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# Microscopical Studies of the Asbestos Fiber Releasability of Dryer Felt Textiles

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## KEYWORDS

Asbestos, dryer felts, textiles, PLM, polarized light microscopy, PCM, SEM, TEM, paper making, glove box, chamber testing

## ABSTRACT

Dryer felts are commercial woven textile materials used in the paper making industry to aid in the removal of moisture from the wet paper product. Some dryer felts used in the paper making industry contained asbestos. Microscopical tests including polarized light microscopy, scanning electron microscopy, phase contrast microscopy, and transmission electron microscopy were used in the testing that determined that particles including asbestos fibers are released from the dryer felts during use.

## INTRODUCTION

Since the development of paper making machines, dryer felt textiles have been used to separate the water from the wet paper material to form dry sheets or rolls of paper. On a paper machine, the main purpose of the dryer felt is to improve the heat transfer from the hot dryer to the paper (1). The dryer felt must have strength to hold the paper tightly against the heat drum, absorbency to pick up and hold water, and porosity to permit the passage of water vapor. Dryer felts are commercial textile materials. Wool fibers were used initially in the dryer felts of the 1800s. Later, woven cotton fabrics were used. To overcome the problems caused by decomposition and attack by heat, a number of different types of fibrous materials were tried in the construction of dryer felt fabrics. Felts with fibers of hemp, linen, Monel wire, dacron, nylon, polyester, polypropylene and acrylic were all tested over the years. In the 1920s asbestos fibers were introduced and found to provide good wear resistance and provide longer performance life than cotton felts (2). The initial asbestos dryer felt had an asbestos face and a backing of hard twisted, loosely woven cotton yarn. The cotton cloth was to take the pull, but be protected by the insulating asbestos layer from the heat of the drying cylinder. The felt had to be able to withstand a continuous cycle of wet and dry conditions. The function of this felt has been described as follows (2): "It (the asbestos material) absorbs water very easily and gives it up again very readily, therefore it dries very quickly. The dryer felts become moist, as it is well known, and must be dried again on the felt dryer." At the beginning portion of the dryer sequence where the paper pulp is first dried, the moisture in the dryer felt is high, over 50% moisture content. As it progresses down the machine, the paper and therefore the felt textile become drier. At the end, the paper and the felt are hot and dry with a moisture content of approximately 5%.

When there was a break in the paper product on a paper machine, workers would blow off the residual paper material from the dryer felt with compressed air with pressures from 60 to 90 psi. A test was performed to gather information about the potential for asbestos fiber release into the air from the felts during this compressed air blowing.

## MICROSCOPICAL METHODS

"A microscope finds many uses in a paper mill" (1) however, there is no standard method for the analysis of dryer felt textiles. To determine the composition of a dryer felt, it is possible to use a modification of the light microscope method used in the determination of the fiber composition of paper, TAPPI (Technical Association of the Pulp and Paper Industry) Method T401 (3). In the paper fiber analysis, the paper is first defibered and then stained on a microscope slide. A number of stains are used to identify various fibers. Common stains include Graff's "C" stain and Herzberg stain. The latter stains rag (cotton) fibers red, bleached wood fibers blue, and ground wood yel-

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low. The "C" stains have a much broader range of colors, so many types of fibers can be identified. Other stains include Selleger's, Alexander's, Kantrowitz-Simmon's, Lofton-Merritt, Wilson's and Bright's. None of these stains affect asbestos fibers and procedures such as polarized light microscopy (PLM) and dispersion staining commonly used with bulk asbestos building samples (4) are employed for identification of the asbestos fibers. A cross-hair eyepiece is used to determine the number of fibers of each type that are present. At least 300 to 500 fibers are usually counted. Weight factors given in Method T401 for each of the types of fibers found in the paper are used to calculate the full composition of the paper sample. For asbestos dryer felt samples, a weight factor for asbestos must be determined for the final calculation.

Air samples are analyzed for asbestos using both light and electron microscope techniques. The standard procedure for the analysis of air samples for asbestos in an occupational environment is the National Institute of Occupational Safety and Health (NIOSH) Method 7400 (5). This procedure requires the use of a phase contrast microscope (PCM) to count fibers greater than 5$\mu$m in length with at least a 3 to 1 aspect ratio. The method counts all fibers seen at 400 times magnification without distinguishing asbestos fibers from other fibers. It counts only fibers greater than approximately 0.25$\mu$m in diameter, the optical resolution limit of the phase contrast microscope. The NIOSH Method 7402 is a transmission electron microscope method that can be used to distinguish the asbestos fibers from the non-asbestos fibers counted by PCM. The NIOSH 7402 method provides a percentage determination of asbestos fibers greater than 5$\mu$m long and 0.25$\mu$m in diameter among all fibers of the same dimensions (6). This percentage can be applied to the NIOSH 7400 PCM count to get information about the concentration of asbestos fibers in the air when there is a mixture of fiber types present.

The International Standards Organization (ISO) Standard Method 10312 is a transmission electron microscope method used to provide very detailed information about asbestos fiber concentrations in air (5). Although it is most often used to measure all asbestos fibers greater than 0.5$\mu$m in length and without limitation as to diameter, it can be used to gather detailed information about the asbestos fibers in the range that would be counted by PCM, namely: asbestos fibers greater than 5$\mu$m long and 0.25$\mu$m in diameter. With an ISO 10312 analysis, not only is there information about the asbestos bundles and fibers that make up a PCM count, but there is also information about how the asbestos structures that contain the fibers are found arranged on the air filter.

The Asbestos Hazard Emergency Response Act (AHERA) Method uses the transmission electron microscope to measure asbestos in air (6). This method was developed for the evaluation of the air in the final clearance of school buildings, but is used for many ambient asbestos air sampling projects. Airborne structures are counted that contain at least one asbestos fiber greater than 0.5 $\mu$m in length, without limitation as to diameter. The method can be used to gather information about the full asbestos fiber exposure because nearly all asbestos fibers are identified and counted. However, the method was developed as a rapid counting procedure and may be biased toward lower counts because it considers one single asbestos fibril or a cluster of asbestos fibrils the same in the final count. (Each fibril or cluster is counted as one asbestos structure.)

Scanning electron microscope (SEM) techniques were also used to examine asbestos on adhesive lift Post-it Note samplers (7). Portions of the notes were cut and placed on a stub. They were lightly coated with carbon or gold to provide a conductive surface for electron microscopy. The samples were scanned first at magnifications of 100 - 300 times for fibrous particles. If no fibers were seen, additional scans were performed at a magnification of 1000 times. Energy dispersive x-ray analysis was used to differentiate the asbestos fibers from other fibers.

## PARTICLE RELEASE TESTING

The testing for particle release from asbestos-containing products is usually done in several phases. The first phase involves a PLM determination that the product does indeed contain asbestos and a close examination of the product to determine whether or not asbestos fibers are seen on the surface of the material. If a product totally encapsulates the asbestos fibers in a binder so that no fibers are visible on the surface, it is unlikely to release fibers during light abrasive activities. The second phase involves testing for release of particles (including asbestos fibers) by hand (onto a finger) or onto a light adhesive material. Post-it Notes provide a reproducible adhesive lift that will not damage the surface of most products. Particles released onto a finger can be transferred to carbon tape and prepared for SEM examination. The Post-it Notes can be prepared directly. The third phase of testing (glove box testing), involves collecting airborne particles in an enclosed glove box chamber under controlled conditions while some activity is

performed on the product. The air sample filters are analyzed by PCM and by TEM. The fourth phase of testing involves a full simulation of an activity in an enclosure large enough for a worker (with protective clothing and respirator) to perform that activity.

In the laboratory, studies of the first three phases of testing were undertaken to determine the releasability of particles including asbestos from the dryer felt textile. No full scale simulation was done. The available dryer felt pieces were small in comparison to the felt textiles used on dryer machines. Individual dryer felts were quite large, often over 200 inches wide and 100 ft long. Several felts could be used on one drying machine.

The studies included the close examination of a number of dryer felts of different styles and types by eye and with the aid of different types of microscopy. Some felts were tested for asbestos identification by polarized light microscopy (PLM). Simple fiber release tests were performed with light adhesive papers (Post-it Notes) and with a wet finger. The particles released onto a finger were transferred to adhesive material and then they and the Post-it Notes were examined by scanning electron microscopy (SEM). A test of airborne fiber release was performed in a closed glove box chamber with air samples collected on membrane filters. The design of the glove box chamber was based on asbestos fiber release testing chamber protocols developed by the Consumer Product Safety Commission (CPSC) and the United States Environmental Protection Agency (USEPA) (8, 9). The testing was done in a NuAire 701 sealed glove box (365 liter volume) with a mixing fan. The glove box had HEPA filters on both the air inlet and outlet. The testing involved two separate tests where an air hose with 60 psi compressed air was directed at each of the two pieces of dryer felt textile material for 5 minutes. The released particles were collected with standard air filter cassettes (0.8 um MCE filters) at 2 and 2.2 liters per minute flow rates. The air filters were prepared using direct procedures and analyzed by phase contrast light microscopy (PCM) and three different transmission electron microscopy (TEM) techniques.

## EQUIPMENT

Close examination was done by stereomicroscopy utilizing a Zeiss Stemi 2000 stereomicroscope having a magnification range from 6.5X to 47X. Asbestos analysis was done by polarized light microscopy including microchemical tests utilizing an Olympus BH-2 polarized light microscope having a magnification range from 40X to 1000X. Finger dust releases and Post-it Notes were examined and analyzed by scanning electron microscopy (SEM) using a JEOL 6400 coupled with an x-ray energy dispersive spectrometry (EDS) Noran Voyager system. The air samples were analyzed by PCM with a Nikon Alphaphot-2 light microscope and by TEM with an analytical electron microscope (AEM), a JEOL 1200 EX, equipped with a Noran EDS x-ray analysis system.

## MATERIALS

Asbestos-containing dryer felts have not been sold commercially since the 1970s. Therefore it was not possible to purchase dryer felt textile pieces for testing. Retired paper mill workers provided 20 pieces of dryer felt textiles that had been associated with a paper mill. Upon testing for asbestos content, two of the 20 were found to contain asbestos. These sample felts were identified as SA-0001 and SA-0005. The manufacturers of the felts were not known. Sample SA-0001 was representative of a tightly woven textile material. Sample SA-0005 was representative of a loosely woven textile. Several hundred additional textile samples were provided from sets of stored samples collected by two manufacturers of dryer felt textiles over a number of years. The samples had been collected at various paper mills and sent to be analyzed in the laboratories of the manufacturers apparently to gain information about competitors' products. The manufacturer's sample packets contained information about the original manufacturer of the felts and most contained analysis sheets from the modified TAPPI T401 microscope method which showed the percentages of various fiber types.

Dryer felt textiles from six manufacturers (A - F) were studied. Early felt styles (1950s) as well as later styles were included in the study. Earlier dryer felt textiles usually contained cotton and asbestos; later felts utilized various synthetic fibers with the asbestos. One felt, comprised totally of synthetic fibers, was included in the study as a control.

## SAMPLE DESCRIPTIONS

Sample CS00103A was a felt from manufacturer F with 39% asbestos. The asbestos fibers were in only one of the fabric directions. The fabric analysis report indicated that the fabric was not resin impregnated. However, the report indicated that the filling (with asbestos) was resin treated prior to weaving. The sample was from a dryer felt that had run approximately 9 months.

Sample CS00118A was a felt from manufacturer F with 64% asbestos. The asbestos fibers were in both fabric directions. The fabric analysis report indicated that the fabric did not appear to be resin impregnated. However, there was clear evidence of a coating on some of the fibers. The sample appeared to be unused.

Sample CS00162A was a felt from manufacturer F with 56% asbestos. The asbestos fibers were used in both directions of the weave. There was no evidence of a resin coating on this felt. The sample appeared to be from an unused felt.

Sample CS00418A was a felt from manufacturer F with 58% asbestos. The asbestos fibers were used in both directions of the weave. The felt was resin treated during finishing which imparted a blue color to the fabric. This sample appears to have been used to some extent.

Sample CS03033A was a felt from manufacturer A with 44% asbestos. The asbestos fibers were used in one of the directions of the weave. The felt was resin treated during finishing. The Sample was in used condition.

Sample CS05506A was a felt from the 1970s that had no asbestos in it. It was from manufacturer D with only synthetic fibers in its composition. The sample appeared to be in unused condition.

Sample CS05600C was a felt from manufacturer D with 41% asbestos. The asbestos fibers were used in one of the directions of the weave. The felt was resin treated during finishing which imparted a purple color to the fabric. The sample appeared to be in unused condition.

Sample CS05628A was a felt from manufacturer D with 53% asbestos. The asbestos fibers were used in one direction of the fabric. Information about this type of felt suggested that it was treated with an acrylic resin during finishing. The felt appeared to be unused.

Sample SCWX014609B was a felt from manufacturer E made in the 1950s that had 16% asbestos. The asbestos fibers were in only one direction of the weave. The piece of felt appeared to be unused. It did not have a coating.

Sample SCWX015562A was a felt from manufacturer C made in the 1950's with asbestos in one of the fabric directions. A colorless resin was found to partially coat some of the fibers. The sample appeared to be unused.

Sample SCWX015565A was a felt from manufacturer C with 80% asbestos. The asbestos fibers were used in one fabric direction. The resinous coating was only in the fabric weave direction containing asbestos. The sample appeared to be unused.

Sample SCWX015591A was a felt from manufacturer C with 75% asbestos. The asbestos fibers were used in both fabric directions. A resinous coating was indicated. The sample was from a dryer felt that had run for 168 days.

Sample SCWX015620A was a felt from manufacturer C made in the 1950s with 23% asbestos. The asbestos fibers were used in both fabric directions. No coating was indicated. This sample appeared to be a sample of a new felt.

Sample SCWX015881A was a felt from manufacturer B with 56% asbestos. The asbestos fibers were used in both fabric directions. This sample came from a felt that had run for 132 days.

Sample SCWX015886A was a felt from manufacturer B with 74% asbestos. The asbestos fibers were used in both fabric directions. This sample came from a felt that had run for 51 days.

Sample SCWX015890B was a felt from manufacturer B with 77% asbestos. The asbestos fibers were used in both fabric directions.

Sample SCWX015903A was a felt from manufacturer B with 33% asbestos. The asbestos fibers were used in both fabric directions. This sample was in used condition.

Sample SCWX015964A was a felt from manufacturer B with 22% asbestos. The asbestos fibers were used in one of the fabric directions. This sample was in unused condition.

Sample SCWX016076B was a felt from manufacturer E with 20% asbestos. The asbestos fibers were used in both of the fabric directions. A polyacrylate coating on the asbestos fibers was indicated. This sample may have had some use but appeared to be in good condition.

Sample SCWX016082B was a felt from manufacturer E with asbestos fibers in both of the fabric directions. The sample condition was listed as "new".

Sample SCWX016126A was a felt from manufacturer B made in the 1950s with asbestos fibers used in both directions of the weave. Information suggested that there may have been a coating of latex initially, however, this used felt showed no indication of any coating. This sample was in used condition.

Sample SCWX016197A was a felt from manufacturer A with 41% asbestos. The asbestos fibers were in one direction of the fabric weave. It showed evidence of a resinous coating on some of the fibers. This sample came from a dryer felt that had been used for 262 days.

Sample SCWX016281B was a felt from manufacturer E with 44% asbestos. The asbestos fibers were in

**Table 1. Summary of Felt Textile Asbestos Analyses and Adhesive Release Testing**

| Sample # | PLM Analysis | SEM of Post-it | SEM of finger dust |
|---|---|---|---|
| CS00103A | Chrysotile | Asbestos Detected | Not Done |
| CS00118A | Chrysotile | Asbestos Detected | Asbestos Detected |
| CS00162A | Chrysotile | Asbestos Detected | Not Done |
| CS00418A | Chrysotile | Asbestos Detected | Not Done |
| CS03033A | Chrysotile | Asbestos Detected | Not Done |
| CS05506A all synthetic | No asbestos detected | No asbestos detected | No asbestos detected |
| CS05600C | Chrysotile | Asbestos Detected | Not Done |
| CS05628A | Chrysotile | Asbestos Detected | Asbestos Detected |
| SCWX014609B | Chrysotile | Asbestos Detected | Not Done |
| SCWX015562A | Chrysotile | Asbestos Detected | Asbestos Detected |
| SCWX015565A | Chrysotile | Asbestos Detected | Not Done |
| SCWX015591A | Chrysotile | Asbestos Detected | Not Done |
| SCXX 015620A | Chrysotile | Asbestos Detected | Not Done |
| SCWX015881A | Chrysotile | Asbestos Detected | Not Done |
| SCWX015886A | Chrysotile | Asbestos Detected | Not Done |
| SCWX015890B | Chrysotile | Asbestos Detected | Not Done |
| SCWX015903A | Chrysotile | Asbestos Detected | Not Done |
| SCWX015964A | Chrysotile | Asbestos Detected | Not Done |
| SCWX016076B | Chrysotile | Asbestos Detected | Asbestos Detected |
| SCWX016082B | Chrysotile | Asbestos Detected | Not Done |
| SCWX016126A | Chrysotile | Asbestos Detected | Asbestos Detected |
| SCWX016197A | Chrysotile | Asbestos Detected | Asbestos Detected |
| SCWX016281B | Chrysotile | Asbestos Detected | Not Done |
| SCWX016298A | Chrysotile | Asbestos Detected | Not Done |
| Sears #2 | Chrysotile | Asbestos Detected | Not Done |
| Sears #3 | Chrysotile | Asbestos Detected | Not Done |

one of the fabric directions. The analysis report indicated a polyacrylate resin on the asbestos portion of the fabric. This used sample had run 126 days.

Sample SCWX016298A was a felt from manufacturer E with asbestos fibers in both of the fabric directions. This sample appeared to be in unused condition.

Sample SCWX016308A was a felt from manufacturer E with asbestos fibers in one of the fabric directions. This sample appeared to be in unused condition.

The sample labeled: "Sears #2" was a felt from manufacturer F with asbestos fibers in both of the fabric directions. Sample Sears #2 appeared to be used.

The sample labeled: "Sears #3" was a felt from manufacturer F with asbestos fibers in one of the fabric directions. Sample Sears #3 appeared to be unused.

## RESULTS OF EXAMINATION, PLM ANALYSES AND ADHESIVE RELEASE

Examination and PLM analysis of Sample SA-0001 showed it to be a white, relatively tightly woven material containing approximately 20% chrysotile asbestos, 45% cotton, 20% polyester, and 15% rayon. Sample SA-0005 was found to be a brown. loosely woven material containing approximately 25% chrysotile asbestos, 15% fiberglass, 18% polyester, 16% Aramid, 25% acrylic and 1% nylon. There was no evidence of a resin coating on the felt fibers of either of the felts. When the felts were handled in both wet and dry conditions, there was microscopical evidence that particles of chrysotile asbestos were released from both the felts onto fingers.

As shown in Table 1, all the manufacturers' felt textile samples that contained asbestos released fibers

*Figure 1. Asbestos Containing dryer felt textile, Sample 015886A as received.*

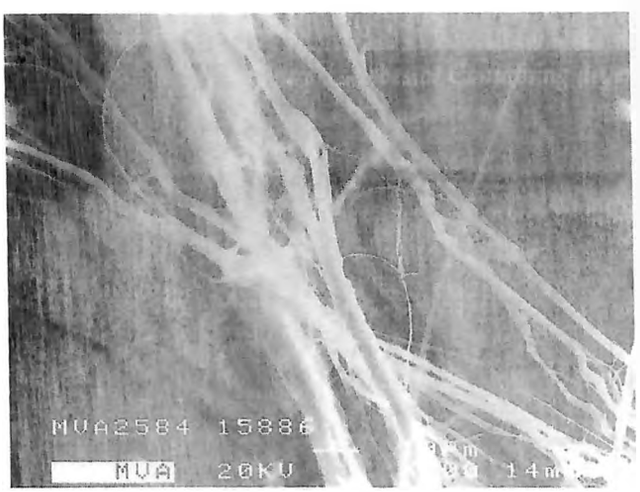


*Figure 2. Scanning electron microscope image of chrysotile asbestos fibers released from the felt shown in Figure 1 onto a Post-it Note light adhesive sampler.*

when subjected to the light adhesive lift test or when touched with a finger. Figures 1 and 2 show an example of a piece of felt textile and a scanning electron microscope image of the asbestos fibers released onto a Post-it Note adhesive test from that felt. The resin coatings associated with a number of the samples did not prevent asbestos fiber release.

## RESULTS OF CHAMBER TESTING

The results of air sample analyses are shown in Table 2. Only samples SA-0001 and SA-0005 were tested in the chamber. By phase contrast microscopy (NIOSH 7400), the fiber concentration in the chamber during compressed air blowing of the felt for both the tightly woven and loosely woven asbestos felts was over 30 fibers per cc. The TEM analyses by NIOSH 7402 showed that 96-97% of the fibers were chrysotile asbestos. The TEM ISO count also showed that there were concentrations over 30 fibers per cc of asbestos fibers larger than 5$\mu$m. The TEM analysis by the AHERA methods showed that there were approximately 10 times as many asbestos fibers of all sizes in the chamber as were counted by the phase contrast method. An example of one of the asbestos structures seen on the air filters is shown in Figure 3. This structure would be counted as a 'fiber' under the light microscope NIOSH 7400 counting rules, but because of the greater resolution of the TEM, was counted as a 'bundle' under the ISO and AHERA counting rules.

**Table 2. Results of Air Sample Analyses from Chamber Tests of Compressed Air on Asbestos Containing Dryer Felt Textiles**

| Sample Number | Description | NIOSH 7400 PCM F/cc | NIOSH 7402 % Asbestos | AHERA TEM Asbestos str/cc | ISO TEM >5 µm F/cc |
|---|---|---|---|---|---|
| 3 | Background | 0.05 | 0% | 0.08 | 0 (0.08) |
| 4 | Background | <0.04[1] | 0% | 0 (0.07)[3] | 0 (0.07) |
| 5 | Blowing Felt 1 | 75[2] | 96% | OL[4] | OL |
| 6 | Blowing Felt 1 | 48[2] | 97% | OL | OL |
| 7 | Background | <0.05 | 0% | 0 (0.08) | 0 (0.08) |
| 8 | Background | <0.04 | 0% | 0 (0.07) | 0 (0.07) |
| 9 | Blowing Felt 5 | 35 | 96% | 360 | 140 |
| 10 | Blowing Felt 5 | 41 | 96% | 550 | 162 |
| 13 | Room Air | <0.002 | 0% | 0.004 | 0 (0.004) |
| 14 | Blank[5] | (2/100) | 0% | 0/10 | 0/10 |

*1. The blank value (2 fibers/100 fields counted) was subtracted in calculating fiber loading densities. Reported values are based on the limit of detection (LOD) of 7 fibers/mm2 for the NIOSH method. Fiber loading densities below this threshold value and the resulting airborne fiber concentrations are reported as less than (<) the calculated LOD value.*

*2. Extreme loading with fibers and much overlap of fiber bundles evident. Values may not be accurate but are certainly higher than samples 9 and 10.*

*3. When no asbestos fibers were found, the analytical sensitivity is given in parenthesis.*

*4. OL = Overloaded, too high to count all sized fibers accurately.*

*5. No air volume was collected for the blank. Values are given in terms of number of fibers or structures per number of areas analyzed.*

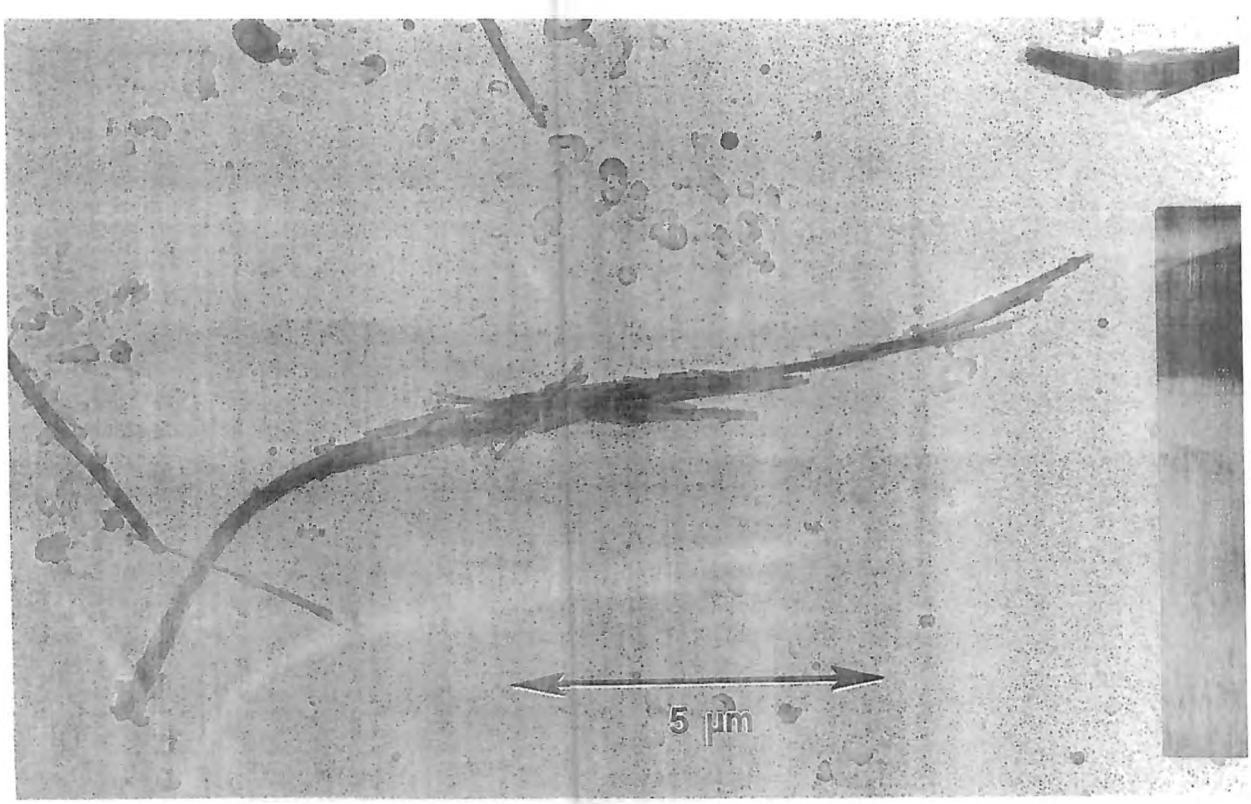


*Figure 3. Transmission electron microscope image of a chrysotile asbestos structure in an air sample collected during the compressed air blowing of an asbestos dryer felt textile (Sample SA-0005). Under the NIOSH 7400 method this structure would be counted as a fiber. Under the AHERA and ISO counting rules this structure would be counted as a bundle.*

## CONCLUSIONS

Dryer felts of early and later styles and in used and unused conditions all released asbestos fibers when touched by hand or subjected to the test of a light adhesive pull of a Post-it note. Resin coatings on the fabric or fibers did not prevent asbestos fibers from being released. For the felt samples tested, when handled in a dry condition, particles of chrysotile asbestos were released from the felt and adhered to fingers. When handled in a wet condition, chrysotile asbestos also adhered to fingers. When the wet residue dried the released asbestos fibers could be seen with the SEM.

No asbestos fibers were found in the testing of the synthetic dryer felt which contained no asbestos.

Chamber testing showed that particles are released from the dryer felt textiles of tight weave and loose weave when it they are blown with 60 psi compressed air. TEM showed that the majority (approximately 96%) of the fibrous particles longer than 5$\mu$m released from the felts during blowing with compressed air were chrysotile asbestos fibers. The airborne concentration of asbestos fibers in the chamber during the blowing of dryer felts with compressed air was over 30 fibers per cc.

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