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# Evaluation of Cut-resistant Sleeves and Possible Fiberglass Fiber Shedding at a Steel Mill

**Diana M. Ceballos**, **Loren C. Tapp**, and **Douglas M. Wiegand**
U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Cincinnati, Ohio

## INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation (HHE) request from employees and union representatives at a steel mill. They were concerned with skin and upper respiratory irritation, and safety and hygiene issues regarding the required use of cut-resistant protective sleeves. The manufacturer of the cut-resistant sleeves reported that the sleeves were made of a blended weave of para-aramid (Kevlar), cellulose, and E-glass fibers. New sleeves were shown to emit very few fibers into the air under controlled use conditions.[(1)] However, employees were concerned that the sleeves could shed respirable fiberglass fibers, that this shedding could increase after repeated launderings, and that this exposure could cause skin irritation, respiratory irritation, or chronic respiratory disease.

During our evaluation, we met with union representatives and company health and safety managers, toured the facility, and confidentially interviewed employees. We collected surface samples using either Stick-to-it lift tape (SKC Inc., Eighty Four, Pa.) or vacuuming with a polycarbonate filter from work surfaces, workers' skin, and workers' clothing, including the surface of new and laundered protective sleeves. We also collected bulk samples of new and laundered protective sleeves and other potential sources of fibers at the steel mill (i.e., insulation materials). These samples were analyzed by stereomicroscope and polarized light microscopy for identification of fiberglass, Kevlar, and cellulose fibers, as well as for fiber morphology and size. This case study focuses on the industrial hygiene sampling component of our evaluation. Information regarding the medical interviews, and safety and hygiene issues related to the use of the sleeves can be found in the NIOSH HHE report. [(2)]



Address correspondence to Diana M. Ceballos, U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, 4674 Columbia Parkway, MSR-11, Cincinnati, OH 45226.

## OBSERVATIONS

During our site visit, all steel mill employees were required to wear a level 4 cut-resistant sleeve to prevent cuts and scratches common in this industry. A long-sleeve cotton shirt (100% cotton Indura flame resistant fabric by Westex Inc., Chicago, Ill.) was also required underneath the cut-resistant sleeves. New and laundered sleeves were available throughout the facility. We obtained the instructions for the washing and drying procedures that the steel mill's contracted laundry service followed when laundering the cut-resistant sleeves. They were identical to the manufacturer's recommendations. From our observations and from talking to the employer and to employees, we learned that sleeves were laundered without tracking the number of cleaning cycles and that some employees laundered their sleeves at home.

## ASSESSMENT

Our main industrial hygiene sampling objectives were to: 1) determine if the cut-resistant sleeves shed fiberglass fibers onto skin, clothing, and work surfaces; 2) characterize the size and morphology of the shed fibers to assess the risk of inhalation or dermal abrasion; and 3) determine if wear and tear from repeated use or laundering could cause fiberglass fiber breakage.

### Qualitative Surface and Skin Fiber Sampling

There are no standard methods for surface sampling of fiberglass fibers, so we adapted published methods for other substances for our evaluation. Tape sampling was selected because gelatin tape sampling has been used to sample manmade fibers in an office building[(3)] and to study mold on surfaces.[(4,5)] Tape has been shown to be an easy and effective method to sample surfaces.[(4)] One study reported that vacuum sampling was comparable to wipe sampling for asbestos; however, vacuum sampling was more efficient on the rough surfaces tested.[(6)] Therefore, we also used vacuum sampling.

We collected fiber samples using either tape or vacuum sampling from surfaces suspected of potentially having fibers from the cut-resistant sleeves. This included work surfaces, clothing, and skin. Samples were collected throughout the steel mill to determine if fibers were being shed in different areas. A new pair of nitrile gloves was worn by the investigator when collecting each sample to avoid cross contamination. Two field blank samples for each method were collected by exposing the media briefly to ambient air.

### Tape Sampling

Stick-to-it lift tape (part number 225-9809, SKC Inc.) was used following manufacturer instructions.[(7)] Figure 1 shows a tape being used to sample on an employee's uniform sleeve after he had removed the cut-resistant sleeves.

### Vacuum Sampling

Polycarbonate filters (37 mm, 0.8 $\mu$m, SKC Inc.) were used with cellulose back-up pads inside conductive three-piece cassettes. Air was drawn through the cassette at 15 liters per minute by an SKC QuickTake 30 pump. Sampling was performed using a modified version of the NIOSH Method 7400 for asbestos and other fibers.[8] However, an open cassette instead of a closed cassette with a nozzle was used to avoid any losses due to static electricity generated during collection. Volumes collected during surface sampling (~15 liters of air) were also lower than for air samples using NIOSH Method 7400 (>400 liters of air).

Once a surface was selected we used a 100-square-centimeter disposable cardboard template (when possible) for consistency. When a guide was not possible because of an irregular shape, we vacuumed the surface for 1 minute (for an approximate volume of 15 liters of air). During vacuuming we kept the cassette at an angle to the surface to avoid a pump fault. We used an overlapping "S" pattern to vacuum the entire surface with horizontal strokes. We then vacuumed the same area using vertical S-strokes, followed by diagonal S-strokes. Figure 2 shows vacuum sampling of a clothing surface.

### Bulk Sampling

Three new and two laundered cut-resistant sleeves were collected and sent to a contract laboratory for analysis. Fibers from the sleeves were compared with other fibers found in the steel mill. Other sources of fibers identified in the facility included yellow insulation used in roofs and pipelines (glass wool) and white fibrous material (Kaowool) used for thermal insulation around ovens and other industrial equipment, expansion relief, or packing behind brickwork in furnaces.

### Qualitative Fiber Analysis

Samples were analyzed by stereomicroscope and polarized light microscopy for identification of any fiberglass, Kevlar, and cellulose fibers, as well as for fiber morphology and size.[9-12] More than 100 standards on file were used as reference materials. Because no sample contained large amounts of particulate less than 5 micrometers ($\mu$m) in width, scanning electron microscope-energy dispersive spectroscopy was not done. Laboratory data provided percentages of each of the fiber types. We could not calculate surface loading (number of fibers per area sampled) because the analysis was qualitative.

## RESULTS

### Qualitative Surface and Skin Fiber Sampling

We collected 4 surface, 33 clothing, and 6 skin surface samples. The surface samples were mostly from containers where sleeves were stored. Clothing surfaces included cut-resistant sleeves or shirts worn under the sleeves. Of the 15 employees we sampled, 60% reported using new (unlaundered) sleeves, and 40% reported using laundered sleeves. Employees who used new sleeves reported using them an average of 6 days, while those who used laundered sleeves reported using them an average of 7 days before replacing them. Skin surface samples included hands and forearms of sleeve users.

Table I presents the fiber results from all surface samples collected using the tape method (cut-resistant sleeves, clothing, and skin) and Table II presents results from all surface samples collected using the vacuum method (cut-resistant sleeves, clothing, and skin). Tape samples contained fiberglass, Kevlar, and/or cellulose fibers. Vacuum samples contained fiberglass and/or cellulose fibers. Where present, the Kevlar fibers averaged 20 μm in width, and the fiberglass fibers averaged 10 μm in width. The Kevlar and fiberglass fibers had variable lengths. None of the Kevlar, fiberglass, or cellulose fibers seen in these surface samples had sharp edges. No fibers were observed on field blanks for the vacuum samples. The field blanks for the tape samples contained fiberglass and cellulose fibers, but no Kevlar fibers. No fibers were present on the media blanks for either the tape or vacuum samples.

### Bulk Analysis

A photograph of a new sleeve is presented in Figure 3. Regardless of whether the cut-resistant sleeve was new or laundered, some of the Kevlar and fiberglass bundles in the sleeves were frayed and broken (Figure 4). Fibers found in the sleeves are shown in Figures 5 and Figures 6. The fiber composition, size, and morphology were similar for new and laundered sleeve samples. Other fiber sources in the steel mill were yellow insulation (100% glass wool) and white fibrous material (99% Kaowool and 1% cellulose fiber).

## DISCUSSION

The first objective of this evaluation was to determine if the cut-resistant sleeves shed fiberglass fibers onto skin, clothing, and work surfaces. We found that fiberglass fibers were shed from new and laundered sleeves. Fiberglass, Kevlar, and cellulose fibers were found on work surfaces, on shirt sleeves under the protective sleeves, and on employees' skin.

Fiberglass fibers may cause reversible upper airway irritation[13] and reversible skin irritation in some individuals.[14-16] Thus, fiberglass exposure could explain reports of eye, nose, throat, and skin irritation from some interviewed employees at the steel mill; however, we could not rule out that the symptoms may have been caused or exacerbated by other factors, such as exposures from particulate and gases emitted during the steel making process.

The second objective was to characterize the size and morphology of the fibers. Fibers found on surfaces, shirt sleeves, and skin were of the same material and width as those from the sleeves. Fibers with a width larger than 3 μm deposit in the upper airways and are not considered respirable.[17-19] Therefore, the large fiberglass and Kevlar fibers we found in our samples (10 to 20 μm in diameter) are unlikely to remain airborne for long periods of time or to pose an inhalation hazard or cause any long-term respiratory effects.[17-19] On the basis of their morphology and size, the fiberglass, Kevlar, and cellulose fibers found in the samples are not classified as human carcinogens.[17-19] Also, the fibers found had no sharp edges, implying a low risk for dermal abrasion.

The third objective was to determine if wear and tear from repeated use or laundering could cause fiberglass fiber breakage. We found no evidence that laundering shortened the size of the fibers. The composition, size, and morphology of fibers from both new and laundered sleeves were similar.

## CONCLUSION

We found that the cut-resistant sleeves shed fiberglass, Kevlar, and cellulose fibers, but these fibers were large and without sharp edges. On the basis of their size and morphology, the shed fibers would most likely deposit in the upper airways, where they could cause reversible irritation. The shed fibers would not be considered respirable; therefore, they are unlikely to cause long-term health effects. There was no difference between shed fibers from new and laundered sleeves suggesting laundering does not promote fiber breakage.

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## RECOMMENDATIONS

These recommendations were developed from our findings and were provided to the employer and employees at the investigated facility. The general principles may apply to other settings where similar types of sleeves are used.

**Elimination and Substitution**

1. Provide employees who have health or safety concerns about the cut-resistant sleeves with alternative sleeves that have appropriate levels of protection for their job tasks.

**Administrative Controls**

1. Create a personal protective equipment (PPE) committee composed of union representatives and managers to discuss PPE issues and determine possible alternatives.
2. Prohibit employees from taking the cut-resistant sleeves home for laundering.
3. Track the number of laundry cycles for the sleeves and follow manufacturer's guidelines on replacement.
4. Train employees in proper care, use, maintenance, inspection, and disposal of sleeves.
5. Continue encouraging employees to wear long-sleeve, flame-resistant shirts under the cut-resistant sleeves.
6. Encourage employees, especially those with skin irritation, to shower before leaving the work environment.[20]
7. Consider providing uniforms with laundry service to production employees to reduce the chance that work-place contaminants may get on their skin or street clothing.
8. Improve communication between the employer and employees regarding responses to employee safety and health concerns.

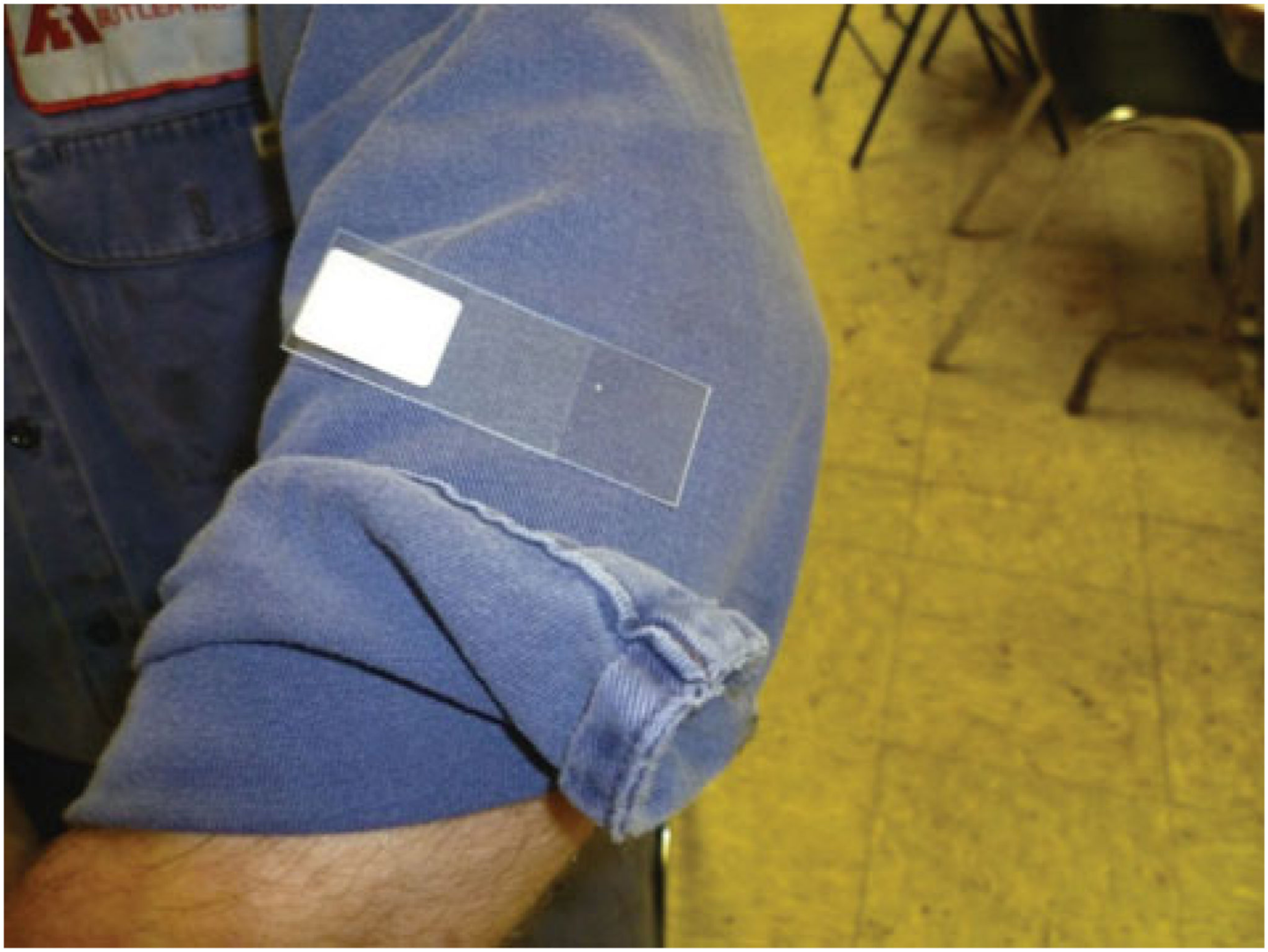

**FIGURE 1.**

Tape sampling on employee's uniform sleeves after removing the cut-resistant sleeve. Sleeves were rolled up only during the interview. (color figure available online)

**FIGURE 2.**
Vacuum sampling on an employee's uniform sleeve after removing cut-resistant sleeve. (color figure available online)

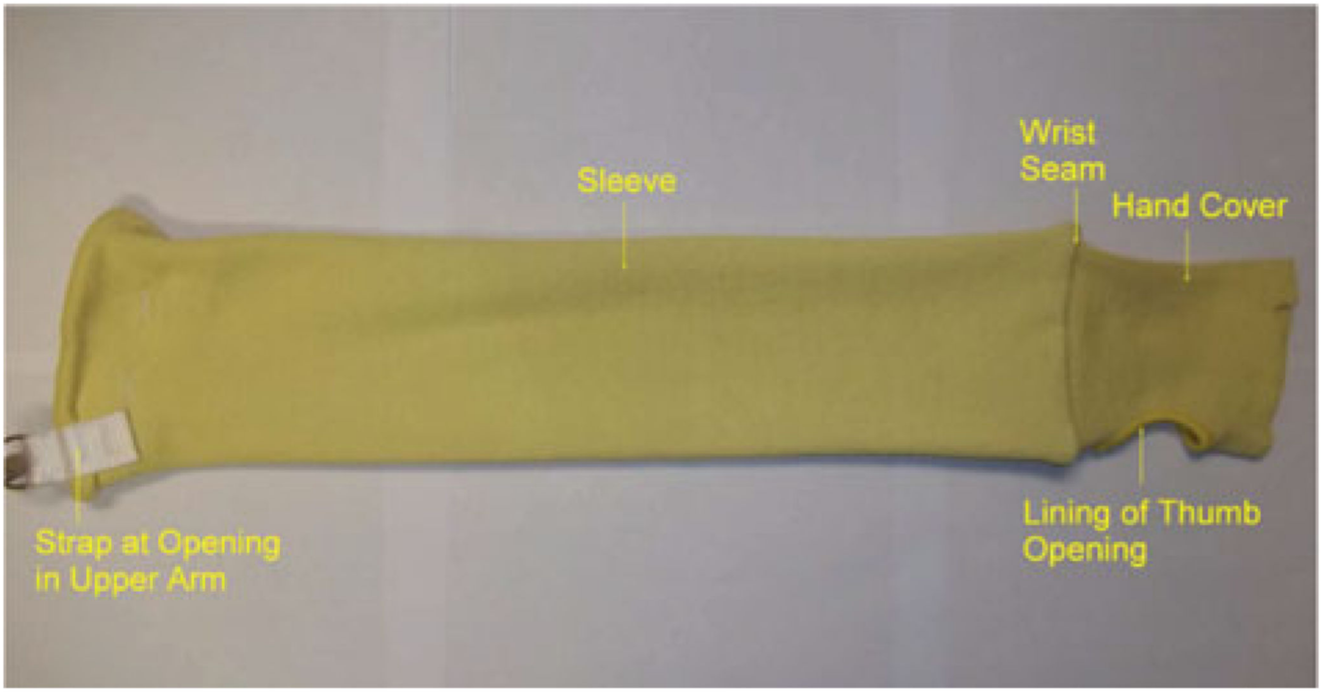


**FIGURE 3.**
Photograph showing outside of new sleeve. (color figure available online)

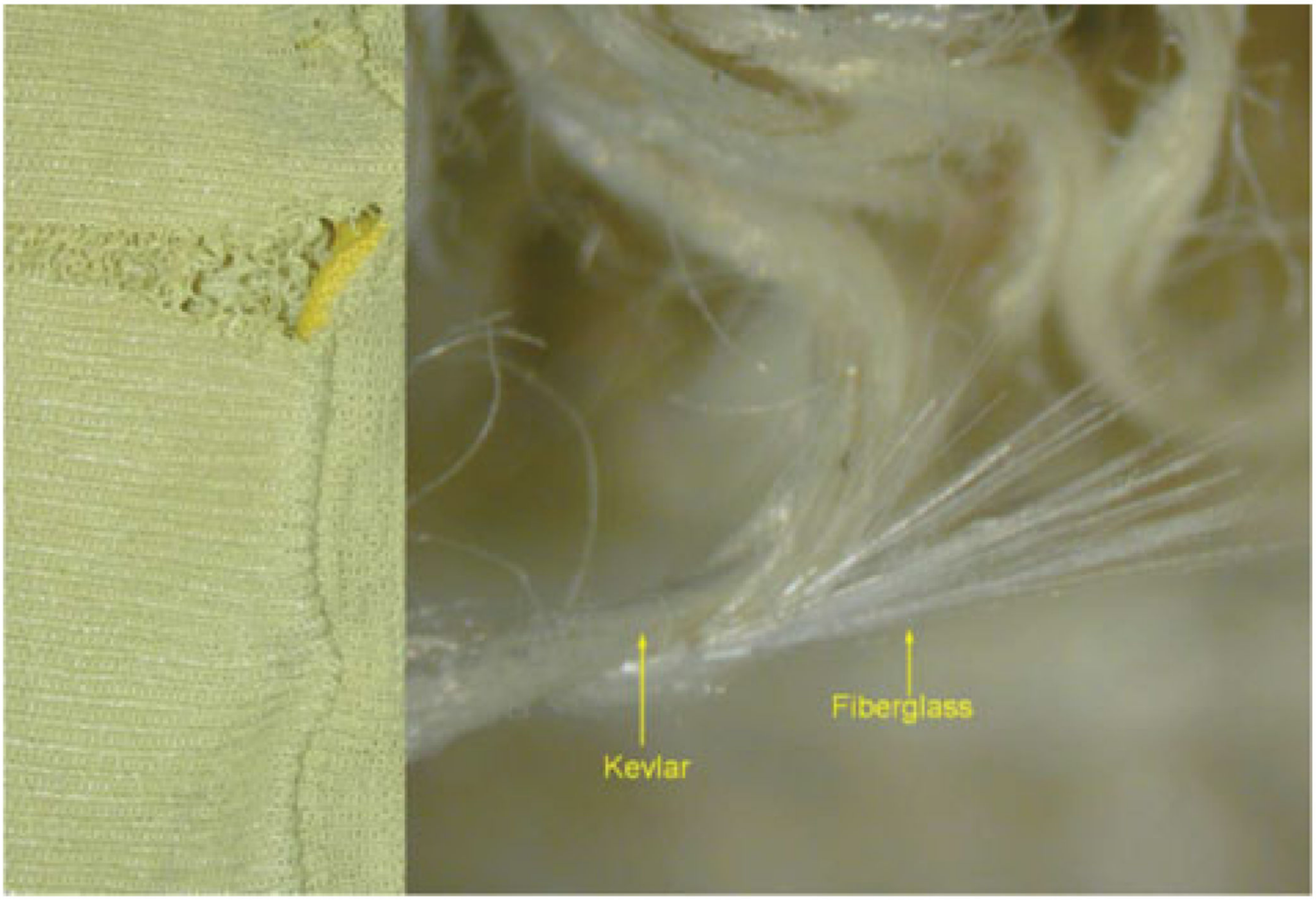


**FIGURE 4.**
Photograph showing tear in laundered sleeve and broken fiberglass bundles in tear at 15×. (color figure available online)

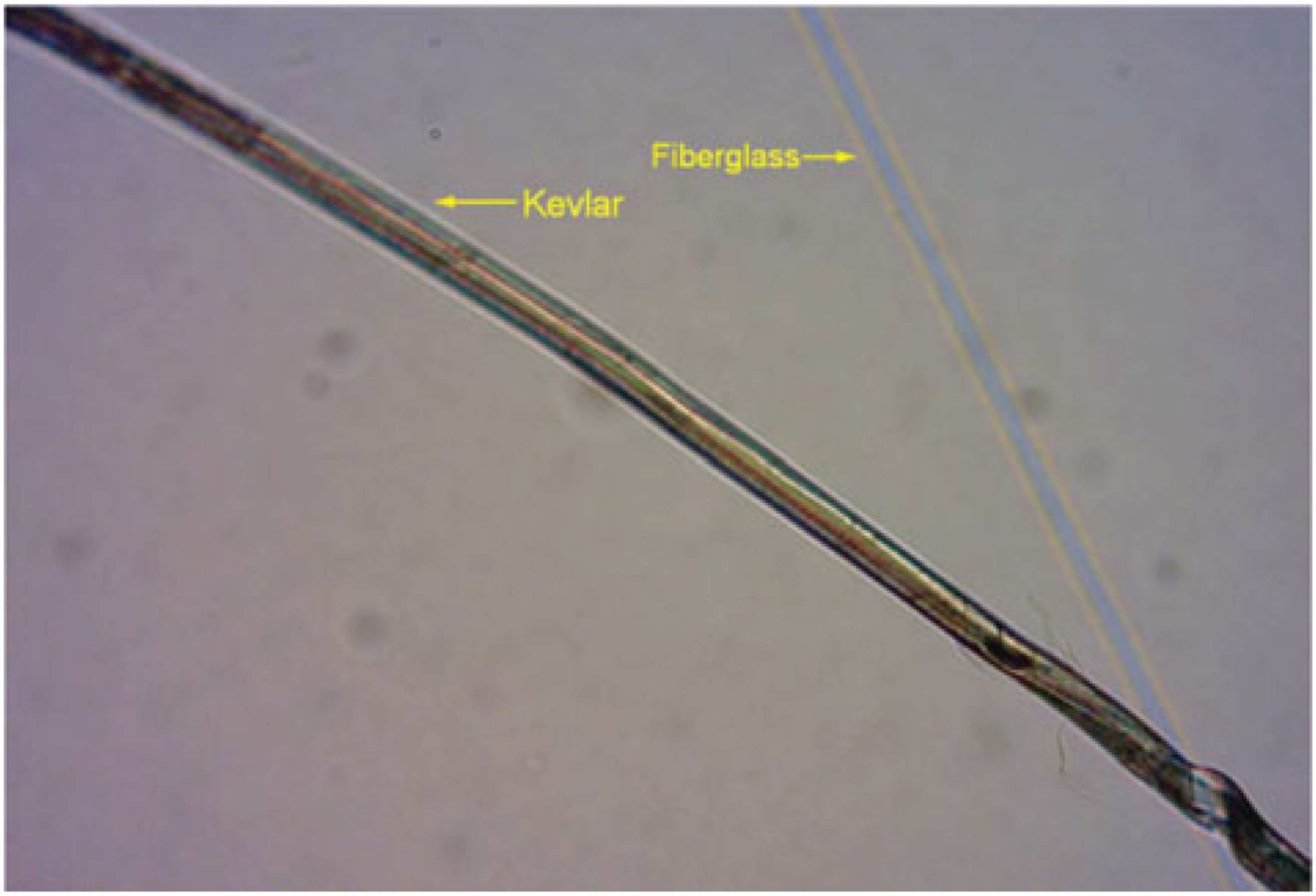


**FIGURE 5.**
Photomicrograph showing Kevlar and fiberglass from sleeve at 200×. (color figure available online)


**FIGURE 6.**
Photomicrograph showing cellulose on sleeve at 200×. (color figure available online)

## TABLE I

### Tape Surface Sampling Fiber Analysis Results[A]

| Sample location | Steel mill location | Percent fiber composition | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fiberglass | Kevlar | Cellulose | Synthetic | Hair | Others[B] |
| new sleeve | hot mill | 50 | 45 | 5 | ND[C] | ND | ND |
| | hot mill | 15 | 35 | 50 | ND | ND | ND |
| | melt shop | 50 | 20 | 10 | ND | ND | 20 |
| | melt shop | 35 | 45 | 10 | ND | ND | 10 |
| | shipping | 35 | 35 | 30 | ND | ND | ND |
| | shipping | 5 | 15 | 80 | ND | ND | ND |
| laundered sleeve | hot mill | 40 | 60 | ND | ND | ND | ND |
| | melt shop | 35 | 30 | 35 | ND | ND | ND |
| | melt shop | 35 | 40 | 25 | ND | ND | ND |
| | melt shop | 45 | 50 | 5 | ND | ND | ND |
| | melt shop | 40 | 55 | 5 | ND | ND | ND |
| | shipping | 90 | 10 | ND | ND | ND | ND |
| shirt | hot mill | 2 | 43 | 55 | ND | ND | ND |
| | hot mill | 2 | 45 | 53 | ND | ND | ND |
| | hot mill | 10 | 45 | 45 | ND | ND | ND |
| | melt shop | 20 | 40 | 40 | ND | ND | ND |
| | melt shop | 2 | 49 | 49 | ND | ND | ND |
| | melt shop | 10 | ND | 75 | 15 | ND | ND |
| | melt shop | 5 | 35 | 60 | ND | ND | ND |
| | melt shop | 5 | 2 | 88 | 5 | ND | ND |
| | shipping | 3 | 95 | 2 | ND | ND | ND |
| | shipping | 5 | 50 | 45 | ND | ND | ND |
| | shipping | 2 | ND | 18 | 80 | ND | ND |
| file cabinet where laundered sleeves stored | hot mill | 2 | ND | 3 | ND | ND | 95 |
| plastic bag where laundered sleeves stored | silicon | 25 | ND | 75 | ND | ND | ND |
| back of hand | melt shop | ND | ND | 5 | ND | ND | 95 |
| | melt shop | ND | ND | 2 | ND | ND | 98 |
| forearm | melt shop | 1 | ND | 10 | ND | 2 | 87 |
| | melt shop | 5 | ND | 10 | 10 | ND | 75 |
| | shipping | ND | 1 | ND | ND | ND | 99 |
| | shipping | 1 | ND | ND | 1 | ND | 98 |
| missing data | transportation | 3 | 40 | 35 | 1 | ND | 21 |
| | transportation | 45 | 45 | 10 | ND | ND | ND |

[A]Field blanks had 20%-25% fiberglass and 75%-80% cellulose.

[B] Other types of fibers include paint, opaque material, and plastic.

[C] ND = none detected.

## TABLE II

### Vacuum Filter Surface Sampling Fiber Analysis Results[A]

| | | Percent fiber composition | | |
|---|---|---|---|---|
| Sample location | Steel mill location | Fiberglass | Cellulose | Opaque material |
| new sleeve | hot mill | 55 | 40 | 5 |
| | melt shop | 30 | 30 | 40 |
| laundered sleeve | hot mill | 45 | 45 | 10 |
| | melt shop | 20 | 50 | 30 |
| | melt shop | 40 | 40 | 20 |
| | melt shop | 10 | 40 | 50 |
| | shipping | 40 | 50 | 10 |
| shirt | hot mill | 10 | 85 | 5 |
| | hot mill | 10 | 10 | 80 |
| | melt shop | 10 | 80 | 10 |
| | shipping | ND[B] | 95 | 5 |
| bin where soiled sleeves were stored | hot mill | 5 | 50 | 45 |
| cloth bag holding new sleeves | shipping | 25 | 35 | 40 |
| missing data | transportation | 10 | 60 | 30 |
| | transportation | 35 | 35 | 30 |

[A]Field blanks did not contain fibers.

[B]ND = none detected.