(Request NIOSH TR-84)

N. A. LEIDEL

USPHS/NIOSH MEMBRANE FILTER METHOD FOR EVALUATING AIRBORNE ASBESTOS FIBERS

I SCOPE

A This method describes the equipment and procedures for collecting, mounting, sizing, and counting asbestos fibers on membrane filters in the evaluation of breathing zone samples of airborne asbestos fibers.

B The method has been successfully applied using 37 mm Millipore AA filters and small battery operated personal sampling pumps at a flow rate of 1.0 to 2.5 liters per minute for time periods of 15 to 150 minutes at concentrations of 1 to 20 fibers (longer than 5 micrometers)/cubic centimeter. Large deviations from these conditions may result in filters with either too few or too many fibers, which will yield air concentration estimates of low statistical precision and accuracy.

C This method considers only fibers with a length to width ratio of 3 to 1 or greater and a length greater than 5 micrometers.

II SUMMARY OF METHOD

A The sample is collected by drawing air through a membrane filter by means of a battery powered personal sampling pump. The filter is transformed from an opaque solid membrane to a transparent, optically homogeneous gel. The fibers are sized and counted by phase-contrast microscope at 400-450X magnification.

III SIGNIFICANCE

A This method was first used by the Asbestosis Research Council in Great Britain[1] and later was slightly modified by the U.S. Public Health Service for asbestos dust studies in the United States[2]. It has been specified as the method of test[3] for the Federal Standard for asbestos in industrial air (29 C.F.R. Part 1910. 93a), in the U.S. Public Health Service Criteria Document on occupational exposure to asbestos[4], and in sampling procedures of the Occupational Safety and Health Administration, Department of Labor.[5]

IV DEFINITIONS

A For definitions of terms used in this method, refer to ASTM Definitions D 1356, Terms Relating to Atmospheric Sampling and Analysis.

V INTERFERENCES

All particulates with a length to width ratio of 3 to 1 or greater and a length greater than 5 micrometers should, in the absence of other information, be considered to be asbestos fibers and counted as such.

VI APPARATUS

A Sampling Equipment

The personal sampling equipment train consists of 1) personal sampling pump, 2) tubing, 3) clothing spring clip, 4) tubing-to-field monitor metal adaptor, and 5) field monitor (collecting filter and holder).

1 Personal sampler pump. The pump must be battery powered and weigh less than 2 pounds (0.91 kg). The pump must be capable of sampling at 1.0 to 2.5 lpm against a flow resistance of 7.5 inches H_2O (1.4 cm Hg) for 8 continuous hours on a fully charged battery. See Note A for sources of pumps that have been found satisfactory for this method.

2 Tubing. Laboratory tubing such as rubber or plastic with 6 mm bore (1/4 inch) and about 90 cm length (3 feet).

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3 Clothing spring clip. This clip attaches the rubber tubing to the lapel or shirt of the individual being monitored. See Note B for the source of a clip that has been found satisfactory for this method. Large spring paper clips will also work.

4 Tubing-to-field monitor adaptor. See See Note C for a source of an adaptor that has been found satisfactory.

5 Field monitor (collecting filter and holder). The only field monitor currently approved by the National Institute for Occupational Safety and Health is manufactured by the Millipore Corporation. The unit consists of: 1) A three-section styrene plastic case designated Millipore Aerosol Monitor Case, 2) a 37 mm diameter plain white cellulose ester membrane filter designated Millipore AA (nominal pore size of 0.8 micrometer), 3) a support pad, and 4) two plastic sealing caps. If a large number of samples are to be taken, it will be less expensive to reuse the plastic cases. Great care must be taken in the cleaning and reassembly process. The outside mating surfaces of the field monitors should be covered with "shrink-fit" sealing bands to seal the units and provide a writing surface for filter identification. See Notes D and E.

B Optical Equipment

For general guidance on microscopes consult Needham(6) and Clark(7) under phase contrast microscopes and accessories.

1 Microscope body with binocular head.

2 10X Huygenian eyepieces are recommended. Other eyepieces can be substituted if necessary.

3 Koehler illumination (preferably built in and having provisions for adjusting light intensity).

4 A Porton reticle is recommended. Others such as the Patterson Globe and Circle can be substituted, if necessary.

5 Mechanical stage.

6 Abbe or Zernike condenser fitted with phase ring (or Heine) with a numerical aperture (N.A.) equal to or greater than the N.A. of the objective.

7 40-45X (N.A. 0.65 to 0.75) positive phase contrast achromatic objective.

8 Phase-ring centering telescope or Bertrand lens.

9 Green filter, if recommended by microscope manufacturer.

10 Stage micrometer with 0.01 mm subdivisions.

C Filter Mounting Equipment

Experience has shown that certain equipment is useful for efficient sample mounting. The following items are recommended for extracting and mounting a portion of the filter onto the microscope.

1 Microscope slides: 2.5 by 7.5 cm (one inch by three inches) glass slides are most commonly used. Sample number, data, initials, etc., can be conveniently written on a frosted end slide.

2 Cover slips: Cover slips are a necessary part of the slide mount and optical system. The shape should be appropriate for the size of the filter wedge. The appropriate cover slip depends upon the objective to be used. Ordinarily objectives are optically corrected for a #1 1/2 (0.17 millimeter) thickness cover slip. Improper cover glass thickness will detract from the final image quality.

3 Scalpel: A scalpel is needed to remove a portion of the filter to be

examined. A number-ten curved blade scalpel works very well.

4 Tweezers: A pair of fine-tipped tweezers is used to remove the membrane filter slice from the field monitor and place it upon the slide.

5 Lens tissue: To insure cleanliness, use of a lint-free lens tissue is recommended. This tissue should also be used for wiping mounting tools and for cleaning slides and cover slips.

6 Glass rod or spatula: A spatula or fire-polished glass rod is needed to spread the mounting solution on the slide.

7 Wheaton Balsam bottle: This special glass container has a glass top which prevents contamination of the mounting solution. A glass rod is included for dispensing the solution.

VII REAGENTS

Chemicals should be reagent grade, free from particles and color, conforming to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

A Dimethyl Phthalate

B Diethyl Oxalate

VIII SAFETY PRECAUTIONS

A Avoid getting the mounting solution on the skin. Wash skin with soap and water if contact occurs.

IX SAMPLING

A General Information

Refer to the Recommended Practice D 1357, for Planning the Sampling of the Atmosphere and Recommended Practice D 2009, for Collecting by Filtration and Determination of Mass, Number, and Optical Sizing of Atmospheric Particulates. These guides are cited only for general principles, as they are intended primarily for air pollution measurements at fixed sampling stations.

B Calibration

The personal sampling pump should be recharged prior to calibration and then calibrated(8) against a bubble meter, wet test meter, spirometer, or similar device at 1.0 to 2.5 lpm. The sampling train used in the calibration (pump, hose, filter) should be the same as the one used in the field. The calibration should be of sufficient accuracy that the 98% confidence limits on the flowrate are ± 10% (two standard deviations).

C Mounting the Sampler

Fasten the sampling pump to the worker's belt and fasten the field monitor to the lapel or shirt front (as close to the face as is practical). Remove the cover of the plastic monitor making certain the exposed filter is facing downward. Turn on the pump and adjust to the previously calibrated flowrate (1.0 to 2.5 lpm). Immediately record the following information in a logbook:

1 Filter number

2 Pump start time and date

3 Flow rate

4 Subject's name

5 Type of operation

6 Ventilation controls and/or if worker is wearing a respirator approved for asbestos.

The pump should be checked periodically during the sampling period for proper operation and flowrate.

D Optimum Sampling Times

Leidel(9) has described the requirements for optimum sampling times for airborne asbestos fibers. A nomogram to aid in the calculation of these times is shown as Figure 1. For typical microscope field areas and pump flow rates the optimum collection times are about 50 to 80 minutes. The nomogram is intended as a guide to be used where no prior knowledge of the air concentration is available. If, after sampling for the times recommended by Figure 1, the sample is very heavily loaded (greater than 10 fibers/field), then the air concentration probably greatly exceeded the ceiling standard of 10 fibers/cm^3. Conversely if the filter fiber density is very low (less than 1 fiber/field) then the air concentration probably was less than the 1976 TWA Standard of 2 fibers/cm^3. The nomogram gives the the sampling times which produce optimum fiber densities on the filter (1 to 5 fibers/field) for air concentrations of 1 to 10 fibers/cm^3.

If the air concentrations are very high or very low, then graphs given by Leidel[9] would aid in the calculation of the proper sampling times. If there is a dense visible cloud, short (5-15 minutes) sampling times should probably be used. To sample for the ceiling standard of 10 fibers/cm^3, a 15-minute period should be used.

E End of Sampling Period

Remove the field monitor, replace the plastic top cover and the small end caps, and store the monitor. Always shut off the pump when changing monitors to avoid contaminating or damaging the pump. Record the pump shutoff time in the logbook.

F Blanks

With each batch (25 to 50 filters) of samples submit two unopened filters which have been subjected to the same handling as the samples except that no air has been drawn through them. Label these as blanks. If the blanks yield fiber counts greater than about 5 fibers/100 fields, then the entire sampling procedure should be examined carefully for the cause of contamination.

G Shipping

The field monitors in which the samplers are collected should be shipped in a rigid container with sufficient packing material to prevent crushing.

H Numbers of Samples

When sampling for the ceiling standard only one sample (15-minute minimum duration) is theoretically necessary. However, several 15-minute samples should be taken during expected periods of peak air concentrations to allow for detection of gross sampling or counting errors.

When sampling for determination of noncompliance with the 8-hour TWA Standard one should continuously sample as large a portion of the work day as is feasible. Normally this would mean 6 to 10 consecutive samples on the same man. However, if this is not feasible the 8-hour TWA air concentration can be estimated from fewer than 6-10 samples. Leidel and Busch[10] have shown an optimum number would be 4 to 7. Refer to (10) for treatment of the data for the determination on noncompliance. See Jones and Brief[11] for how to treat data taken for an environmental monitoring program.

X CALIBRATION AND STANDARDIZATION

A Porton Reticle

The asbestos fiber count procedure consists of comparing fiber length by comparison with calibrated circles, and counting all fibers greater than 5 micrometers in length within a given counting field area. It is recommended that a Porton reticle be used for this purpose. The Porton reticle is a glass plate inscribed with a series of circles and rectangles. The square on the left, divided into six rectangles, is defined as the counting field.

B Placement in Eyepiece

The Porton reticle is placed inside the Huygenian eyepiece where it rests on the field-limiting diaphragm. The reticle should be kept clean, since dirt on the reticle is in focus and will complicate the counting and sizing process. For mounting in other eyepieces such as a Ramsden, a counting collar must be used.

C Stage Micrometer

The Porton reticle cannot be used for counting until it has been properly calibrated with a stage micrometer. Most stage micrometer scales are approximately two millimeters long and are divided into units of one-hundredth of a millimeter or ten micrometers.

D Microscope Adjustment

Follow the manufacturer's instructions while observing the following guidelines.

1 The light source image must be in focus and centered on the condenser iris or annular diaphragm.

2 The object for examination must be in focus.

3 The illuminator field iris must be in focus, centered on the sample, and opened only to the point where the field of view is illuminated.

4 The phase rings (annular diaphragm and phase-shifting elements) must be concentric.

E Porton Reticle Calibration Procedure

Each eyepiece-objective-reticle combination on the microscope must be calibrated. Should any of the three be changed (disassembly, replacement, zoom adjustment, etc.) the combination must be re-calibrated. Calibration may change if interpupillary distance is changed. For proper calibration, the following procedure should be followed closely.

With a 10X objective in place, place the stage micrometer on the mechanical stage, focus, and center the image. Change to the 40-45X objective and adjust the first scale division to coincide with the left boundary of the Porton rectangle. Count the number of divisions between the left and right boundaries of the long horizontal dimension of the largest rectangle, estimating any portion of the final division. This measurement represents 200 L units and one divides the measurement by 200 to find "L". The large rectangle is 100 L units long on the short vertical dimension. The calculated "L" is inserted into the formula $D = L\,(2^{N})^{\frac{1}{2}}$ where "N" is the circle number (indicated on the reticle) and "D" is the circle diameter. Since the circle diameters vary logarithmically, every other circle doubles in diameter. For example, number three is twice the diameter of number one; number four is twice the diameter of number two. When the circle sizes have been determined, the counting field area consisting of the left six smaller rectangles can be calculated from the relation $10{,}000\ L^2$. This completes the reticle calibration for this specific objective - eyepiece - recticle combination.

XI PROCEDURE

A Mounting

A very important part of the sample evaluation is the mounting process. This process involves a special mounting medium of prescribed viscosity. The mixture must be stirred periodically until the filters have dissolved and a homogeneous mixture is formed. The normal shelf life of the mounting solution is about six months. Twenty milliliters of mounting solution will prepare approximately 300 samples.

B Sample Mounting

Cleanliness is important! A dirty working area may result in sample contamination and erroneous counts. The following steps should be followed when mounting a sample.

1 Clean the slides and cover slips with lens tissue. Lay the slide down on a clean surface with the frosted end up. It is a good practice to rest one edge of the cover slip on the slide and the other edge on the working surface. By doing this, you keep the bottom surface (the one which contacts the filter) from becoming contaminated.

2 Wipe all the mounting tools clean with lens tissue and place them on a clean surface (i.e., lens tissue). When mounting a series of filters the scalpel should be wiped clean before cutting each sample.

3 Using a glass rod which is supplied with the Wheaton balsam bottom, apply a small drop of mounting solution onto the center of the slide. It may be necessary to adjust the quantity of solution used or the size of the wedge. The correct amount will result in the solution extending only slightly beyond the filter boundary. If the quantity is greater than this, adverse particle migration will occur.

4 With the spatula or a supplemental glass rod, spread the mounting media into a triangular shape. The size of this triangle should coincide with the dimension of the filter wedge.

5 Separate the middle and bottom sections of the field monitor case to expose the fragile filter. Cut a triangular wedge from the center to the edge of the filter using the scalpel. The size of the wedge should approximate one-eighth of the filter surface.

6 Grasp the filter wedge with the tweezers in the outer area of the filter which was clamped between the monitor case sections. Do not touch the filter with your fingers. Place the wedge, sampled side up, upon the mounting medium.

7 Pick up the cover slip with the tweezers and carefully place it on the filter wedge. Once this contact has been made, <u>do not reposition the cover slip</u>.

8 Label the slide with the sample number and current date before proceeding to the next filter.

9 The sample should become transparent after about fifteen minutes. If the filter appears cloudy, it may be necessary to press <u>very lightly</u> on the cover slip. This is rarely necessary.

10 Discard the sample mount after three days if it has not been counted. Crystals which appear similar to asbestos fibers may begin to grow at the mounting media/air interfaces. They seldom present any problems if the slide is examined before three days. In any case, stay away from the filter's edges when counting and sizing.

C Counting and Sizing

1 <u>Finding and inspecting counting fields</u>. Place the slide on the mechanical stage and position the center of the wedge under the objective lens and focus upon the sample. Nearly all of the particulates (particles and fibers) will be found in the upper ten to fifteen micrometers of the filter surface. When counting and sizing, continual use of the fine focus control is required to insure that nothing is missed. Start counting from one end of the wedge and progress along a radial line to the other end (count in either direction from circumference to wedge tip). Random fields are selected, without looking into the eyepieces, by slightly advancing the slide in one direction with the mechanical stage control.

D Achieving Comparable Results

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

2 Count only fibers greater than 5 micrometers in length. (Be as accurate as possible in accepting or rejecting fibers near this length). Measure curved fibers along the curve to estimate the total length.

3 Count as many fields as necessary to yield a total count of at least 100 fibers. Exceptions: a) count at least 20 fields even if you count more than 100 fibers and b) stop at 100 fields even if you haven't reached 100 fibers.

4 Select the field of view without looking through the microscope's eyepieces to eliminate unconsciously selecting "heavy" or "light" areas.

5 The fields are selected along the entire length of a radial line running between the outside perimeter and the tip of the wedge.

6 When an agglomerate (mass of material) covers a significant portion of the field of view (approx. 1/6 or greater) reject the field and select another. (Do not include it in the number of fields counted). However, report the fact as it may have meaning to sampling or medical personnel.

7 Bundles of fibers are counted as one fiber unless both ends of a fiber crossing another can be clearly resolved.

8 For fibers that cross either one or two sides of the counting field, the following procedure is used to obtain a representative count. First, arbitrarily select a) the left and bottom sides and b) the upper and lower left corners or vertical direction as "decision aids."

Then count any fiber greater than 5 micrometers in length, but only if the fiber:

a lies entirely within the counting area or,

b crosses the left or bottom sides, or

c crosses the upper or lower left corners, or

d crosses both the top and bottom sides.

Reject and do not count all other fibers. Refer to Figures 2 through 7.

XII CALCULATIONS

A Calculation of Airborne Concentration

Asbestos fiber airborne concentration may be calculated from the following formula:

$$C = \frac{(F - B)(W)}{(A)(V)}$$

Where:

C = Airborne fiber concentration in fibers >5 μm/cm^3

F = Average fiber count in fibers >5 μm/field.

B = Average fiber count of blank(s) or control filter(s) in fibers >5 μm/field. (It is subtracted to eliminate the error or background contamination).

W = 855 mm^2 for 37 mm diameter filter (the portion of the Millipore filter which is exposed when mounted in the field monitor case, i.e., the effective filter area).

A = The area of the counting field of a calibrated reticle expressed in mm^2/field.

V = Total air volume collected through filter expressed in milliliters.

XIII PRECISION AND ACCURACY

A An accuracy and precision study of the membrane filter counting procedure for asbestos has been conducted by Conway and Holland.[12] They conducted an intralaboratory study involving six counters. Three of the counters were experienced while the other three had only a short familiarization with the rules for fiber counting. The conclusions of the study included:

1 The precision of the procedure for filters not containing an abundance of

fine fibers can be estimated by a standard deviation of 16.2%. This value includes variation among counters and observed interaction effects.

2 The accuracy of the procedure for similar filters may be estimated for a 100-fiber count by a standard deviation of 21.4%. This assumes that the contribution of the overall variance from the nonuniform fiber distribution is additive.

3 The fiber concentration varies significantly between angular sectors on a given filter. Where approximately 100 fibers are counted, the standard deviation of the fiber count distribution for the whole filter appears to be represented by $1.6 \cdot (n)^{\frac{1}{2}}$, rather than $(n)^{\frac{1}{2}}$ which is a property of the Poisson distribution, where (n) is the total number of fibers counted.

4 A high percentage of very fine fibers on the filter can significantly affect the standard deviations and confidence limits for counts by different counters. After combining variations in fiber concentrations over the entire filter with those for different counters it was concluded:

a For filters with a low concentration of fine fibers, the standard deviation is estimated at 21% and the 95% confidence interval is $\pm$ 43%.

b For filters with a high concentration of fine fibers, the standard deviation is estimated at 25% and the 95% confidence interval is $\pm$ 50%.

B Lynch, Kronoveter, and Leidel[13] have also reported on the precision of the method. Their intralaboratory study utilized the data from a large number of dust counts made by different methods by experienced counters over a period of years in an epidemiologic study of the asbestos products industry. They concluded that the standard deviation of counts of fibers longer than 5 micrometers on membrane filters could be estimated from the relation $\sigma = (n)^{0.591}$. Thus for counts of about 100 fibers, the standard deviation could be estimated at about 15.2% and the 95% confidence limits at $\pm$ 30.4%. These values are lower than the precision values reported by Conway and Holland.[12]

REFERENCES

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13 Lynch, J. R., K. J. Kronoveter, and N. A. Leidel: "Validity of the Poisson Distribution in Dust Counting," USPHS, NIOSH, TR-83, (To be published 1973).

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NOTES

A Sources of personal sampler pumps

1 Mine Safety Appliance Company
201 North Braddock Avenue
Pittsburgh, PA 15208

2 National Environmental Instruments, Inc.
P.O. Box 590
Warwick, RI 02888

3 Willson Products Division
P.O. Box 622
Reading, PA 19603

B Source of clothing spring clip

Catalog number 1140
John F. McGuire Company
120 Bacon Street
Pawtucket, RI 02860

C Source of tubing-to-field monitor adaptor

Catalog number LH/L
Bection, Dickinson, & Company
Rutherford, NJ

D Source of field monitor

1 Complete monitor (plastic case, filter, pad, and caps), catalog number MAWP 037AO (50/box).

2 Filters and pads only, catalog number AAWP 03700 (100/box).

3 Monitors only, catalog number M0000 37AO (50/box), from the

Millipore Corporation
Ashby Road
Bedford, MA 01730

E Source of sealing bands

Cellulose bands, white, opaque, 41 X 25, #28 (minimum order 2500)

Walter H. Jelly & Company
2822 Birch Street
Franklin Park, IL 60131

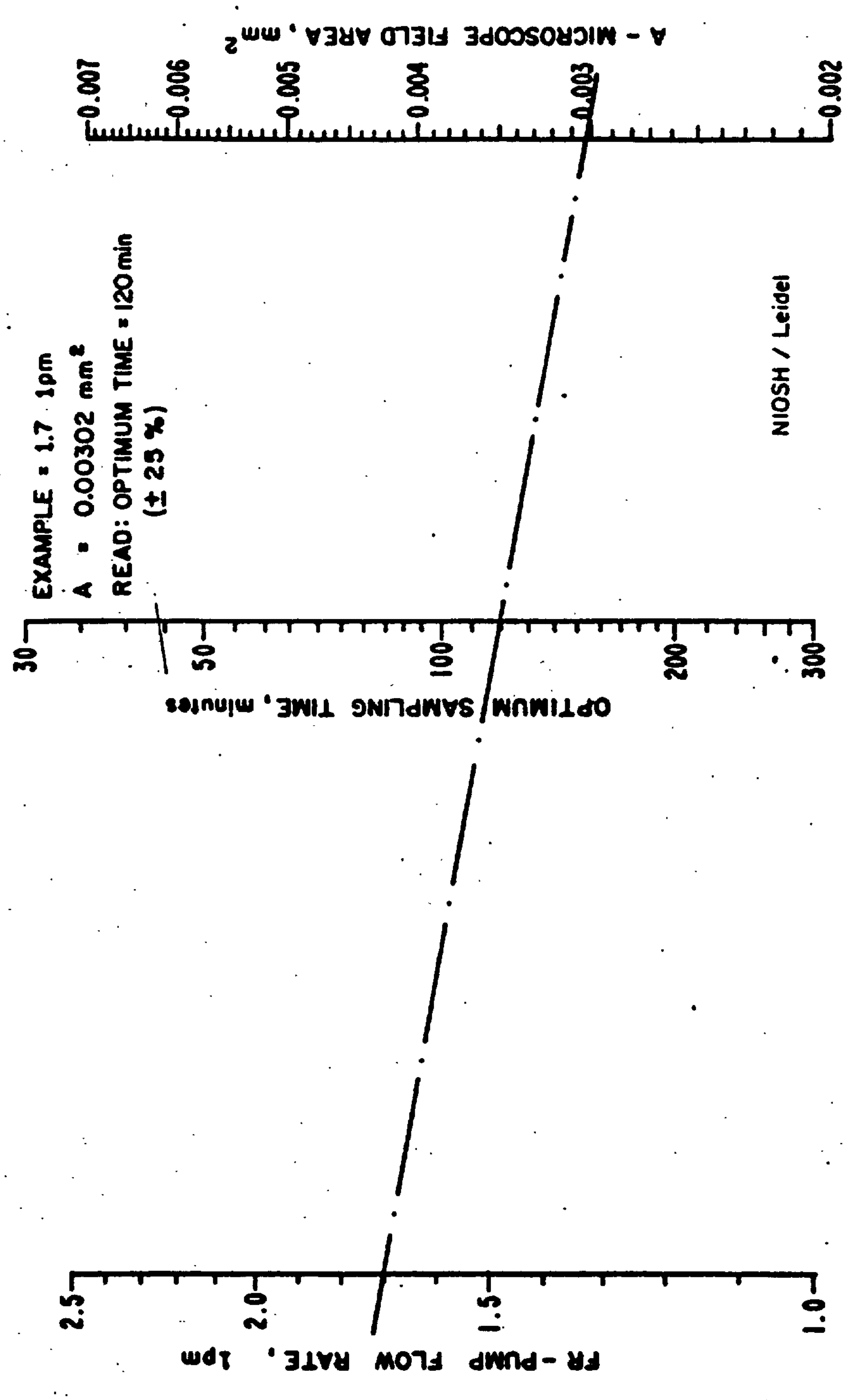


Fig. 1 - Nomogram for optimum sampling times for airborne asbestos fibers.

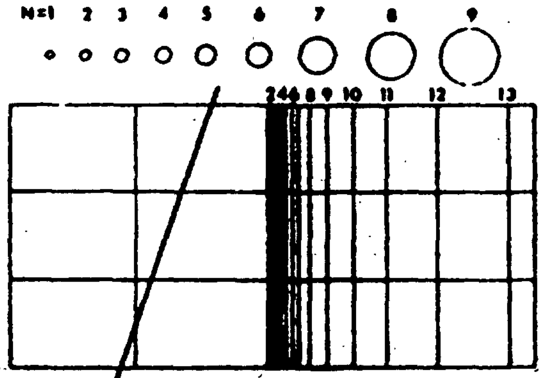


Figure 2. COUNT, fiber crosses both top and bottom sides.

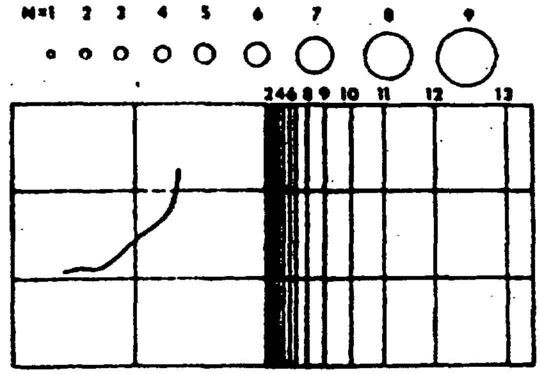


Figure 3. COUNT as one fiber.

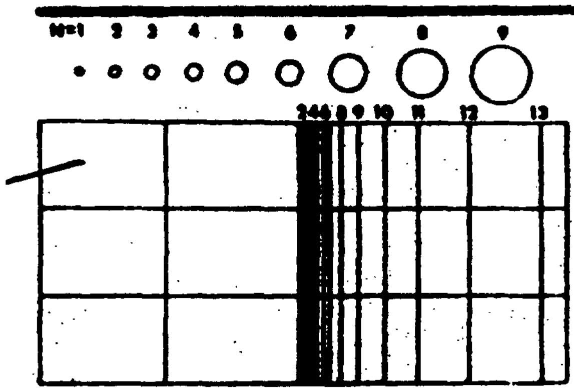


Figure 4. COUNT, fiber crosses left side.

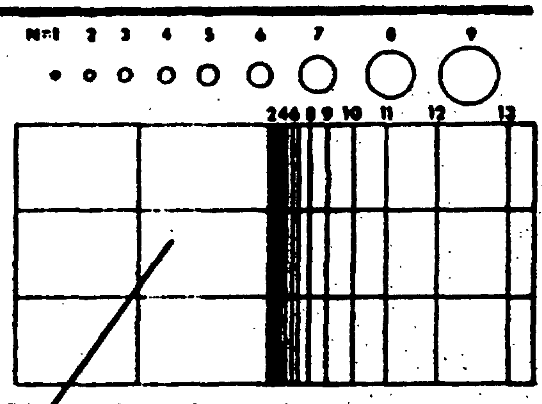


Figure 5. COUNT, fiber crosses bottom side.

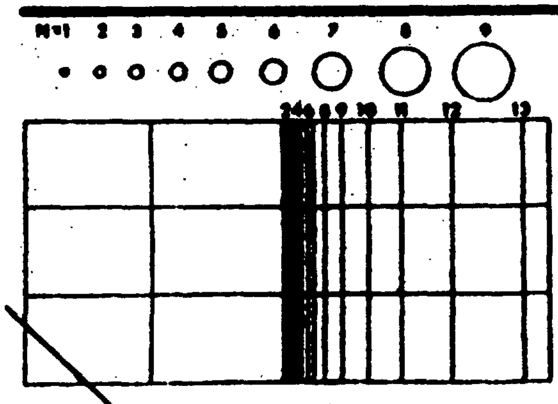


Figure 6. COUNT, fiber crosses lower left corner.

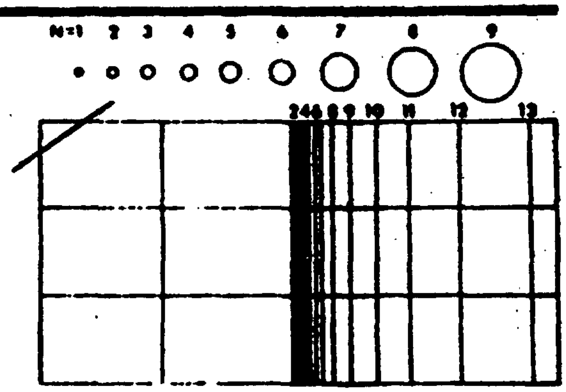
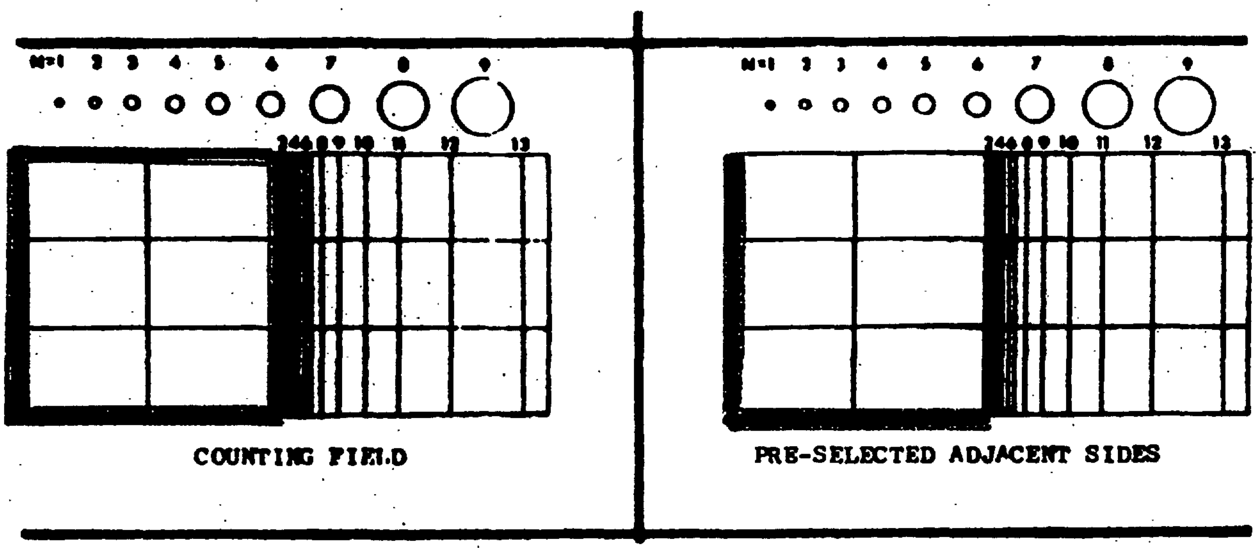
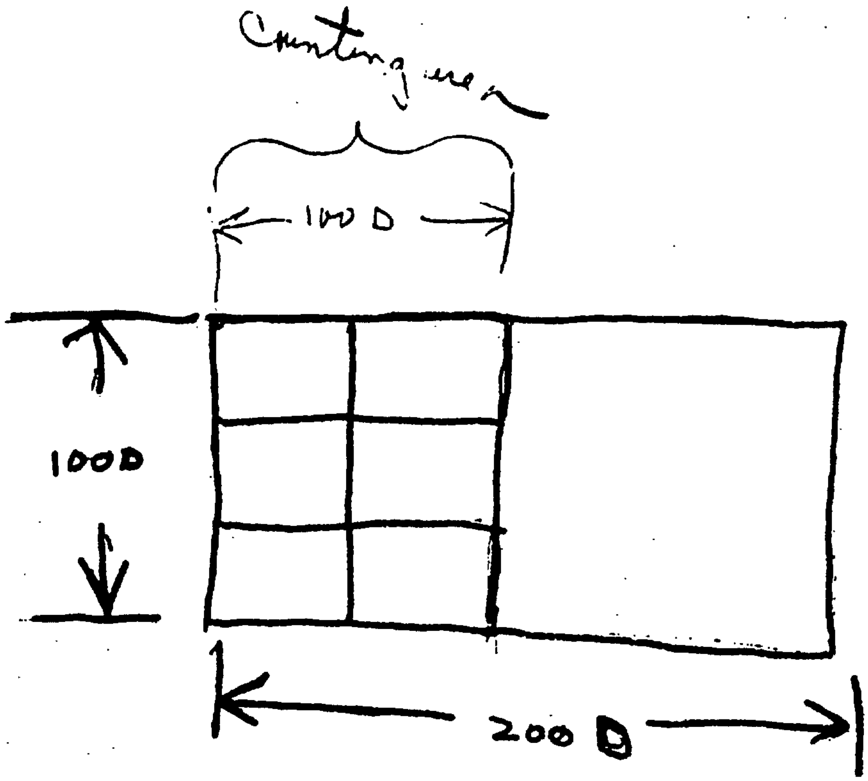


Figure 7. COUNT, fiber crosses upper left corner.



COUNTING FIELD

PRE-SELECTED ADJACENT SIDES

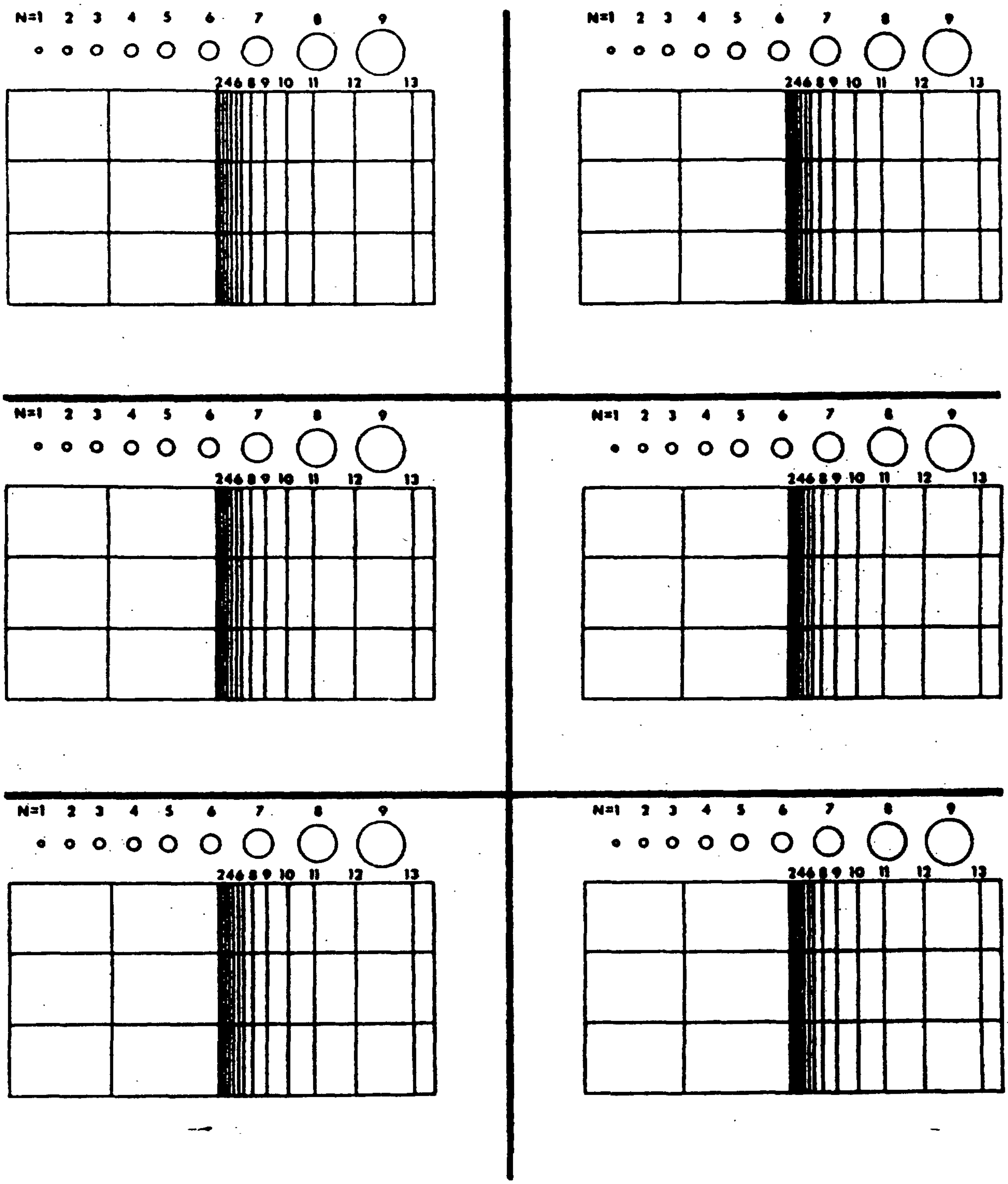


40X 100D units = .81 mm = 810 μ
1 D unit = 8.1 μ

100X 100 D units = .37 mm = 370 μ
1 D unit = 3.7 μ

450X 100 D units = .085 mm = 85 μ
1 D unit = .85 μ

counting field = $(.085\ mm)^2$ = .007225 mm^2 (field area)


N=1 2 3 4 5 6 7 8 9
2 4 6 8 9 10 11 12 13

Part No. T113, Model BC Personal Air Sampler complete with pump, rechargable battery, and sampling head (including cyclone and pre-weighed cassette	$213.00
Part No. T16124, Battery Charger with charging leads for above	$ 50.00
Part No. T121, pre-weighed cassettes, 10 cassettes/package	$ 13.00

Willson Products Division, ESB Inc.
P. O. Box 622
Reading, Pa. 19603

Millipore Field Monitors, Cat.No. MAWP 037 A0, 50/carton	$ 30.00
Millipore field monitor refills, Cat.No. AAWP 037 00, 100/box	15.5

Forceps

Millipore Corporation
Bedford, Mass. 01730

Dispensing Buret, 1000 ml or 2000 ml

(any chemical supply house)

Diethyl Oxalate (Ethyl Oxalate)

Dimethyl Phthalate (Methyl Phthalate)

(any chemical supply house)

Wheaton Balsam Bottle

1)	N51MP Series 50 Phase Teaching Microscope with 4x scanning objective, 10x phase 45x phase objectives with mechanical stage	$448.00
2)	Case for above, Cat.No. A01650 (optional)	$ 38.00
3)	Spare bulb, Cat.No. A0611	$ .50
4)	Burrell Cat.No. 58-492, AO-400 microscope stage micrometer, 2 mm scale in 200 parts on 75 x 25 mm slide	$ 30.00
5)	Huygenian eyepiece 10x, AO-C1142 (must accept 21 mm dia. eyepiece reticle)	$ 30.00
6)	Part No. 30,084 porton reticle	$ 17.50
7)	Cat.No. 12-552 microscope slides, 75 x 25 mm, one frosted end	$ 5.40/ gross
8)	Cat.No. 12-520B micro cover glass, square, size 22 mm sq	$ 3.06/
9)	Lens tissue	
10)	Luer Slip adapter, Cat.No. LH/L 1/4" I.D. hose connector	$ [illegible].75

Burrell Corporation
2223 Fifth Avenue
Pittsburgh, Pa. 15219

1-2-3-4-5

Edmund Scientific Co.
300 Edscorp Bldg.
Barrington, N.J. 08007

6

Fisher Scientific Co.
585 Alpha Drive
Pittsburgh, Pa. 15238
(or any chemical supply house)

7-8-9

Environmental Compliance Corp.
400 Greentree Rd.
Pittsburgh, Pa. 15220

10

ASBESTOS COUNT RECORD SHEET

SAMPLE ____________ OPERATION ______________________________

FLOW __________ TIME __________ VOLUME ________ DATE _______

FILTER AREA (mm^2) _______ FIELD AREA (mm^2) _______ K = _____

AV.COUNT _______________ CONCENTRATION ______________________

COMMENTS ____

0				
5				
10				
15				
20				
25				

SUB-TOTALS

FIBERS/ FIELDS

$$\frac{\text{AVERAGE NET COUNT X K}}{\text{AIR VOLUME SAMPLED (ml)}} = \text{FIBERS/ml}$$

_________________________________ =