loose and can be removed.

c. If the underlayment panel does not come up intact, remove each piece as it breaks by cutting the existing resilient flooring at the break.

d. Wear heavy gloves and be very careful of wood splinters and fasteners sticking out of the back of the underlayment. Each underlayment panel (or piece of panel) should be removed from the work area as soon as it has been pried up to avoid injuries (such as stepping on a nail). Flatten protruding fasteners with a hammer. Place scrapped panels in dumpsters or on skids with the nails pointing downward. Identify with a label stating—"Caution—contains asbestos. Avoid creating dust. Breathing asbestos may cause bodily harm. Dispose in an approved landfill only."

e. After each panel has been removed, pull out any nails or fasteners still in the subfloor. Dispose of these and any other nails or fasteners which have been removed but are still laying in the work area.

f. You don't need to use a chisel to start the removal of panels after the first panel has been removed. Simply work the pry bar under the exposed edge of the next panel.

g. When removal of the underlayment/existing floor is complete, thoroughly check the exposed subfloor. Renail loose areas and reset any "popped" nails or fasteners.

h. Install the new underlayment and floor covering according to Armstrong's installation instructions.

APPENDIX C
DATA TABULATION

ANALYSIS OF FOWLER DATA ON EXPOSURE OF FLOOR MECHANICS TO FIBER CONCENTRATIONS

Phase-Contrast Microscopy

Survey No.	Sample No.	Duration (min)	Volume (liters)	Count (fibers/sq mm)	Blank (fibers/sq mm)	Adjusted Count (fibers/sq mm)	Concentration (fibers/cc)	Background (fibers/cc)	Net Conc. (fibers/cc)	8-hr TWA Conc. (fibers/cc)	30-min Max. Conc. (fibers/cc)
1	MI028	380	1083	101.9	5.4	96.5	0.0343	0.0017	0.0326	0.0258	0.4130
1	MI029	321	963	28.0	5.4	22.6	0.0090	0.0017	0.0073	0.0049	0.0785
2	MI030	346	847	114.6	5.4	109.2	0.0496	0.0015	0.0481	0.0347	0.5552
2	MI031	348	940	63.7	5.4	58.3	0.0239	0.0015	0.0224	0.0162	0.2596
3	MI038	127	273	164.0	2.3	161.8	0.2281	0.0310	0.1971	0.0522	0.8344
3	MI039	130	189	44.6	2.3	42.4	0.0863	0.0310	0.0553	0.0150	0.2395
3	MI041	132	244	72.0	2.3	69.8	0.1101	0.0310	0.0791	0.0217	0.3478
4	MI037	137	253	33.8	2.3	31.6	0.0480	0.0210	0.0270	0.0077	0.1233
4	MI036	118	260	23.6	2.3	21.4	0.0316	0.0210	0.0106	0.0026	0.0418
5	MI024	101	242	124.2	1.5	122.7	0.1952	0.0110	0.1842	0.0388	0.6202
5	MI015	101	242	94.3	1.5	92.8	0.1476	0.0110	0.1366	0.0288	0.4600
6	MI066	79	190	28.7	1.5	27.2	0.0551	0.0031	0.0520		0.1370
6	MI070	90	204	39.5	1.5	38.0	0.0717	0.0031	0.0686	0.0398	0.2058
6	MI048	52	120	55.4	1.5	53.9	0.1729	0.0031	0.1698		0.2944
6	MI076	79	143	66.9	1.5	65.4	0.1761	0.0031	0.1730		0.4555
6	MI067	88	183	29.9	1.5	28.4	0.0597	0.0031	0.0566	0.0483	0.1662
6	MI072	54	159	37.6	1.5	36.1	0.0874	0.0031	0.0843		0.1518
7	MI095	275	645	38.9	2.5	36.4	0.0217	0.0000 *	0.0217	0.0124	0.1992
7	MI093	272	427	368.0	2.5	365.5	0.3295	0.0000 *	0.3295	0.1867	2.9879
8	MI215	141	264	63.7	1.3	62.4	0.0910	0.0100	0.0810	0.0238	0.3807
8	MI216	157	305	75.8	1.3	74.5	0.0940	0.0100	0.0840	0.0275	0.4398
9	MI219	198	366	51.0	1.3	49.7	0.0523	0.0140	0.0383	0.0158	0.2526
9	MI222	197	399	35.7	1.3	34.4	0.0332	0.0140	0.0192	0.0079	0.1260
10	MI223	191	357	70.1	1.3	68.8	0.0742	0.0087	0.0655	0.0261	0.4170
10	MI226	194	371	39.5	1.3	38.2	0.0396	0.0087	0.0309	0.0125	0.2001
									Arithmetic Mean	0.0309	0.4155
									Geometric Mean	0.0204	0.2775

*Less than detection limit

ANALYSIS OF FOWLER DATA ON EXPOSURE OF FLOOR MECHANICS TO FIBER CONCENTRATIONS

Transmission Electron Microscopy

Survey No.	Sample No.	Duration (min)	Volume (liters)	Count (fibers/sq mm)	Blank (fibers/sq mm)	Adjusted Count (fibers/sq mm)	Concentration (fibers/cc)	Asbestos (percent)
1	MU028	380	779	6.2	0.0	6.2	0.0031	8.9
1	MU029	321	770	6.2	0.0	6.2	0.0031	34.2
2	MU030	346	744	0.0	0.0	0.0	0.0000	0.0
2	MU031	348	853	12.4	0.0	12.4	0.0056	23.4
3	MU036	127	165	6.2	0.0	6.2	0.0145	6.3
3	MU037	130	247	24.7	0.0	24.7	0.0385	44.6
3	MU041	132	244	6.2	0.0	6.2	0.0098	8.9
4	MU038	137	151	6.2	0.0	6.2	0.0158	32.9
4	MU039	118	130	0.0	0.0	0.0	0.0000	0.0
5	MU019	101	184	12.4	0.0	12.4	0.0259	13.3
5	MU024	101	202	0.0	0.0	0.0	0.0000	0.0
6	MU067	79	186	0.0	0.0	0.0	0.0000	0.0
6	MU057	90	192	12.4	0.0	12.4	0.0249	34.7
6	MU041 ?	52	111	6.2	0.0	6.2	0.0215	12.4
6	MU070	79	139	0.0	0.0	0.0	0.0000	0.0
6	MU064	88	152	0.0	0.0	0.0	0.0000	0.0
6	MU066	54	95	6.2	0.0	6.2	0.0251	28.7
7	MU088	275	508	24.7	0.0	24.7	0.0187	86.1
7	MU090	272	375	0.0	0.0	0.0	0.0000	0.0
8	MU215	141	245	6.2	0.0	6.2	0.0097	10.7
8	MU216	157	317	6.2	0.0	6.2	0.0075	8.0
9	MU219	198	365	0.0	0.0	0.0	0.0000	0.0
9	MU222	197	371	0.0	0.0	0.0	0.0000	0.0
10	MU223	191	359	6.2	0.0	6.2	0.0066	9.0
10	MU225	194	367	6.2	0.0	6.2	0.0065	16.4
							Arithmetic Mean	15.1
							Median	10.2

ANALYSIS OF FOWLER DATA ON EXPOSURE OF INDUSTRIAL HYGIENISTS TO FIBER CONCENTRATIONS

Phase-Contrast Microscopy

Survey No.	Sample No.	Duration (min)	Volume (liters)	Count (fibers/sq mm)	Blank (fibers/sq mm)	Adjusted Count (fibers/sq mm)	Concentration (fibers/cc)	Background (fibers/cc)	Net Conc. (fibers/cc)	8-hr TWA Conc. (fibers/cc)	30-min Max. Conc. (fibers/cc)
1	M1026	337	1011	25.5	5.4	20.1	0.0077	0.0017	0.0060	0.0042	0.0669
1	M1027	266	798	14.6	5.4	9.2	0.0044	0.0017	0.0027	0.0015	0.0243
2	M1033	312	842	17.2	5.4	11.8	0.0054	0.0015	0.0039	0.0025	0.0405
2	M1032	342	992	22.9	5.4	17.5	0.0068	0.0015	0.0053	0.0038	0.0603
3	M1043	123	148	39.5	2.3	37.2	0.0968	0.0310	0.0658	0.0169	0.2697
3					2.3						
3					2.3						
4					2.3						
4					2.3						
5	M1012	101	242	80.9	1.5	79.4	0.1263	0.0110	0.1153	0.0243	0.3882
5	M1020	101	242	68.2	1.5	66.7	0.1061	0.0110	0.0951	0.0200	0.3202
6					1.5						
6	M1047	166	261	32.5	1.5	31.0	0.0457	0.0031	0.0426	0.0147	0.2359
6					1.5						
6					1.5						
6	M1075	209	478	46.5	1.5	45.0	0.0362	0.0031	0.0331	0.0144	0.2309
6					1.5						
7	M1087	268	791	40.1	2.5	37.6	0.0183	0.0000 *	0.0183	0.0102	0.1635
7	M1097	346	865	29.3	2.5	26.8	0.0331	0.0000 *	0.0331	0.0239	0.3821
8	M1208	148	315	28.0	1.3	26.7	0.0326	0.0100	0.0226	0.0070	0.1117
8	M1206	130	239	59.2	1.3	57.9	0.0933	0.0100	0.0833	0.0226	0.3608
9	M1214	186	388	22.9	1.3	21.6	0.0214	0.0140	0.0074	0.0029	0.0461
9	M1211	196	379	19.7	1.3	18.4	0.0187	0.0140	0.0047	0.0019	0.0306
10	M1230	193	372	19.1	1.3	17.8	0.0184	0.0087	0.0097	0.0039	0.0625
10											
								Arithmetic Mean	0.0109		0.1746
								Geometric Mean	0.0074		0.1190

* less than detection limit