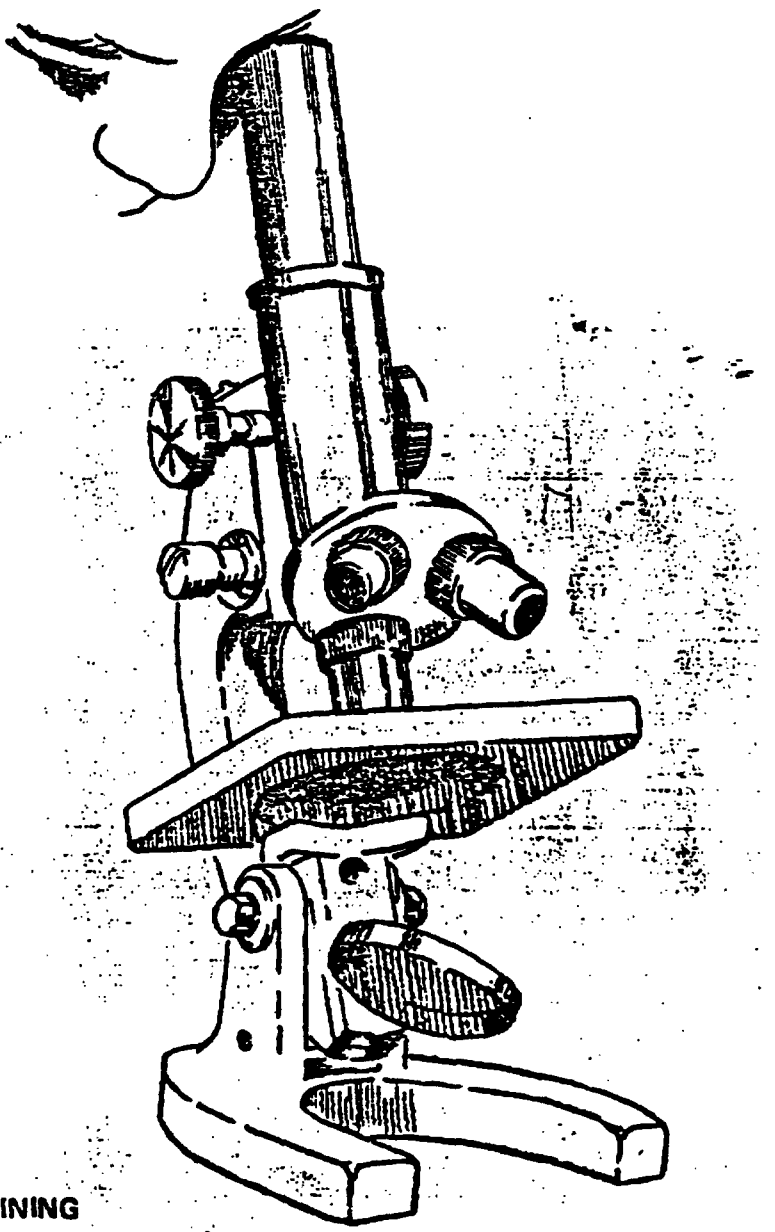
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Sampling & Evaluating Airborne Asbestos Dust



DIVISION OF TRAINING

National Institute for Occupational Safety and Health
U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Health Services and Mental Health Administration

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SAMPLING AND EVALUATING AIRBORNE ASBESTOS DUST

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FOREWORD

The United States Public Health Service has established a sampling and evaluation procedure for determining airborne asbestos dust exposures. The sample is collected by drawing air through a membrane filter by means of a battery powered vacuum pump. The filter is changed into a transparent homogeneous plastic mount, and the fibers are sized and counted by phase-contrast microscopy. This method was first used by the Asbestosis Research Council in Great Britain[1] and later slightly modified by the U.S. Public Health Service for asbestos dust studies in the United States. It is specified in the emergency asbestos standard as published in the Federal Register on December 7, 1971.

UNIFORM procedures must be used for sampling and evaluating asbestos dust if reproducible results are to be achieved. Detailed equipment and procedures used by the United States Public Health Service are described herein. Mention of commercial concerns or products does not constitute endorsement by the Public Health Service or the U.S. Department of Health, Education, and Welfare.

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SAMPLING AIRBORNE ASBESTOS

INTRODUCTION TO SAMPLING

To determine an airborne asbestos concentration, a sample is collected upon a molecular pore filter. This is accomplished with the use of a miniature-battery-powered-vacuum pump which draws air through a cellulose-ester-membrane filter. This sampling unit is attached to a worker and collects an airborne dust sample which is representative of his exposure at his breathing zone. A description and assembly of the required equipment and a recommended procedure for collecting the sample are included within this report. This procedure is intended to represent a standardized method so that results may be accurate and reproducible.

I SAMPLING EQUIPMENT

A Pump Description

In purchasing a personal sampler we recommend the following guidelines set forth by the Bureau of Mines (Title 30, Part 18, 68 of the Federal Rules and Regulations) and the National Institute for Occupational Safety and Health (Title 30, Part 74). In addition to these guidelines, the following specifications are listed with the intent of minimizing some of the possible sampling problems. These specifications are a result of several years of extensive field use and laboratory testing:

1 Weight - The pump should not weigh more than four pounds.

2 Construction - The case and components should be of durable construction and the case should be tight fitting so as to minimize the amount of dust entering the case.

3 Switch - The pump should have an on/off switch mounted on the outside of the case. The switch should be protected against accidental operation during use and protected to keep dust from entering.

4 Flow rate Adjustment - The pump should have an external means of adjusting the flow rate which is indicated by a built-in rotameter. To prevent accidental adjustment, the adjustment should be either recessed or covered.

5 Flow Rate Range - The pump should be capable of operating in a range of 1.0 to 2.5 lpm. The flow rate should be calibrated within a plus-or-minus 5% accuracy.

6 Flow Rate Stability - The flow rate should remain within plus-or-minus 0.2 lpm over an 8-hour period when the pump is operated at 1.7 lpm. Not more than two adjustments of the flow rate (due to battery discharge) should be required to maintain accuracy over an 8-hour period.

7 Duration of Operation - The pump should be capable of operating for 8-hours at a flow rate of at least 1.7 lpm against a resistance of 6" of H_2O measured at the pump inlet.

8 Belt Clip - The pump unit should be provided with a belt clip which will hold the pump securely to the worker's belt.

9 Battery - For continuous operation the pump unit should be equipped with a rechargeable battery. A suitable connection should be provided, so that the battery may be recharged without removing it from the pump. (See addresses for pump manufacturers).

B Sampling Head

A 37mm Millipore field monitor is used as the sampling head. This unit consists of, in order from top to bottom, (1) inlet

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plug, (2) cap, (3) middle retaining section, (4) cellulose ester filter, (5) support pad, (6) base section, (7) outlet plug. These field monitors may be purchased assembled or in parts (cases, filters, and pads). The complete field monitor assembly is considered to be ready for use upon receipt from Millipore Corporation. Additional filters and pads can be ordered through Millipore.* To aid in eliminating contamination, we recommend banding the two bottom monitor sections with a cellulose band. (See Figure 3 for photograph of sampling train)

C Additional Sampling Equipment

The following additional equipment or equal is required to collect a personal sample. Addresses of the commercial concerns which supply all of the mentioned equipment are given in the address section.

1 Rubber tubing - non-collapsable, 32" to 36" in length and with a 1/4" I.D. Tubing is connected between the pump and the field monitor.

2 Adapter - leur slip adapter (#LH/L, 1/4" I.D. hose connector. Used to connect the tubing to the field monitor outlet.

3 Clip - A plastic band and spring clip are used to hold the field monitor and hose securely to the worker. This can be constructed from an 1/2" plastic band and a #1140 clip. Two are recommended per sampler.

4 Belt - A belt should be available with each sampling unit. This will enable you to attach the pump to the subjects waist in the event he is not wearing a belt.

II LABORATORY PREPARATION

A Preparing Field Monitors

If extensive sampling is to be performed it may be economically advantageous to re-use the field monitor cases. If one would elect to do so, the following steps are recommended:

1 Disassemble the used field monitors and wash them in warm soapy water. Then rinse them in tap water.

2 Lay out the monitor sections in a dust free area and allow to dry.

3 Place a support pad and filter in the bottom section.

4 Assemble tightly all three sections. Be sure the middle section forms a good seal against the filter.

5 It will only be necessary to replace the inlet plug.

6 A cellulose band can be placed around the middle and bottom sections. These bands, which shrink upon drying, can also provide a surface for recording data.

B Pump Calibration

The accuracy of the analyses can be no greater than the accuracy of the volume of air which is measured. Therefore, it is necessary to calibrate each sampling pump within ± 5% accuracy for any given flow rate between 1.0 and 2.5 lpm.

The calibration of the sampling pumps would be performed preferably by a primary standard. One accurate and inexpensive calibrator is the bubble meter. Another good calibrator is the spirometer. Both are primary standards for calibration and both will produce a high degree of accuracy. If an intermediate standard has to be used, a wet-test meter is recommended. Rotameters are discouraged as calibration instruments because of the tendency to give incorrect results on the pulsation-type flows encountered with these pumps.

The actual calibration set-up will be the same for all calibration instruments. The calibration instrument should be connected in sequence with the filter monitor followed

*Criteria is being developed for certification of other filter types.

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by the personal pump. Rubber tubing between filter monitor and pump should be of the same kind and length as that used in the field.

For reasons of economics, simplicity and accuracy, the bubble-meter method is recommended. The following is a pump calibration procedure using this method.

1 Assemble a ring stand with two adjustable clamps.

2 Clamp a 1000-2000 ml burette vertically onto the ring stand so that the wide mouth is approximately 4" from the ring stand base.

3 Dispense 100 ml of soap solution into the beaker.

4 Wet entirely the walls of the burette with the soap solution and empty the excess into the beaker.

5 Assemble the sampling train the same as that used in the field. Do not remove the top cap but only remove the top inlet plug.

6 Adapt the filter to the burette with a short piece of tubing and a leur slip adapter.

7 Touch the mouth of the burette to the soap solution in the beaker. This will form a soap film at the mouth of the burette.

8 Start the pump and time the bubble for one minute. Knowing how many milliliters it traveled in a minute you can convert to lpm.

EXAMPLE:

If it takes one minute to travel fifteen hundred milliliters, then the flow rate is one and one half lpm.

III SAMPLING PROCEDURE

A Theory of Sampling

In order to obtain representative samples of the workers' exposure a sufficient number of samples will be required for each worker. Dust concentrations will vary daily, seasonably, and with the weather. To find the low and high dust concentrations it will be necessary to collect samples under varying conditions of weather, on different days, and at different times during his working shift. It will be necessary when sampling a worker to make note of any changes in his production rate or a change in his work routine. Changes in production rates on near by operations should also be noted. These changes can have a direct effect upon the workers' exposure.

NOTE: In accordance with the Threshold Limit Values the exposure for asbestos is five fibers per ml (fibers greater than five microns in length). This level of exposure is for an eight hour workday, for a 40 hour work week; hence, a sufficient number of samples are needed to permit a time weighted average concention throughout a complete cycle of operations or throughout the work shift.

There also exists a Ceiling Limit, this limit places a definite boundary in which the concentration should not be permitted to exceed. This limit should not exceed ten fibers per ml (fibers greater than five microns in length) for any 15 minute sampling period.

B Selecting a Subject

Once a subject has been selected briefly outline the intent of the sampling. Inform him that the personal sampler will not interfere with his normal duties. Emphasize the importance of continuing to work in a routine manner. A good working relationship between the subject and yourself can help prevent and overcome many inherent sampling problems.

To better approximate the actual average dust concentration the worker should be sampled as long as possible through his 8 hour work shift. To achieve this result a few precautionary measures will be necessary:

1 Some preliminary sampling of the worker will be required. Sample

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times of 15-30 minutes at flow rates of 1.5-2.0 lpm are necessary to determine the dustiness of the operation. A portion of the sample is then analyzed for the feasibility of counting. (Analytical method described under sample evaluation). The feasibility of counting is determined by the ease in which the counters are able to see and size the fibers accurately. The following conditions could hinder the accuracy of counting:

a Collection of a large amount of asbestos fibers could cause a possible overlapping of fibers which can hinder the differentiation of fiber lengths.

b Contamination of other airborne particulates. Heavy concentration of particulates hinders the sizing of fibers. Fibers may be partially or entirely obscured from view.

NOTE: An ideal field count would be 1 to 5 fibers/field with a particulate count of ≤ 50. This particulate count is based on those particles whose diameters are <2μ and comprise at least 90% of the total.

Once you have determined the relative dustiness of the operation, sample the worker accordingly. Remember, sampling time should only be as long as your ability to evaluate the sample accurately. If short sampling times are required, it will be necessary to take an appropriate number of samples for correlation with the Threshold Limit Value.

C Placement of Sampler

When making sample placements, consider times for breaks and lunch periods in scheduling the placement and removal of samples. Once the sampler has been placed on a subject check its operation periodically to determine whether the units are operating satisfactorily and if the subject is performing said duties as previously recorded.

The following is a recommended procedure for sampler attachment and the recording of data:

1 Attach the pump to the subjects belt, generally at his back. Supply him with a belt if he does not have one. Position the pump so that it does not interfere with the working operations of the subject.

2 Place the field monitor unit over either shoulder and attach the two hose clips to some part of his clothing.

A recommended sampling arrangement consists of one clip positioned near the field monitor and attached to the worker's collar; the second clip is attached to some part of his clothing at his back. This arrangement will hold the field monitor securely in place and help prevent sampling interference. Make sure the sampling head is located at the workers breathing zone. This area is anywhere on the worker's shoulder or upper chest.

3 Remove the top cap of the field monitor so the entire filter is visible. The middle section remains in place holding the filter in the monitor. Always make sure the face of the monitor is in either a horizontal or slightly vertical (downward) position. Never allow the face of the monitor to point upward.

4 Turn on the pump and record the time. Adjust the flow to a given rate and observe the pump to make sure it is operating accurately.

5 Record the following information immediately to help minimize error:

a Filter number

b Starting time

c Subject's name

d Type of operation being performed by subject

e Ventilation controls and/or if worker is wearing a respirator.

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The following additional information can be filled in at your convenience:

a Type of sample

b Flow rate

c Date

d Name of person collecting sample

e Production activity in the plant-low, high or just average

f Any remarks about the sample that will help in the future review of the data.

6 Once the sample has been collected the following suggestions are recommended for the removal of the sampler.

a Before shutting off the pump, check the unit to be sure it is operating properly.

b Check pump and filter numbers with the numbers previously recorded for each location and operation.

c Turn off pump and record the time. The total time covered by the sample should be expressed in minutes and the total volume of air pumped expressed in liters.

d Replace caps on field monitors and store in a clean location. Put aside and label as blanks a few unsampled filters. These filters will be used as control samples in your fiber counting.

EVALUATING AIRBORNE ASBESTOS DUST

INTRODUCTION

The following procedure describes a technique for counting and sizing asbestos dust which has been collected upon a membrane filter. The filters used in this technique are thirty-seven millimeter diameter cellulose-esther membrane filters manufactured by the Millipore Corporation. The slide mounting technique refers only to this type of filter. The filters are nearly one hundred percent efficient for any asbestos dust, even for fibers with diameters well below the eight tenths of a micron pore size. Filters may be purchased premounted in convenient field monitor cases. Slide mounts of the filters are temporary. The following procedures and recommendations will produce accurate, reproduceable results if each step is performed exactly as described.

I THE MICROSCOPE LABORATORY

Dust counting and sizing requires intense concentration. The efficiency of the microscopist will be enhanced by the ease in which he is able to perform his duties; therefore, it is important to supply him with a suitable microscope laboratory. The area should be dust and smoke free, and out of the way of normal traffic. This not only lessens sample contamination, but also protects the microscope. Since the counting and sizing procedure is strenuous, the microscope table should be vibration free, resulting in a sharper microscope image. A chair with adjustable height is essential for the comfort of the microscopist.

II MICROSCOPE EQUIPMENT

The evaluation procedure requires the use of a microscope to measure the length and width of asbestos fibers. A fiber is distinguished from a particle by having an aspect ratio of at least 3:1. Airborne samples of asbestos contain fibers whose sizes extend far below the maximum resolving power of the best optical microscopes. However, since the U.S. asbestos dust standard is based on fibers five microns and larger, optical microscopy can be used for performing the evaluation. Due to the matching index of refraction of asbestos fibers and the mounting medium, phase contrast microscopy is required for adequate vision. To achieve maximum performance from a phase contrast microscope, it is necessary to incorporate Koehler illumination as an integral part of the optical system.[5-9]

Phase Contrast Microscopy

A Explanation

There may be some speculation as to why a phase-contrast microscope is such an important part of the evaluation process. This feeling may stem from the fact that light field microscopes have been in use for many years for evaluating dust levels taken with the impinger. In order to fully understand why a phase-contrast microscope is necessary, a brief comparison of the two types follows.

Common light-field microscopy depends upon the fact that light bends when it passes through two substances which differ in index of refraction. This effect of bending causes changes in light intensity which gives contrast to the specimen image. Therefore, the image is best developed by using a mounting media with an index of refraction as different from the particles to be viewed as possible. Particulates which are examined (under light-field microscopes) when immersed in a media of the same refractive index are practically invisible.[10,11]

Since the mounting procedure of millipore type AA filters produces a situation where the indices of refraction of the asbestos and of the media nearly match, conventional light field microscopy cannot be utilized. In order to produce image contrast under this circumstance, one can select from a

variety of contrast-producing methods. These instruments use the wave-form structure of light to produce interference images. Of the several available methods, phase-contrast microscopy is adequate and probably the least expensive.

A phase contrast microscope differs from a light field microscope simply by the addition of an annular-ring diaphragm and a phase-shifting element. The annular-ring diaphragm is located in the condenser. This diaphragm enables the condenser to focus a hollow cone of light onto the specimen. An alternative to this Zirnike-phase-contrast condenser, is the Heine type. This condenser has a special mirror element to create the light cone. Because of the simplicity of operation as compared to the Abbe-diaphragm-type condenser, the Zernike condenser may be more desirable. The phase-shifting element is located at the back focal plane of the microscope's objective lens. This element is coated with a film to absorb a large percentage of the light passing through it. On the film, a ring of dielectric material is placed. This ring advances or retards the green light passing through it by one quarter of a wave length (a ninety-degree shift in phase).

The image production of a phase-contrast can be summarized as follows:

> The condenser's cone of light passes through the sample and is then separated into two parts: the undiffracted beam, which is unchanged, and the diffracted beam which is altered because it passes through a particle. Next, these two beams pass through the objective lens and into the phase-shifting element where approximately 75% undiffracted light is absorbed and where the diffracted light is shifted ninety degrees out of phase. When the two portions of the original cone of light are recombined, constructive or destructive interference occurs, producing an image having a significant amount of contrast.

B Requirements for the Microscope

Since the basic principles showing the role of a phase-contrast microscope have been discussed, one might need a guideline for use in purchasing a phase-contrast system. (Figure 1 shows the recommended items).

1 Basic Microscope Body

The body of the microscope should have a binocular head. This enables the microscopist to examine the sample through two eyes, which reduces visual fatigue from long-term counting. The fine-focus mechanism should have very little free movement, since it will be used to examine minute detail which involves a heavy reliance on fine-focussing.

2 Eye Pieces

Huygenian type eyepieces are recommended. The reticle (to be discussed) can be placed on an aperture shelf inside the eyepiece and will have an ideal field area compared to the view. Wide field eyepieces are highly undesirable because the field area is too small in comparison to the field of view. Some high quality objective lenses (apochromats, fluorites) require compensating eyepieces (Huygenian types are available).

3 Reticle

The Porton reticle is placed inside the eyepieces. It is a glass disc which contains a rectangle and measuring scale.

4 Stage

A mechanical stage is necessary for positioning the slide. Two knobs control movements in the X and Y directions for scanning the sample.

5 Illumination

Koehler illumination is required for phase-contrast observation. Illumina-

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tion systems may be built into the microscope or purchased as a supplemental unit. The illuminator should have a ribbon filament (or at least a flat-wound coil). The illuminator should have a focusable lens system which projects an enlarged focussed image of the filament onto the substage (microscope) condenser iris. The illuminator must have a field iris, the image of which is focussed in the plane of the sample (Figure 2).

6 Condenser

The microscope should be equipped, at least, a Zernike, Heine, or Abbe condenser containing an adjustable iris diaphragm and annular diaphragm.

7 Objective Lens

The objective should be approximately 4 mm in focal length (40-45X) and have a numerical aperture of at least 0.65. It must be positive (bright field) contrast. (When several grades of contrast are available, purchase the highest).

8 Annular-Ring Diaphragm

The condenser must contain an annular-ring diaphragm which corresponds to the objective.

9 Telescope

Microscopes which do not contain a Bertrand lens require a phase-ring centering telescope. Its use permits observation of the back focal plane of the objective, enabling the microscopist to critically center (make concentric) the phase-contrast elements.

10 Filter

A green filter is preferred for a phase-contrast system since the optical design is based on the wavelength of green light. Also, since the human eye is most sensitive to green, less eye-strain is encountered. Beyond that, the red tint produced in poorer lenses is blackened by the filter, producing heightened contrast.

Note: The microscopist can buy a phase-contrast kit from most manufacturers. This usually consists of a 10X, 40X and 90X objective, an Abbe condenser having a wheel containing appropriate annular-ring diaphragms for all objectives, a phase ring centering telescope, and a green filter. Since certain sample may warrant observation at magnifications other than that needed here, it is to the microscopist's advantage to purchase the kit.

III SAMPLE MOUNTING

A field monitor is used for the collection of the sample. This unit consists of three plastic sections with the filter and support pad retained between the middle and bottom sections (Figure 3). After the sample has been collected, the next process is the preparation of the filter for analysis.

A Mounting Equipment

Experience has shown that certain equipment is useful for efficient sample mounting. The following items are recommended for extracting and placing a portion of the filter upon the slide. (Figure 4)

1 Scalpel: A scalpel or scissors is needed to remove a portion of the filter. Either a pair of micro-scissors or a number-ten-curved-blade scalpel works best.

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

3 Slides: One inch by three inch glass slides are most commonly used. Sample number, data, initials, etc. can be conveniently written on a frosted end slide.

4 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 thickness

used is dependent on the correction factor built into the objective. Nearly every 4 mm phase contrast objective is optically corrected for a number one and one half (. 17 millimeter) thickness cover slip. Therefore, improper cover glass thickness will detract from the final image quality.

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

6 Glass Rod: 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 hinders contamination of the solution. A glass rod is included for dispensing the solution.

B Mounting Procedure

A very important part of the sample evaluation is the mounting process. This process involves a special mounting media of prescribed viscosity. The viscosity is designed so as to expedite filter clearing and hamper particle migration. Once the sample has been mounted, an elapsed time of approximately fifteen minutes is needed before the sample is ready for evaluation.

1 Preparation of the Mounting Solution

The mounting solution consists of two chemicals, dimethyl pthalate and diethyl oxalate, which are combined in a one to one ratio by volume. These chemicals are poured into a Wheaton balsam bottle. Five hundredths of a gram of clean filter material per milliliter is added to reach the prescribed viscosity. It will be necessary to stir the solution until the filters have dissolved and a homogeneous mixture is formed. Twenty milliliters of mounting solution will prepare approximately three hundred samples. The normal shelf life of the mounting solution is about six months, after which time fiber-shaped crystals may begin to form. The crystallizing process can be retarded by keeping the solution in the Wheaton balsam bottle and in a cool place.

2 Sample Mounting

Keep in mind that cleanliness is important! A clean working area will help achieve better results. The following steps should be followed when mounting a sample:

Step 1

Clean the slides and cover slips with lens tissue. Remember to lay the slide down 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.

Step 2

Wipe all of 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 or scissors should be wiped clean before cutting each sample.

Step 3

Using the glass rod which is supplied with the Wheaton balsam bottle, drop a small amount of mounting solution onto the center of the slide. Do not touch the slide with the rod, this can contribute to the contamination of the mounting solution. It may be necessary to make adjustments on the quantity of solution which is used. The correct amount will result in the solution extending only slightly beyond the filter boundary. If the quantity is greater than this, particle migration will occur.

Step 4

Using 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.

Step 5

Separate the middle and bottom sections of the field monitor case, exposing the fragile filter. Cut a triangular wedge from the filter using the scalpel or microscissors. The size of the wedge should approximate one-eighth of the filter surface.

Step 6

Using the tweezers, grasp the filter wedge in the area which was sandwiched by the monitor case sections. Place the wedge, sample side up, upon the mounting media.

Step 7

Using tweezers, pick up the cover slip and place it on the filter/media combination. Press lightly on the cover until it makes contact with the now-dissolving filter. Once this contact has been made, do not reposition the cover slip.

Step 8

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

Step 9

The sample should become transparent after about fifteen minutes. If the filter appears cloudy, it may be necessary to again press lightly on the cover slip.

Step 10

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

IV CALIBRATION

The asbestos dust count procedure consists of judging fiber length by comparison with calibrated circles, and counting all fibers of a certain size within a certain field area. This is done with the use of a Porton reticle (Figure 5). The Porton reticle is a rectangle consisting of two squares. The square on the left, divided into six rectangles, is the counting area. The square on the right contains a logrithmic scale which extends the measuring range beyond that of the circles.

The Porton reticle is easily placed inside a Huygenian-type eyepiece where it rests on the built-in aperture. A split ring is included with the reticle to aid mounting when there is no aperture present. In certain eyepieces, the aperture may be moved up and down making it possible to slightly vary the magnification. The reticle should be kept clean, since dirt on the reticle is in focus may complicate the counting and sizing process.

The Porton reticle is useless for counting unless it is properly calibrated with a stage micrometer. A stage micrometer is a glass slide with a scale unit which can be seen only under a microscope. Most stage micrometer scales are about two millimeters long and are divided into units of one-hundreth of a millimeter or ten microns. (See Figure 6 calibration of Porton reticle with stage micrometer). Before calibrating, the microscope must be set up according to the manufacturers directions.

The microscopist may find the following will hold true for most microscopes. The enlarged image of the illuminator's filament must be focussed either on the condenser's fully closed iris or at the back focal plane of the objective lens. It is important that the phase-shifting element ring and annular diaphragm be concentric. Most microscopes have centering controls which allow manual correction if necessary. Next, close the illuminator's field iris, and focus the condenser's image in the sample's focal place.

Each eyepiece-objective-reticle combination on your microscope must be calibrated. Should any of the three be changed (disassembly, replacement, breakage) the combination

should be re-calibrated. For proper calibration, the following procedure should be closely followed.

With the 10X objective in place, put the stage micrometer on the mechanical stage focus, and center the image. Change to the 4 mm (40-45X) objective and adjust the first scale division to coincide with the left boundary of the porton rectangle. Count the number of divisions from here to the right boundary of the rectangle, estimating any portion of the final division. (See Figure 6) This measurement represents two hundred "L" units. Divide by 200 to find "L". This unit is inserted into the formula $D = L\sqrt{2^N}$ where "D" is the circle diameter, "L" is the unit of length, and "N" is the circle number (indicated on the reticle). Since the circle diameters vary logrithmically, 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. After all of the circle sizes have been determined the field area must be calculated $(100L)^2$. This completes the reticle calibration for this specific objective - eyepiece - reticle combination. Figure 7 shows a calibration card containing information on three objective lenses and an illustration of a Porton reticle.

V COUNTING AND SIZING

Place the slide in 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 microns of the filter surface. When counting and sizing, frequent use of the fine focus control will help to insure that nothing is missed. Start counting from one end of the wedge and progress in a straight line to the other end (count in either direction from circumference to wedge tip). To determine the average fiber deposition per field it is necessary to examine twenty random field areas or one-hundred fibers whichever is last. Random fields are selected, without looking into the eyepieces, by slightly advancing the slide with the mechanical stage control. A field area is the left half of a Porton reticle (rectangles one through six in Figure 5.

The following rules are necessary to achieve comparable results.

Rule 1

Only size fibers with greater than or equal to a 3:1 aspect ratio.

Rule 2

Only count fibers greater than five microns in length. (Be as accurate as possible in sizing fibers near the five mirror cut off)

Rule 3

Count and size fibers inside the field area.

Rule 4

Size and count fibers which cross two pre-selected adjacent sides and have one end inside the field area.

VI CALCULATION OF CONCENTRATION

Asbestos dust concentration may be calculated from the following formula:

$$C = \frac{(A.F.C. - B.A.F.C.)(\text{Filter Area})}{(\text{Field Area})(\text{Volume})(1000)}$$

C Concentration in fibers/milliliter

A.F.C. Average fiber count for twenty field areas

B.A.F.C. Average fiber count of blank or control filter. (It is subtracted to eliminate the error of background contamination.)

Filter Area

855 mm for 37 mm diameter (the portion of the Millipore filter which is exposed when mounted in the field monitor case).

Field Area

The area of the counting field in a calibrated Porton reticle expressed in mm^2.

Volume

Samples air volume (flow rate X time)

1000 Converts liters to milliliters

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