Customer Self-Monitoring Program Overview for Airborne Fiber

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May 2012

The HTIW Coalition is an association of the leading North American producers of refractory ceramic fiber (RCF), alkaline earth silicate wools (AES) and poly crystalline wool (PCW) – Morgan Thermal Ceramics, Unifrax I LLC, ANH Refractories Company, and Nutec Fibratec. The HTIW Coalition develops and promotes proper work practices and standards for the industry, conducts health research and disseminates information on the proper handling and use of high temperature insulation wools. For more information about the HTIW Coalition please visit www.HTIWCoalition.org.
Airborne Fiber Self-Monitoring Program Overview

Prepared as a Service of the HTIW Coalition Product Stewardship Program

May 2012

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1. **BASIC EQUIPMENT REQUIREMENTS:**

The basic components required to begin airborne fiber sampling may include the following:

(1) Industrial hygiene sampling pumps (with charger),
(2) Flow Calibrator (primary standard),
(3) Tygon tubing,
(4) Filter cassettes,
(5) Data Collection and Chain of Custody forms.

(1) **Industrial Hygiene (IH) Sampling Pumps:**

IH sampling pumps can be purchased through a variety of manufacturers and suppliers. SKC, Gilian, and MSA are just three examples of IH pump manufacturers. For airborne fiber sampling, a pump should be able to maintain a flowrate generally in the range of 0.5 liters per minute (LPM) to 3 LPM. Most sampling will be performed using a flowrate of 1.0 to 2.5 LPM.

For routine airborne fiber sampling, relatively basic pumps are generally all that are required. The number of IH pumps required will be determined by how often and how many workers will be sampled. An appropriate charger should also be purchased for the number of pumps available.

(2) **Flow Calibrator:**

A means of calibrating the sample pumps before and after each use is a necessary step in the airborne fiber sampling process. Typically calibrators are a "bubble meter" type or the new "dry cell" type. The dry cell calibrators tend to cost more but are easier to use and do not require a "soap film" solution. One calibrator is all that is normally required and are often sold by the same firms manufacturing the sample pumps.

(3) **Tygon Tubing:**

Tygon tubing is a clear, flexible hose used to connect the sample pump to the filter cassette. This usually can be purchased from the sample pump manufacturers as well as some hardware stores. The tubing size generally used is ¼ inch ID (and 3/8 inch OD). It is suggested that the pump manufacturer be consulted to determine which tubing size is appropriate for its pump.

Some manufacturers of this sampling equipment also offer packages or kits that might include a few pumps with a charger, a calibrator, tubing and perhaps even a carrying case. In some cases, this may be the most economical means of obtaining all the necessary equipment.

(4) **Filter Cassettes:**

The filter cassette type used for airborne fiber sampling is a 25 millimeter, mixed cellulose ester (MCE), 0.8 micron pore size filter, with 50 mm extension cowl. In many cases, the laboratory to be used for analysis of the samples will supply filter cassettes “ready to use”.

(5) **Data collection and Chain of Custody Forms:**

A data collection form is the paperwork used to track information for each sample (person’s name, job function, start/stop times, calibration, etc.). A chain of custody form is the “tracking” paperwork used to convey sample information to the laboratory. These forms are discussed in more detail later in this document.
AIRBORNE FIBER SAMPLING GUIDELINES:

(1) Operators of sampling equipment (pumps, calibrators, etc) should read the manufacturers’ instructions and become familiar with proper operation of the equipment.

(2) Charge sample pumps & calibrator prior to use in accordance with manufacturers instructions.

(3) Turn on sample pumps and let run several minutes prior to PRE-calibration. It is best to let pumps warm up in same area or at the same temperature as the area which they will be used.

(4) Connect 1 small section of tubing to filter cassette outlet (remove little red/blue caps) and connect to sample pump.

(5) Connect 2nd small section of tubing to cassette inlet and appropriate port on calibrator.

(6) Turn on calibrator and note sample flow rate. If necessary, adjust flowrate (on sampling pump) to 1.0 to 2.5 liters per minute (lpm). See Figure 1 below.

FIGURE 1: Example of sample pump connected to calibrator

(7) Once flowrate is within 1.0 to 2.5 lpm range, record three consecutive readings on data collection sheet in PRE-CAL section. Also document date and time of PRE-calibration. Detach calibration tubing from sampling pump.

(8) After calibration, attach length of tubing (approx 34 inches +/-) with collar clip(s) to sampling pump.

(9) Open bottom “face” of filter cassette (leave small blue cap intact) and then attach top to sampling pump tubing after removing little red cap. Save caps and cassette face. The sample pump is typically attached to a person’s belt with the tubing passing over the shoulder and connecting to the filter cassette near the lapel (within the worker’s “breathing zone”). The sample cassette should be oriented approximately 45 degrees downward. See Figure 2.
(10) Record filter cassette ID # on sample data sheet as well as sample start time. Worker name or area, and additional support information, should also be recorded on the sample data sheet.

(11) Check samples periodically to ensure pumps are running and record work tasks and other pertinent information on sample data sheet (PPE, engineering controls, tools used, type of fiber handled, etc.).

(12) Filter cassettes should be changed based on how much fiber deposition there is on the filter. Rough estimate is approximately every 2 hours +/-. Record start/end times for filter cassettes on sample data sheet when changing filter cassettes. Used filter cassettes should be capped and sealed/wrapped end-to-end. Masking tape works well for wrapping cassettes end-to-end.

(13) Take two unopened/unused filter cassettes and open the face and top cap and then replace the face and cap on each cassette. These two cassettes will be considered field blanks and should also be sealed/wrapped end-to-end. Their ID #’s should be recorded on a sample data sheet with the air volume listed as zero (0) on the sample data sheet and when transcribed to the chain of custody form. Field blanks are a routine part of an analytical QA/QC check.

(14) Upon completion of sampling, record final stop time on sample data sheet, cap/tape cassette.

(15) POST calibrate each sampling pump (as in steps 3 to 5 above) and record 3 consecutive readings in appropriate space on sample data sheet.

(16) Package all used (and sealed/wrapped) cassettes in Ziploc type baggie.
(17) Calculate the average PRE-calibration flowrate (from 3 readings prior to sampling) and then calculate the POST-calibration flowrate (from 3 readings upon completion of sampling). Average the PRE & POST calibration flowrates together for an overall average flowrate (to 3 decimal places) and record in appropriate space on sample data sheet. (Pre-, post, and overall flowrate calculations should be to 3 decimal places.)

(18) Calculate minutes for each filter cassette used for sampling. Multiply “minutes” by the overall average flowrate to determine VOLUME for each filter cassette (rounded to nearest whole #) and record in appropriate space on the sample data sheet.

(19) On “chain-of custody” form, enter appropriate company information (date, address, phone, etc.). Transcribe all filter cassette ID #’s with corresponding sample volumes.

(20) Submit cassettes to laboratory, with chain-of custody, for analysis. Analysis should be noted as NIOSH 7400B (airborne fiber).

(21) Upon receipt of sample results, transcribe results (fibers/cc or f/cc) for each filter cassette onto sample data sheet.

(22) Calculate actual TWA (time weighted average) for each worker/area. See example below. Multiply minutes times results for each filter cassette.

<table>
<thead>
<tr>
<th>Field #</th>
<th>Minutes</th>
<th>Result (f/cc)</th>
<th>“min x result”</th>
</tr>
</thead>
<tbody>
<tr>
<td>001</td>
<td>118</td>
<td>x 0.05</td>
<td>5.9</td>
</tr>
<tr>
<td>002</td>
<td>115</td>
<td>x 0.10</td>
<td>11.5</td>
</tr>
<tr>
<td>003</td>
<td>122</td>
<td>x 0.25</td>
<td>30.5</td>
</tr>
<tr>
<td>SUM =</td>
<td>355</td>
<td>SUM = 47.9</td>
<td></td>
</tr>
</tbody>
</table>

Sum up the minutes column (= 355) and the “min x result” column (= 47.9).

Divide “min x result” sum by the minutes sum to get actual TWA:

$$\frac{47.9}{355} = 0.135 \text{ f/cc} = \text{actual TWA}.$$  

(23) If the sample period is 480 minutes (and workers are working normal 8-hour shifts), the actual TWA will be equivalent to the 8-hour TWA. If the sample period is less than 480 minutes, an 8-hour TWA may be assumed to be equivalent to an actual TWA if the sampling period for the actual TWA is representative of normal exposures and routine operations over a worker’s 8-hour shift.

(24) Notify workers of their respective airborne fiber monitoring results. Documentation of this notification is recommended. A recordkeeping system is suggested for all airborne fiber monitoring. This will be useful in tracking trends and conducting analysis of tasks and operations with regard to potential fiber fiber exposures.
Please feel free to call an HTIW Coalition member company’s Product Stewardship Program Hotline for specific questions:

- Morgan Thermal Ceramics: 1-800-722-5681
- Unifrax I LLC: 1-800-322-2293
- ANH Refractories: 1-800-237-6742
- Nutec Fibratec: 1-866-978-4715

References:

These basic instructions are adopted from the following sources:


For a detailed description of workplace protection and product stewardship practices recommended by HTIW Coalition and endorsed by OSHA, see the HTIW Coalition publication “PSP-2012”, which can be obtained from HTIW Coalition, an HTIW Coalition member company, or downloaded from the HTIW Coalition website at www.HTIWCoalition.org.
2. **NIOSH 7400B SAMPLING METHOD:**

The NIOSH 7400B sampling method, found on the following pages, describes the technical detail of the sample collection and analytical procedure for airborne fiber.
### FORMULA: Various

**MW:** Various

**CAS: see Synonyms**

**RTECS: Various**

**METHOD:** 7400, Issue 2

**EVALUATION:** FULL

**Issue 1:** Rev. 3 on 15 May 1989

**Issue 2:** 15 August 1994

**OSHA:** 0.1 asbestos fiber (> 5 µm long)/cc; 1 f/cc, 30 min excursion; carcinogen

**MSHA:** 2 asbestos fibers/cc

**NIOSH:** 0.1 f/cc (fibers > 5 µm long), 400 L; carcinogen

**ACGIH:** 0.2 f/cc crocidolite; 0.5 f/cc amosite; 2 f/cc chrysotile and other asbestos; carcinogen

**PROPERTIES:** solid, fibrous, crystalline, anisotropic

**SYNONYMS [CAS #]:** actinolite [77536-66-4] or ferroactinolite [15669-07-5]; amosite [12172-73-5]; anthophyllite [77536-67-5]; chrysotile [12001-29-5]; serpentine [18786-24-8]; crocidolite [12001-28-4]; tremolite [77536-68-6]; amphibole asbestos [1332-21-4]; refractory ceramic fibers [142844-00-6]; fibrous glass

**SAMPLE**

**SAMPLER:** FILTER

(0.45- to 1.2-µm cellulose ester membrane, 25-mm; conductive cowl on cassette)

**FLOW RATE***: 0.5 to 16 L/min

**VOL-MIN***: 400 L @ 0.1 fiber/cc

**-MAX***: (step 4, sampling)

*Adjust to give 100 to 1300 fiber/mm²

**SHIPMENT:** routine (pack to reduce shock)

**SAMPLE STABILITY:** stable

**BLANKS:** 2 to 10 field blanks per set

**MEASUREMENT**

**TECHNIQUE:** LIGHT MICROSCOPY, PHASE CONTRAST

**ANALYTE:** fibers (manual count)

**SAMPLE PREPARATION:** acetone - collapse/triacetin - immersion method [2]

**COUNTING RULES:** described in previous version of this method as "A" rules [1,3]

**EQUIPMENT:**

1. positive phase-contrast microscope

2. Walton-Beckett graticule (100-µm field of view) Type G-22

3. phase-shift test slide (HSE/NPL)

**CALIBRATION:** HSE/NPL test slide

**RANGE:**

100 to 1300 fibers/mm² filter area

**ESTIMATED LOD:** 7 fibers/mm² filter area

**PRECISION (\(\bar{z}\)):** 0.10 to 0.12 [1]; see EVALUATION OF METHOD

**APPLICABILITY:** The quantitative working range is 0.04 to 0.5 fiber/cc for a 1000-L air sample. The LOD depends on sample volume and quantity of interfering dust, and is <0.01 fiber/cc for atmospheres free of interferences. The method gives an index of airborne fibers. It is primarily used for estimating asbestos concentrations, though PCM does not differentiate between asbestos and other fibers. Use this method in conjunction with electron microscopy (e.g., Method 7402) for assistance in identification of fibers. Fibers < ca. 0.25 µm diameter will not be detected by this method [4]. This method may be used for other materials such as fibrous glass by using alternate counting rules (see Appendix C).

**INTERFERENCES:** If the method is used to detect a specific type of fiber, any other airborne fiber may interfere since all particles meeting the counting criteria are counted. Chain-like particles may appear fibrous. High levels of non-fibrous dust particles may obscure fibers in the field of view and increase the detection limit.

**OTHER METHODS:** This revision replaces Method 7400, Revision #3 (dated 5/15/89).
REAGENTS:

1. Acetone,* reagent grade.
2. Triacetin (glycerol triacetate), reagent grade.

*See SPECIAL PRECAUTIONS.

EQUIPMENT:

1. Sampler: field monitor, 25-mm, three-piece cassette with ca. 50-mm electrically conductive extension cowl and cellulose ester filter, 0.45- to 1.2-µm pore size, and backup pad.

NOTE 1: Analyze representative filters for fiber background before use to check for clarity and background. Discard the filter lot if mean is ≥ 5 fibers per 100 graticule fields. These are defined as laboratory blanks. Manufacturer-provided quality assurance checks on filter blanks are normally adequate as long as field blanks are analyzed as described below.

NOTE 2: The electrically conductive extension cowl reduces electrostatic effects. Ground the cowl when possible during sampling.

NOTE 3: Use 0.8-µm pore size filters for personal sampling. The 0.45-µm filters are recommended for sampling when performing TEM analysis on the same samples. However, their higher pressure drop precludes their use with personal sampling pumps.

NOTE 4: Other cassettes have been proposed that exhibit improved uniformity of fiber deposit on the filter surface, e.g., bellmouthed sampler (Envirometrics, Charleston, SC). These may be used if shown to give measured concentrations equivalent to sampler indicated above for the application.

2. Personal sampling pump, battery or line-powered vacuum, of sufficient capacity to meet flow-rate requirements (see step 4 for flow rate), with flexible connecting tubing.

3. Wire, multi-stranded, 22-gauge; 1” hose clamp to attach wire to cassette.

4. Tape, shrink- or adhesive-.

5. Slides, glass, frosted-end, pre-cleaned, 25- × 75-mm.

6. Cover slips, 22- × 22-mm, No. 1½, unless otherwise specified by microscope manufacturer.

7. Lacquer or nail polish.

8. Knife, #10 surgical steel, curved blade.

EQUIPMENT (continued):

10. Acetone flash vaporization system for clearing filters on glass slides (see ref. [5] for specifications or see manufacturer’s instructions for equivalent devices).

11. Micropipets or syringes, 5-µL and 100- to 500-µL.

12. Microscope, positive phase (dark) contrast, with green or blue filter, adjustable field iris, 8 to 10× eyepiece, and 40 to 45× phase objective (total magnification ca. 400×); numerical aperture = 0.65 to 0.75.

13. Graticule, Walton-Beckett type with 100-µm diameter circular field (area = 0.00785 mm²) at the specimen plane (Type G-22). Available from Optometrics USA, P.O. Box 699, Ayer, MA 01432 [phone (508)-772-1700], and McCrone Accessories and Components, 850 Pasquinelli Drive, Westmont, IL 60559 [phone (312) 887-7100].

NOTE: The graticule is custom-made for each microscope. (see APPENDIX A for the custom-ordering procedure).

14. HSE/NPL phase contrast test slide, Mark II. Available from Optometrics USA (address above).

15. Telescope, ocular phase-ring centering.

16. Stage micrometer (0.01-mm divisions).

SPECIAL PRECAUTIONS: Acetone is extremely flammable. Take precautions not to ignite it. Heating of acetone in volumes greater than 1 mL must be done in a ventilated laboratory fume hood using a flameless, spark-free heat source.

SAMPLING:

1. Calibrate each personal sampling pump with a representative sampler in line.

2. To reduce contamination and to hold the cassette tightly together, seal the crease between the cassette base and the cowl with a shrink band or light colored adhesive tape. For personal sampling, fasten the (uncapped) open-face cassette to the worker’s lapel. The open face should be oriented downward.

NOTE: The cowl should be electrically grounded during area sampling, especially under conditions of low relative humidity. Use a hose clamp to secure one end of the wire (Equipment, Item 3) to the monitor’s cowl. Connect the other end to an earth ground (i.e., cold water pipe).

3. Submit at least two field blanks (or 10% of the total samples, whichever is greater) for each set of samples. Handle field blanks in a manner representative of actual handling of associated samples in the set. Open field blank cassettes at the same time as other cassettes just prior to sampling. Store top covers and cassettes in a clean area (e.g., a closed bag or box) with the top covers from the sampling cassettes during the sampling period.

4. Sample at 0.5 L/min or greater [6]. Adjust sampling flow rate, \( Q \) (L/min), and time, \( t \) (min), to produce a fiber density, \( E \), of 100 to 1300 fibers/mm² (3.85×10⁴ to 5×10⁵ fibers per 25-mm filter with effective...
collection area \( A_c = 385 \text{ mm}^2 \) for optimum accuracy. These variables are related to the action level (one-half the current standard), \( L \) (fibers/cc), of the fibrous aerosol being sampled by:

\[
t = \frac{A_c \times E}{Q \times L \times 10^3}.
\]

NOTE 1: The purpose of adjusting sampling times is to obtain optimum fiber loading on the filter. The collection efficiency does not appear to be a function of flow rate in the range of 0.5 to 16 L/min for asbestos fibers [7]. Relatively large diameter fibers (>3 µm) may exhibit significant aspiration loss and inlet deposition. A sampling rate of 1 to 4 L/min for 8 h is appropriate in atmospheres containing ca. 0.1 fiber/cc in the absence of significant amounts of non-asbestos dust. Dusty atmospheres require smaller sample volumes (≤400 L) to obtain countable samples. In such cases take short, consecutive samples and average the results over the total collection time. For documenting episodic exposures, use high flow rates (7 to 16 L/min) over shorter sampling times. In relatively clean atmospheres, where targeted fiber concentrations are much less than 0.1 fiber/cc, use larger sample volumes (3000 to 10000 L) to achieve quantifiable loadings. Take care, however, not to overload the filter with background dust. If ≥50% of the filter surface is covered with particles, the filter may be too overloaded to count and will bias the measured fiber concentration.

NOTE 2: OSHA regulations specify a minimum sampling volume of 48 L for an excursion measurement, and a maximum sampling rate of 2.5 L/min [3].

5. At the end of sampling, replace top cover and end plugs.

6. Ship samples with conductive cowl attached in a rigid container with packing material to prevent jostling or damage.

NOTE: Do not use untreated polystyrene foam in shipping container because electrostatic forces may cause fiber loss from sample filter.

SAMPLE PREPARATION:

NOTE 1: The object is to produce samples with a smooth (non-grainy) background in a medium with refractive index ≤ 1.46. This method collapses the filter for easier focusing and produces permanent (1–10 years) mounts which are useful for quality control and interlaboratory comparison. The aluminum “hot block” or similar flash vaporization techniques may be used outside the laboratory [2]. Other mounting techniques meeting the above criteria may also be used (e.g., the laboratory fume hood procedure for generating acetone vapor as described in Method 7400—revision of 5/15/85, or the non-permanent field mounting technique used in P&CAM 239 [3,7–9]). Unless the effective filtration area is known, determine the area and record the information referenced against the sample ID number [1,9–11].

NOTE 2: Excessive water in the acetone may slow the clearing of the filter, causing material to be washed off the surface of the filter. Also, filters that have been exposed to high humidities prior to clearing may have a grainy background.

7. Ensure that the glass slides and cover slips are free of dust and fibers.

8. Adjust the rheostat to heat the “hot block” to ca. 70 °C [2].

NOTE: If the “hot block” is not used in a fume hood, it must rest on a ceramic plate and be isolated from any surface susceptible to heat damage.

9. Mount a wedge cut from the sample filter on a clean glass slide.

a. Cut wedges of ca. 25% of the filter area with a curved-blade surgical steel knife using a rocking motion to prevent tearing. Place wedge, dust side up, on slide.

NOTE: Static electricity will usually keep the wedge on the slide.

b. Insert slide with wedge into the receiving slot at base of “hot block”. Immediately place tip of a micropipet containing ca. 250 µL acetone (use the minimum volume needed to consistently clear the filter sections) into the inlet port of the PTFE cap on top of the “hot block” and inject the
acetone into the vaporization chamber with a slow, steady pressure on the plunger button while holding pipet firmly in place. After waiting 3 to 5 s for the filter to clear, remove pipet and slide from their ports.

CAUTION: Although the volume of acetone used is small, use safety precautions. Work in a well-ventilated area (e.g., laboratory fume hood). Take care not to ignite the acetone. Continuous use of this device in an unventilated space may produce explosive acetone vapor concentrations.

c. Using the 5-µL micropipet, immediately place 3.0 to 3.5 µL triacetin on the wedge. Gently lower a clean cover slip onto the wedge at a slight angle to reduce bubble formation. Avoid excess pressure and movement of the cover glass.

NOTE: If too many bubbles form or the amount of triacetin is insufficient, the cover slip may become detached within a few hours. If excessive triacetin remains at the edge of the filter under the cover slip, fiber migration may occur.

d. Mark the outline of the filter segment with a glass marking pen to aid in microscopic evaluation.

e. Glue the edges of the cover slip to the slide using lacquer or nail polish [12]. Counting may proceed immediately after clearing and mounting are completed.

NOTE: If clearing is slow, warm the slide on a hotplate (surface temperature 50 °C) for up to 15 min to hasten clearing. Heat carefully to prevent gas bubble formation.

CALIBRATION AND QUALITY CONTROL:

10. Microscope adjustments. Follow the manufacturer’s instructions. At least once daily use the telescope ocular (or Bertrand lens, for some microscopes) supplied by the manufacturer to ensure that the phase rings (annular diaphragm and phase-shifting elements) are concentric. With each microscope, keep a logbook in which to record the dates of microscope cleanings and major servicing.

a. Each time a sample is examined, do the following:

   (1) Adjust the light source for even illumination across the field of view at the condenser iris. Use Kohler illumination, if available. With some microscopes, the illumination may have to be set up with bright field optics rather than phase contract optics.

   (2) Focus on the particulate material to be examined.

   (3) Make sure that the field iris is in focus, centered on the sample, and open only enough to fully illuminate the field of view.

b. Check the phase-shift detection limit of the microscope periodically for each analyst/microscope combination:

   (1) Center the HSE/NPL phase-contrast test slide under the phase objective.

   (2) Bring the blocks of grooved lines into focus in the graticule area.

   NOTE: The slide contains seven blocks of grooves (ca. 20 grooves per block) in descending order of visibility. For asbestos counting, the microscope optics must completely resolve the grooved lines in block 3 although they may appear somewhat faint, and the grooved lines in blocks 6 and 7 must be invisible when centered in the graticule area. Blocks 4 and 5 must be at least partially visible but may vary slightly in visibility between microscopes. A microscope which fails to meet these requirements has resolution either too low or too high for fiber counting.

   (3) If image quality deteriorates, clean the microscope optics. If the problem persists, consult the microscope manufacturer.

11. Document the laboratory’s precision for each counter for replicate fiber counts.

   a. Maintain as part of the laboratory quality assurance program a set of reference slides to be used on a daily basis [13]. These slides should consist of filter preparations including a range of loadings and background dust levels from a variety of sources including both field and reference samples (e.g., PAT, AAR, commercial samples). The Quality Assurance Officer should maintain custody of the reference slides and should supply each counter with a minimum of one reference
slide per workday. Change the labels on the reference slides periodically so that the counter does not become familiar with the samples.

b. From blind repeat counts on reference slides, estimate the laboratory intra- and intercounter precision. Obtain separate values of relative standard deviation ($S_r$) for each sample matrix analyzed in each of the following ranges: 5 to 20 fibers in 100 graticule fields, >20 to 50 fibers in 100 graticule fields, and >50 to 100 fibers in 100 graticule fields. Maintain control charts for each of these data files.

NOTE: Certain sample matrices (e.g., asbestos cement) have been shown to give poor precision.

12. Prepare and count field blanks along with the field samples. Report counts on each field blank.

NOTE 1: The identity of blank filters should be unknown to the counter until all counts have been completed.

NOTE 2: If a field blank yields greater than 7 fibers per 100 graticule fields, report possible contamination of the samples.

13. Perform blind recounts by the same counter on 10% of filters counted (slides relabeled by a person other than the counter). Use the following test to determine whether a pair of counts by the same counter on the same filter should be rejected because of possible bias: Discard the sample if the absolute value of the difference between the square roots of the two counts (in fiber/mm²) exceeds $2.77X S_r'$ where $X = \text{average of the square roots of the two fiber counts (in fiber/mm²)}$ and $S_r' = S_r / 2$ where $S_r$ is the intracounter relative standard deviation for the appropriate count range (in fibers) determined in step 11. For more complete discussions see reference [13].

NOTE 1: Since fiber counting is the measurement of randomly placed fibers which may be described by a Poisson distribution, a square root transformation of the fiber count data will result in approximately normally distributed data [13].

NOTE 2: If a pair of counts is rejected by this test, recount the remaining samples in the set and test the new counts against the first counts. Discard all rejected paired counts. It is not necessary to use this statistic on blank counts.

14. The analyst is a critical part of this analytical procedure. Care must be taken to provide a non-stressful and comfortable environment for fiber counting. An ergonomically designed chair should be used, with the microscope eyepiece situated at a comfortable height for viewing. External lighting should be set at a level similar to the illumination level in the microscope to reduce eye fatigue. In addition, counters should take 10- to 20-minute breaks from the microscope every one or two hours to limit fatigue [14]. During these breaks, both eye and upper back/neck exercises should be performed to relieve strain.

15. All laboratories engaged in asbestos counting should participate in a proficiency testing program such as the AIHA-NIOSH Proficiency Analytical Testing (PAT) Program for asbestos and routinely exchange field samples with other laboratories to compare performance of counters.

MEASUREMENT:

16. Center the slide on the stage of the calibrated microscope under the objective lens. Focus the microscope on the plane of the filter.

17. Adjust the microscope (Step 10).

NOTE: Calibration with the HSE/NPL test slide determines the minimum detectable fiber diameter (ca. 0.25 µm) [4].

18. Counting rules: (same as P&CAM 239 rules [1,10,11]: see examples in APPENDIX B).

a. Count any fiber longer than 5 µm which lies entirely within the graticule area.

1. Count only fibers longer than 5 µm. Measure length of curved fibers along the curve.

2. Count only fibers with a length-to-width ratio equal to or greater than 3:1.

b. For fibers which cross the boundary of the graticule field:

1. Count as ½ fiber any fiber with only one end lying within the graticule area, provided that the fiber meets the criteria of rule a above.
(2) Do not count any fiber which crosses the graticule boundary more than once.
(3) Reject and do not count all other fibers.

c. Count bundles of fibers as one fiber unless individual fibers can be identified by observing both ends of a fiber.

d. Count enough graticule fields to yield 100 fibers. Count a minimum of 20 fields. Stop at 100 graticule fields regardless of count.

19. Start counting from the tip of the filter wedge and progress along a radial line to the outer edge. Shift up or down on the filter, and continue in the reverse direction. Select graticule fields randomly by looking away from the eyepiece briefly while advancing the mechanical stage. Ensure that, as a minimum, each analysis covers one radial line from the filter center to the outer edge of the filter. When an agglomerate or bubble covers ca. 1/6 or more of the graticule field, reject the graticule field and select another. Do not report rejected graticule fields in the total number counted.

NOTE 1: When counting a graticule field, continuously scan a range of focal planes by moving the fine focus knob to detect very fine fibers which have become embedded in the filter. The small-diameter fibers will be very faint but are an important contribution to the total count. A minimum counting time of 15 s per field is appropriate for accurate counting.

NOTE 2: This method does not allow for differentiation of fibers based on morphology. Although some experienced counters are capable of selectively counting only fibers which appear to be asbestiform, there is presently no accepted method for ensuring uniformity of judgment between laboratories. It is, therefore, incumbent upon all laboratories using this method to report total fiber counts. If serious contamination from non-asbestos fibers occurs in samples, other techniques such as transmission electron microscopy must be used to identify the asbestos fiber fraction present in the sample (see NIOSH Method 7402). In some cases (i.e., for fibers with diameters >1 µm), polarized light microscopy (as in NIOSH Method 7403) may be used to identify and eliminate interfering non-crystalline fibers [15].

NOTE 3: Do not count at edges where filter was cut. Move in at least 1 mm from the edge.

NOTE 4: Under certain conditions, electrostatic charge may affect the sampling of fibers. These electrostatic effects are most likely to occur when the relative humidity is low (below 20%), and when sampling is performed near the source of aerosol. The result is that deposition of fibers on the filter is reduced, especially near the edge of the filter. If such a pattern is noted during fiber counting, choose fields as close to the center of the filter as possible [5].

NOTE 5: Counts are to be recorded on a data sheet that provides, as a minimum, spaces on which to record the counts for each field, filter identification number, analyst’s name, date, total fibers counted, total fields counted, average count, fiber density, and commentary. Average count is calculated by dividing the total fiber count by the number of fields observed. Fiber density \( \text{fibers/mm}^2 \) is defined as the average count \( \text{fibers/field} \) divided by the field (graticule) area \( \text{mm}^2/\text{field} \).

CALCULATIONS AND REPORTING OF RESULTS

20. Calculate and report fiber density on the filter, \( E \) \( \text{fibers/mm}^2 \), by dividing the average fiber count per graticule field, \( F/\eta_f \), minus the mean field blank count per graticule field, \( B/\eta_b \), by the graticule field area, \( A_f \) (approx. 0.00785 mm²):

\[
E = \frac{(F/\eta_f - B/\eta_b)}{A_f}, \text{ fibers/mm}^2.
\]

NOTE: Fiber counts above 1300 fibers/mm² and fiber counts from samples with >50% of filter area covered with particulate should be reported as “uncountable” or “probably biased.” Other fiber counts outside the 100–1300 fiber/mm² range should be reported as having “greater than optimal variability” and as being “probably biased.”

21. Calculate and report the concentration, \( C \) \( \text{fibers/cc} \), of fibers in the air volume sampled, \( V \) \( \text{L} \), using the effective collection area of the filter, \( A_e \) (approx. 385 mm² for a 25-mm filter):
\[ C = \frac{E A_c}{V \times 10^3} \]

NOTE: Periodically check and adjust the value of \( A_c \), if necessary.

22. Report intralaboratory and interlaboratory relative standard deviations (from Step 11) with each set of results.

NOTE: Precision depends on the total number of fibers counted [1,16]. Relative standard deviation is documented in references [1,15–17] for fiber counts up to 100 fibers in 100 graticule fields. Comparability of interlaboratory results is discussed below. As a first approximation, use 213% above and 49% below the count as the upper and lower confidence limits for fiber counts greater than 20 (Figure 1).

EVALUATION OF METHOD:

Method Revisions:

This method is a revision of P&CAM 239 [10]. A summary of the revisions is as follows:

1. Sampling:
   The change from a 37-mm to a 25-mm filter improves sensitivity for similar air volumes. The change in flow rates allows for 2-m³ full-shift samples to be taken, providing that the filter is not overloaded with non-fibrous particulates. The collection efficiency of the sampler is not a function of flow rate in the range 0.5 to 16 L/min [10].

2. Sample preparation technique:
   The acetone vapor-triacetin preparation technique is a faster, more permanent mounting technique than the dimethyl phthalate/diethyl oxalate method of P&CAM 239 [2,4,10]. The aluminum “hot block” technique minimizes the amount of acetone needed to prepare each sample.

3. Measurement:
   a. The Walton-Beckett graticule standardizes the area observed [14,18,19].
   b. The HSE/NPL test slide standardizes microscope optics for sensitivity to fiber diameter [4,14].
   c. Because of past inaccuracies associated with low fiber counts, the minimum recommended loading has been increased to 100 fibers/mm² filter area (a total of 78.5 fibers counted in 100 fields, each with field area = 0.00785 mm².) Lower levels generally result in an overestimate of the fiber count when compared to results in the recommended analytical range [20]. The recommended loadings should yield intracounter \( S_\epsilon \) in the range of 0.10 to 0.17 [21–23].

Interlaboratory Comparability:

An international collaborative study involved 16 laboratories using prepared slides from the asbestos cement, milling, mining, textile, and friction material industries [9]. The relative standard deviations (\( S_\epsilon \)) varied with sample type and laboratory. The ranges were:

<table>
<thead>
<tr>
<th>Rules</th>
<th>Intralaboratory ( S_\epsilon )</th>
<th>Interlaboratory ( S_\epsilon )</th>
<th>Overall ( S_\epsilon )</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIA (NIOSH A Rules)*</td>
<td>0.12 to 0.40</td>
<td>0.27 to 0.85</td>
<td>0.46</td>
</tr>
<tr>
<td>Modified CRS (NIOSH B Rules)†</td>
<td>0.11 to 0.29</td>
<td>0.20 to 0.35</td>
<td>0.25</td>
</tr>
</tbody>
</table>

*Under AIA rules, only fibers having a diameter less than 3 \( \mu \)m are counted and fibers attached to particles larger than 3 \( \mu \)m are not counted. NIOSH A Rules are otherwise similar to the AIA rules.

†See Appendix C.

A NIOSH study conducted using field samples of asbestos gave intralaboratory \( S_\epsilon \) in the range 0.17 to 0.25 and an interlaboratory \( S_\epsilon \) of 0.45 [21]. This agrees well with other recent studies [9,14,16].
At this time, there is no independent means for assessing the overall accuracy of this method. One measure of reliability is to estimate how well the count for a single sample agrees with the mean count from a large number of laboratories. The following discussion indicates how this estimation can be carried out based on measurements of the interlaboratory variability, as well as showing how the results of this method relate to the theoretically attainable counting precision and to measured intra- and interlaboratory $S_r$. (NOTE: The following discussion does not include bias estimates and should not be taken to indicate that lightly loaded samples are as accurate as properly loaded ones).

Theoretically, the process of counting randomly (Poisson) distributed fibers on a filter surface will give an $S_r$ that depends on the number, $N$, of fibers counted:

$$S_r = \frac{1}{\sqrt{N}}.$$  

Thus $S_r$ is 0.1 for 100 fibers and 0.32 for 10 fibers counted. The actual $S_r$ found in a number of studies is greater than these theoretical numbers [17,19–21].

An additional component of variability comes primarily from subjective interlaboratory differences. In a study of ten counters in a continuing sample exchange program, Ogden [15] found this subjective component of intralaboratory $S_r$ to be approximately 0.2 and estimated the overall $S_r$ by the term:

$$\frac{[N + (0.2 \times N)^2]^{1/2}}{N}.$$

Ogden found that the 90% confidence interval of the individual intralaboratory counts in relation to the means were $+2 \times S_r$ and $−1.5 \times S_r$. In this program, one sample out of ten was a quality control sample. For laboratories not engaged in an intensive quality assurance program, the subjective component of variability can be higher.

In a study of field sample results in 46 laboratories, the Asbestos Information Association also found that the variability had both a constant component and one that depended on the fiber count [14]. These results gave a subjective interlaboratory component of $S_r$ (on the same basis as Ogden’s) for field samples of ca. 0.45. A similar value was obtained for 12 laboratories analyzing a set of 24 field samples [21]. This value falls slightly above the range of $S_r$ (0.25 to 0.42 for 1984–85) found for 80 reference laboratories in the NIOSH PAT program for laboratory-generated samples [17].

A number of factors influence $S_r$ for a given laboratory, such as that laboratory’s actual counting performance and the type of samples being analyzed. In the absence of other information, such as from an interlaboratory quality assurance program using field samples, the value for the subjective component of variability is chosen as 0.45. It is hoped that the laboratories will carry out the recommended interlaboratory quality assurance programs to improve their performance and thus reduce the $S_r$.

The above relative standard deviations apply when the population mean has been determined. It is more useful, however, for laboratories to estimate the 90% confidence interval on the mean count from a single sample fiber count (Figure 1). These curves assume similar shapes of the count distribution for interlaboratory and intralaboratory results [16].

For example, if a sample yields a count of 24 fibers, Figure 1 indicates that the mean interlaboratory count will fall within the range of 227% above and 52% below that value 90% of the time. We can apply these percentages directly to the air concentrations as well. If, for instance, this sample (24 fibers counted) represented a 500-L volume, then the measured concentration is 0.02 fibers/mL (assuming 100 fields counted, 25-mm filter, 0.00785 mm² counting field area). If this same sample were counted by
a group of laboratories, there is a 90% probability that the mean would fall between 0.01 and 0.08 fiber/mL. These limits should be reported in any comparison of results between laboratories.

Note that the $S_r$ of 0.45 used to derive Figure 1 is used as an estimate for a random group of laboratories. If several laboratories belonging to a quality assurance group can show that their interlaboratory $S_r$ is smaller, then it is more correct to use that smaller $S_r$. However, the estimated $S_r$ of 0.45 is to be used in the absence of such information. Note also that it has been found that $S_r$ can be higher for certain types of samples, such as asbestos cement [9].

Quite often the estimated airborne concentration from an asbestos analysis is used to compare to a regulatory standard. For instance, if one is trying to show compliance with an 0.5 fiber/mL standard using a single sample on which 100 fibers have been counted, then Figure 1 indicates that the 0.5 fiber/mL standard must be 213% higher than the measured air concentration. This indicates that if one measures a fiber concentration of 0.16 fiber/mL (100 fibers counted), then the mean fiber count by a group of laboratories (of which the compliance laboratory might be one) has a 95% chance of being less than 0.5 fibers/mL; i.e., $0.16 + 2.13 \times 0.16 = 0.5$.

It can be seen from Figure 1 that the Poisson component of the variability is not very important unless the number of fibers counted is small. Therefore, a further approximation is to simply use $+213\%$ and $-49\%$ as the upper and lower confidence values of the mean for a 100-fiber count.
The curves in Figure 1 are defined by the following equations:

\[ U_{CL} = \frac{2X + 2.25 + [(2.25 + 2X)^2 - 4(1 - 2.25S_r^2)X^2]^{1/2}}{2(1 - 2.25S_r^2)} \]

and

\[ L_{CL} = \frac{2X + 4 - [(4 + 2X)^2 - 4(1 - 4S_r^2)X^2]^{1/2}}{2(1 - 4S_r^2)} \]

where \( S_r \) = subjective interlaboratory relative standard deviation, which is close to the total interlaboratory \( S_r \) when approximately 100 fibers are counted,

\( X \) = total fibers counted on sample,

\( L_{CL} \) = lower 95% confidence limit, and

\( U_{CL} \) = upper 95% confidence limit.

Note that the range between these two limits represents 90% of the total range.

REFERENCES:


METHOD WRITTEN BY:

Paul A. Baron, Ph.D., NIOSH/DPSE.

APPENDIX A. CALIBRATION OF THE WALTON-BECKETT GRATICULE

Before ordering the Walton-Beckett graticule, the following calibration must be done to obtain a counting area \(D\) 100 µm in diameter at the image plane. The diameter, \(d_c\) (mm), of the circular counting area and the disc diameter must be specified when ordering the graticule.

1. Insert any available graticule into the eyepiece and focus so that the graticule lines are sharp and clear.
2. Set the appropriate interpupillary distance and, if applicable, reset the binocular head adjustment so that the magnification remains constant.
3. Install the 40 to 45× phase objective.
4. Place a stage micrometer on the microscope object stage and focus the microscope on the graduated lines.
5. Measure the magnified grid length of the graticule, \(L_o\) (µm), using the stage micrometer.
6. Remove the graticule from the microscope and measure its actual grid length, \(L_\alpha\) (mm). This can best be accomplished by using a stage fitted with verniers.
7. Calculate the circle diameter, \(d_c\) (mm), for the Walton-Beckett graticule:

\[
d_c = \frac{L_\alpha}{L_o} \times D.
\]

Example: If \(L_o = 112 \mu\text{m}\), \(L_\alpha = 4.5 \text{ mm}\), and \(D = 100 \mu\text{m}\), then \(d_c = 4.02 \text{ mm}\).
8. Check the field diameter, \(D\) (acceptable range 100 µm ± 2 µm) with a stage micrometer upon receipt of the graticule from the manufacturer. Determine field area (acceptable range 0.00754 mm² to 0.00817 mm²).
APPENDIX B. COMPARISON OF COUNTING RULES

Figure 2 shows a Walton-Beckett graticule as seen through the microscope. The rules will be discussed as they apply to the labeled objects in the figure.

Figure 2. Walton-Beckett graticule with fibers.
These rules are sometimes referred to as the “A” rules:

<table>
<thead>
<tr>
<th>Object</th>
<th>Count</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 fiber</td>
<td>Optically observable asbestos fibers are actually bundles of fine fibrils. If the fibrils seem to be from the same bundle, the object is counted as a single fiber. Note, however, that all objects meeting length and aspect ratio criteria are counted whether or not they appear to be asbestos.</td>
</tr>
<tr>
<td>2</td>
<td>2 fibers</td>
<td>If fibers meeting the length and aspect ratio criteria (length &gt;5 µm and length-to-width ratio &gt; 3 to 1) overlap, but do not seem to be part of the same bundle, they are counted as separate fibers.</td>
</tr>
<tr>
<td>3</td>
<td>1 fiber</td>
<td>Although the object has a relatively large diameter (&gt;3 µm), it is counted as fiber under the rules. There is no upper limit on the fiber diameter in the counting rules. Note that fiber width is measured at the widest compact section of the object.</td>
</tr>
<tr>
<td>4</td>
<td>1 fiber</td>
<td>Although long fine fibrils may extend from the body of a fiber, these fibrils are considered part of the fiber if they seem to have originally been part of the bundle.</td>
</tr>
<tr>
<td>5</td>
<td>Do not count</td>
<td>If the object is ≤ 5 µm long, it is not counted.</td>
</tr>
<tr>
<td>6</td>
<td>1 fiber</td>
<td>A fiber partially obscured by a particle is counted as one fiber. If the fiber ends emanating from a particle do not seem to be from the same fiber and each end meets the length and aspect ratio criteria, they are counted as separate fibers.</td>
</tr>
<tr>
<td>7</td>
<td>½ fiber</td>
<td>A fiber which crosses into the graticule area one time is counted as ½ fiber.</td>
</tr>
<tr>
<td>8</td>
<td>Do not count</td>
<td>Ignore fibers that cross the graticulate boundary more than once.</td>
</tr>
<tr>
<td>9</td>
<td>Do not count</td>
<td>Ignore fibers that lie outside the graticule boundary.</td>
</tr>
</tbody>
</table>

APPENDIX C. ALTERNATE COUNTING RULES FOR NON-ASBESTOS FIBERS

Other counting rules may be more appropriate for measurement of specific non-asbestos fiber types, such as fibrous glass. These include the “B” rules given below (from NIOSH Method 7400, Revision #2, dated 8/15/87), the World Health Organization reference method for man-made mineral fiber [24], and the NIOSH fibrous glass criteria document method [25]. The upper diameter limit in these methods prevents measurements of non-thoracic fibers. It is important to note that the aspect ratio limits included in these methods vary. NIOSH recommends the use of the 3:1 aspect ratio in counting fibers.

It is emphasized that hybridization of different sets of counting rules is not permitted. Report specifically which set of counting rules are used with the analytical results.

“B” Counting Rules

1. Count only ends of fibers. Each fiber must be longer than 5 µm and less than 3 µm diameter.
2. Count only ends of fibers with a length-to-width ratio equal to or greater than 5:1.
3. Count each fiber end which falls within the graticule area as one end, provided that the fiber meets rules 1 and 2 above. Add split ends to the count as appropriate if the split fiber segment also meets the criteria of rules 1 and 2 above.
4. Count visibly free ends which meet rules 1 and 2 above when the fiber appears to be attached to another particle, regardless of the size of the other particle. Count the end of a fiber obscured by another particle if the particle covering the fiber end is less than 3 µm in diameter.
5. Count free ends of fibers emanating from large clumps and bundles up to a maximum of 10 ends (5 fibers), provided that each segment meets rules 1 and 2 above.
6. Count enough graticule fields to yield 200 ends. Count a minimum of 20 graticule fields. Stop at 100 graticule fields, regardless of count.
7. Divide total end count by 2 to yield fiber count.

APPENDIX D. EQUIVALENT LIMITS OF DETECTION AND QUANTITATION

<table>
<thead>
<tr>
<th>Fiber density on filter*</th>
<th>Fiber concentration in air, f/cc</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fibers per 100 fields</td>
</tr>
<tr>
<td>200</td>
<td>255</td>
</tr>
<tr>
<td>100</td>
<td>127</td>
</tr>
<tr>
<td>LOQ</td>
<td>80.0</td>
</tr>
<tr>
<td>50</td>
<td>64</td>
</tr>
<tr>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>10</td>
<td>12.7</td>
</tr>
<tr>
<td>8</td>
<td>10.2</td>
</tr>
<tr>
<td>LOD</td>
<td>5.5</td>
</tr>
</tbody>
</table>

*Assumes 385 mm² effective filter collection area, and field area = 0.00785 mm², for relatively “clean” (little particulate aside from fibers) filters.
3. **SAMPLE DATA COLLECTION FORM EXAMPLES:**

The following page is an example of a sample data collection form used for each sample collected. Sample data collection forms may come in various layouts but generally collect pertinent information for each sample collected.

It is important that sample data collection forms be filled out completely and accurately for quality assurance and quality control purposes.

The next page after the “sample data collection form” example is a blank form for reference.
**INDUSTRIAL HYGIENE SAMPLE DATA SHEET**

<table>
<thead>
<tr>
<th>SAMPLE ID</th>
<th>COMPANY</th>
<th>FIB/SIL</th>
<th>METHOD</th>
<th>DATE</th>
<th>IH</th>
<th>CUSTOMER</th>
<th>WORKER</th>
<th>IND. SEG.</th>
<th>PUMP CALIBRATION</th>
<th>FUNCT. CATEGORIES</th>
<th>FUNCT. CATEGORIES</th>
<th>FUNCT. CATEGORIES</th>
<th>FUNCT. CATEGORIES</th>
<th>FUNCT. CATEGORIES</th>
<th>FUNCT. CATEGORIES</th>
<th>FUNCT. CATEGORIES</th>
<th>FUNCT. CATEGORIES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ABC Insulation</td>
<td></td>
<td></td>
<td>7/15/2008</td>
<td></td>
<td>ABC</td>
<td>1</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FACILITY NAME**
ABC Insulation

**LOCATION**
2235 Sanborn Street
Rancho Santa Margarita, CA 22305

**DATE**
7/15/2008

**CONTACT INFO**
NAME: Jack Smith
HSE Manager
PHONE: 445-668-9885

**RESPIRATOR TYPE**
3M 1/2 Face APR

**OTHER PERSONAL EQUIPMENT**
Safety Glasses, Glove and Disposable Outergarments

**CAS ID**

<table>
<thead>
<tr>
<th>PUMP START</th>
<th>STOP</th>
<th>RESULTS</th>
<th>JOB</th>
<th>COMMENTS/ OBSERVATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUMBER</td>
<td>TIME</td>
<td>TIME</td>
<td>MINUTES</td>
<td>VOLUME</td>
</tr>
<tr>
<td>2ABC</td>
<td>550</td>
<td>8:05</td>
<td>11:06</td>
<td>181</td>
</tr>
<tr>
<td>4ABC</td>
<td>550</td>
<td>11:06</td>
<td>13:46</td>
<td>160</td>
</tr>
<tr>
<td>5ABC</td>
<td>550</td>
<td>13:46</td>
<td>15:55</td>
<td>129</td>
</tr>
</tbody>
</table>

**INDUSTRY SEGMENTS:**
P = PRODUCER
VF = VACUUM FORMER
FR = FURNACE RELATED
R = RESALE
G = OTHER (NEC)

**CALIBRATION BY:**

**DATA COLLECTED BY:**

**NUMBER OF WORKERS IN EACH FJC AT THIS FACILITY (CUSTOMERS ONLY—LEAVE BLANK FOR MFG SAMPLES):**

<table>
<thead>
<tr>
<th>ASBLY</th>
<th>AUX</th>
<th>FIN</th>
<th>INST</th>
<th>MIF</th>
<th>OTHER</th>
<th>REM</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

**OBSERVATIONS ON ADMIN. AND ENG. CONTROLS:**
Install Blanket in Thermal Oxidizer Unit
Wet Mist Blanket before Cutting
**CHAIN of CUSTODY FORM EXAMPLES:**

A chain of custody form (CoC) is a tracking and information form that is filled out and sent with the filter cassettes to the analytical laboratory. CoC forms should be requested from the laboratory to be used for analysis.

It is important that CoC forms be filled out completely and accurately for quality assurance and quality control purposes.

An example of a completed CoC is found on the following page. Each laboratory generally has their own CoC format but the basic information contained within each CoC form is generally the same.
Request for Laboratory Analytical Services

**Bureau Veritas North America, Inc.**

<table>
<thead>
<tr>
<th>Report results to:</th>
<th>Client Project</th>
<th>Send invoice to:</th>
<th>P.O. No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Number:</td>
<td>Name</td>
<td></td>
</tr>
<tr>
<td>Company</td>
<td></td>
<td>Company</td>
<td></td>
</tr>
<tr>
<td>Mailing Address</td>
<td></td>
<td>Address</td>
<td></td>
</tr>
<tr>
<td>City, State, Zip</td>
<td></td>
<td>City, State, Zip</td>
<td></td>
</tr>
<tr>
<td>Telephone No.</td>
<td></td>
<td>Fax No.</td>
<td></td>
</tr>
</tbody>
</table>

**Soil samples only: Which state are these from?**

<table>
<thead>
<tr>
<th>Water samples are:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drinking water</td>
</tr>
<tr>
<td>Groundwater</td>
</tr>
<tr>
<td>Wastewater</td>
</tr>
</tbody>
</table>

**ANALYSIS REQUESTED**

(List each analyte on the lines below, multiple analytes per line)

<table>
<thead>
<tr>
<th>Client Sample Identification</th>
<th>Date Sampled</th>
<th>Time Sampled</th>
<th>Matrix/Media</th>
<th>Air Volume (Liters)</th>
<th>No. of Containers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Collected by:**

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Collector’s Signature:</th>
<th>Date/Time</th>
</tr>
</thead>
</table>

**Relinquished by:**

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Received by:</th>
<th>Date/Time</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Relinquished by:</th>
<th>Date/Time</th>
</tr>
</thead>
</table>

**Method of Shipment:**

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Sample Condition on Receipt:</th>
</tr>
</thead>
</table>

**Authorized by:**

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>(Signature MUST accompany request!) (Explain)</th>
</tr>
</thead>
</table>

**Ship to:**

- **Detroit** (IH, Environmental, & Asbestos)
  22345 Roethel Drive
  Novi, Michigan, 48375
  Phone: 248.344.2652, Toll-free 800.806.5887
  Fax: 248-344-2655

- **Visit our Website:**
  [http://labonline.claytongrp.com](http://labonline.claytongrp.com)

- **Atlanta** (Asbestos & Electron Microscopy)
  3830 Chastain Meadow Pkwy., Suite 300
  Kennesaw, Georgia, 30144
  Phone: 770.499.7500, Toll-free 800.252.9919
  Fax: 770.499.7511
AIRBORNE FIBER SAMPLING LABORATORY REPORT of RESULTS:

A copy of a laboratory report showing airborne fiber sampling results is shown on the following page. After receipt, the results from the laboratory report are transcribed to the appropriate spaces on the sample data collection forms to calculate TWAs.
November 09, 2006

UNIFRAX CORPORATION
2351 Whirlpool Street
Niagara Falls, NY 14305-2413

Clayton Work Order No. ...

Reference:

Dear:

Clayton Group Services received 22 samples on 11/3/2006 9:05:27 AM and reported on 11/9/2006 for the analyses presented in the following report.

The results apply only to the samples analyzed in this project. Please note that any unused portion of the samples will be discarded after a thirty-day holding period, unless you have requested otherwise.

We appreciate the opportunity to assist you. If you have any questions concerning the report, please contact the analyst whose name appears on the report or myself at (770) 499-7500.

Sincerely,

[Signature]
Alan M. Segrave, P.G.
Director, Laboratory Services
### ANALYTICAL RESULTS

**CLIENT:** UNIFRAX CORPORATION  
**Date:** 09-Nov-06

**Work Order No.:**  
**Client Reference:**

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<th>Fiber Concentration</th>
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Sample overloaded, not analyzed

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<th>Fiber Concentration</th>
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