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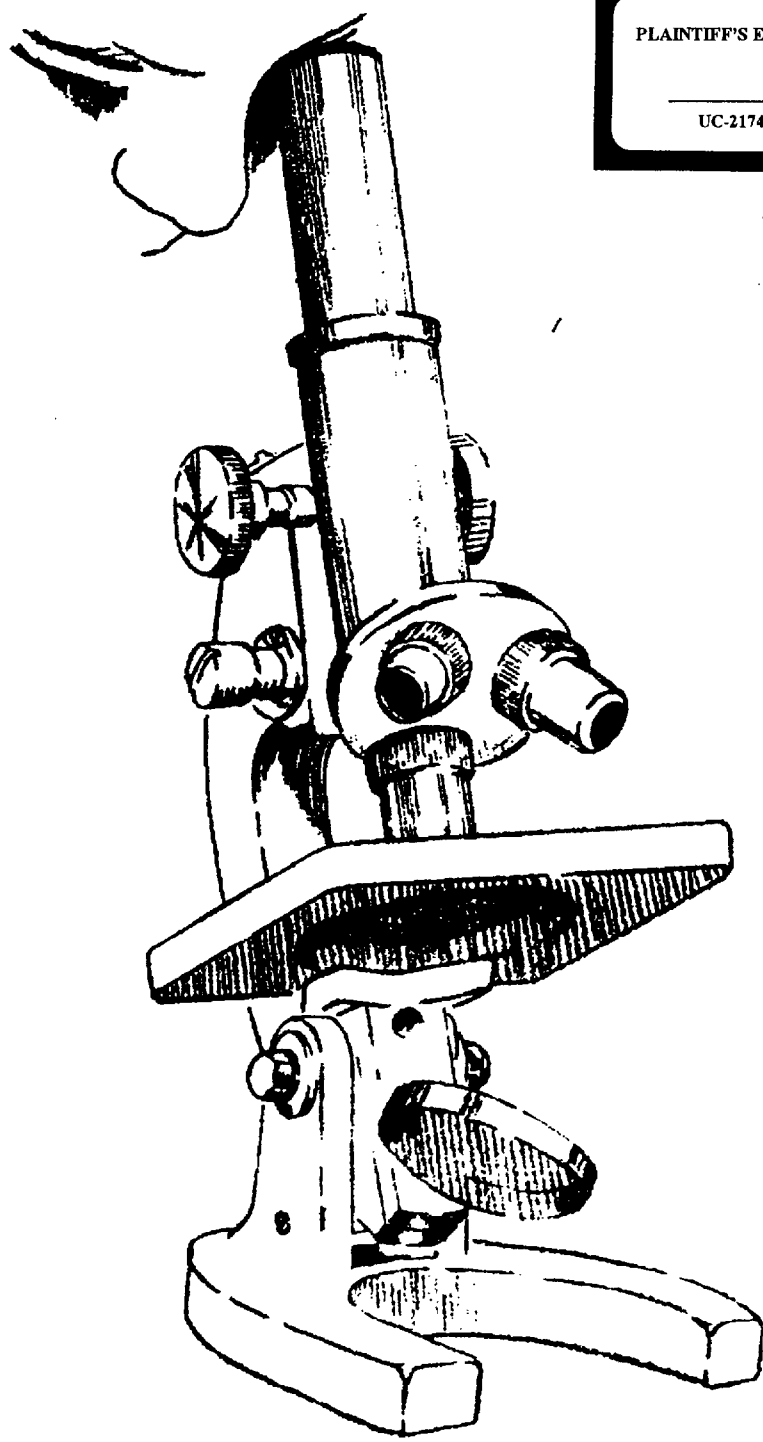
Evaluating Airborne Asbestos Dust

PLAINTIFF'S EXHIBIT

UC-2174

Ralph Zumwalde,

Engineering Technician



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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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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

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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, with an 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 samples 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

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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

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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

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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 $D = L\sqrt{2N}$ 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 ($100\ L^2$). 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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SPECIFICATIONS FOR PHASE CONTRAST MICROSCOPES

FOR

ASBESTOS COUNTING

1. Microscope body with a binocular head and a fine focus accuracy of .005 mm.
2. Binocular with 10X Huygenian eyepieces
3. Porton reticle
4. Mechanical stage
5. Koehler illumination (preferably built in and having provisions for adjusting light intensity)
6. Abbe condenser with an adjustable iris, Zernike, Abbe, Heine
7. 40 - 45 X (.65 -.75 N.A.) Positive (bright field) phase-contrast objective
8. Annular ring condenser diaphragm (corresponding to the objective)
9. Phase ring centering telescope
10. Green filter, Stage Micrometer

Note: Most manufacturers sell a basic body unit and built-in illumination system as a unit.

Phase-contrast accessories can usually be purchased as a kit usually consisting of a 10X, 40X and 90X objective, an Abbe condenser containing appropriate annular ring diaphragsm, a phase ring centering telescope, and a green filter. It is to the microscopist's advantage to purchase the kit.

A list of manufacturers of phase-contrast microscopes is given here to aid in selecting a proper instrument.

Bausch and Lomb
Scientific Instrument Division
72624 Bausch Street
Rochester, New York 14502

E. Leitz Inc.
Rockleigh, New Jersey 07647

Olympus Microscopes
Micro Optics Company
28165 Greenfield
Southfield, Michigan 48075

Unitron Instrument Company
Microscope Sales Division
66 Needham Street
Newton Highlands, Mass. 02161

Nacker Instruments
Box 646
West Caldwell, New Jersey 07006

Niko Inc.
Instrument Division
Garden City, New York 11530

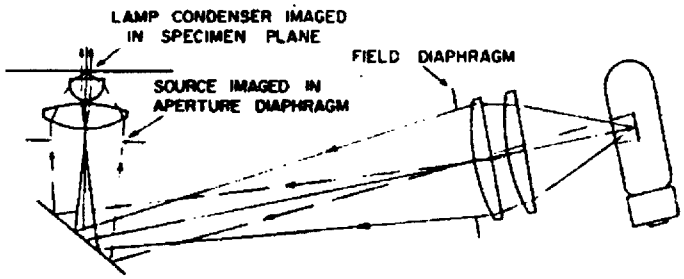
American Optical Corporation
Reichert Products
Buffalo, New York 14215

Carl Zeiss
444 Fifth Avenue
New York, New York 10018

Figure 1

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KOEHLER ILLUMINATION

Figure 2

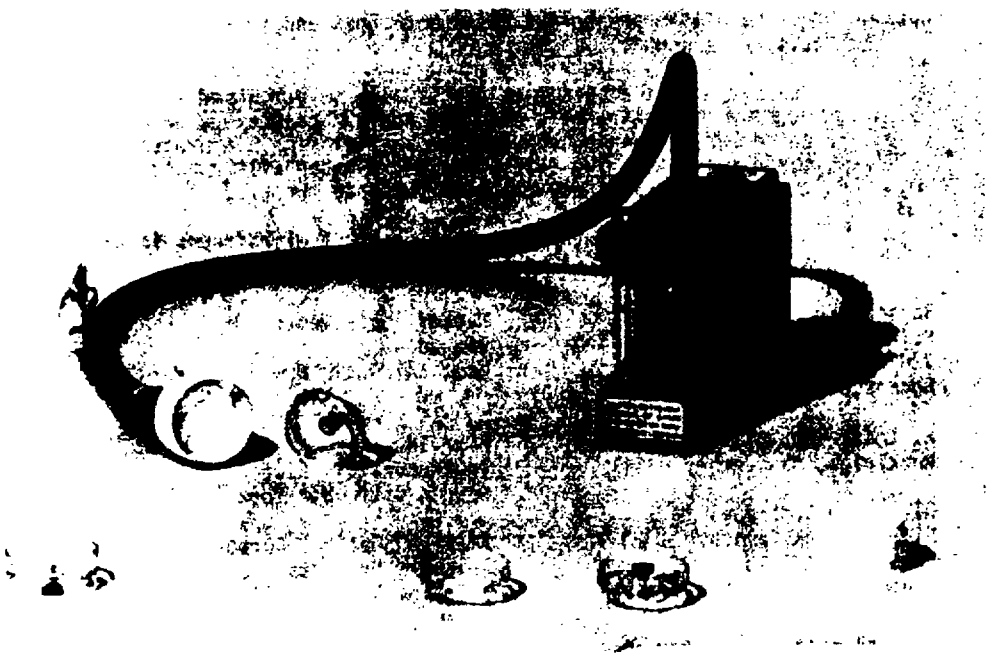


Figure 3

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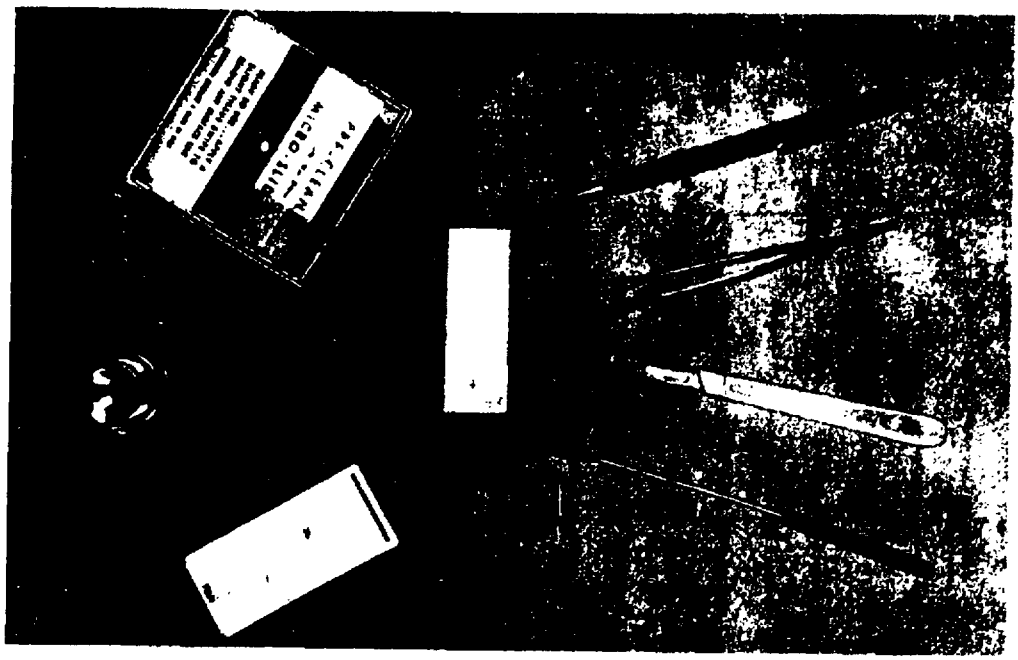


Figure 4

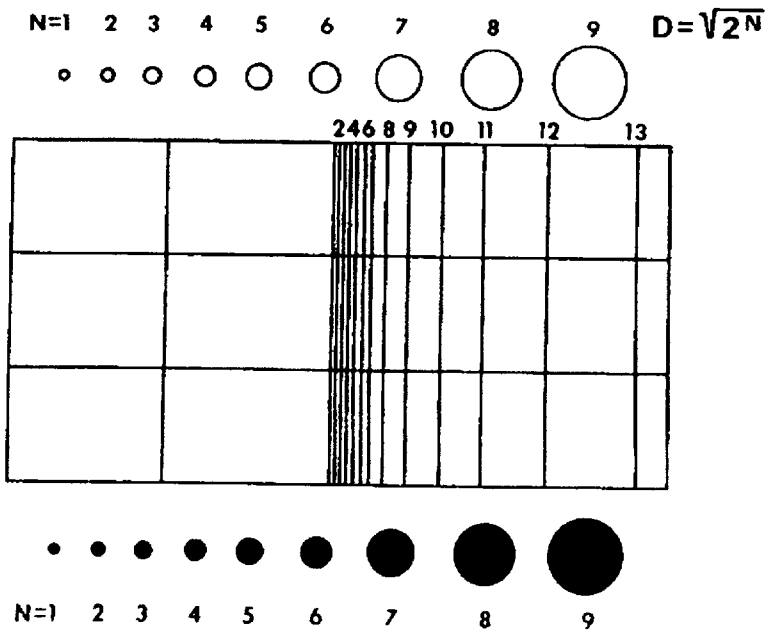


Figure 5

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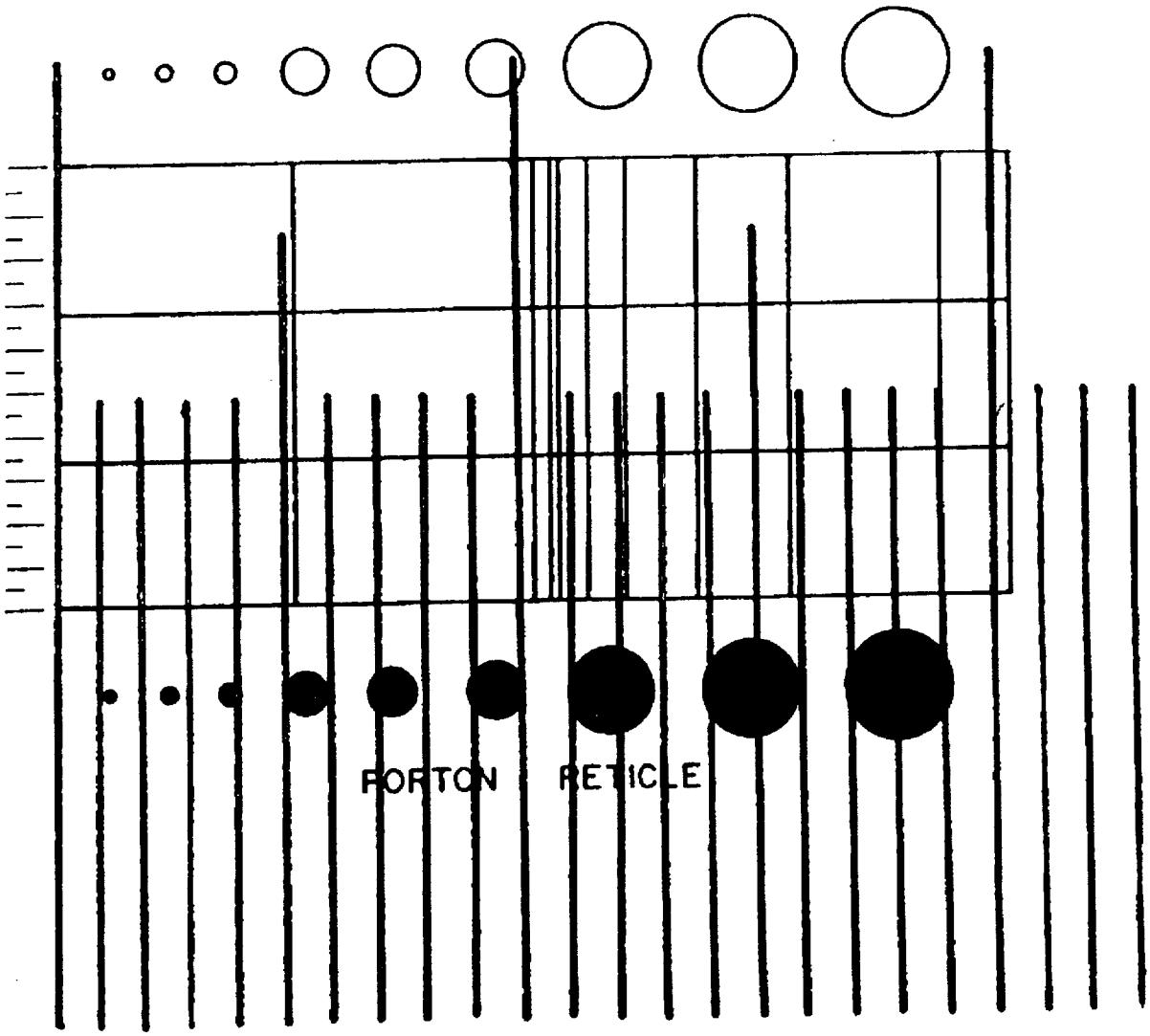


Figure 6

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#1642 B & L Dynoptic 10x Huygenian Eyepieces
by R. Zumwalde 12/10/71

	10x	43x	97x
200L	0.632mm	0.148mm	0.065mm
100L	0.316	0.074	0.0325
1L	0.00316	0.00074	0.000325
Diam. Circle #1	4.46μ	1.05μ	0.46μ
2	6.32μ	1.48μ	0.65μ
3	8.92	2.10	0.92
4	12.64	2.96	1.32
5	17.84	4.20	1.84
6	25.28	5.92	2.64
7	35.68	8.40	3.68
8	50.56	11.84	5.28
9	71.36	16.80	7.36
10	101.12	23.68	10.56
11	142.72	33.60	14.72
12	202.24	47.36	21.12
13	285.44	67.20	29.44
Field Area	0.0998mm	0.0055mm^2	0.00106mm^2

Figure 7

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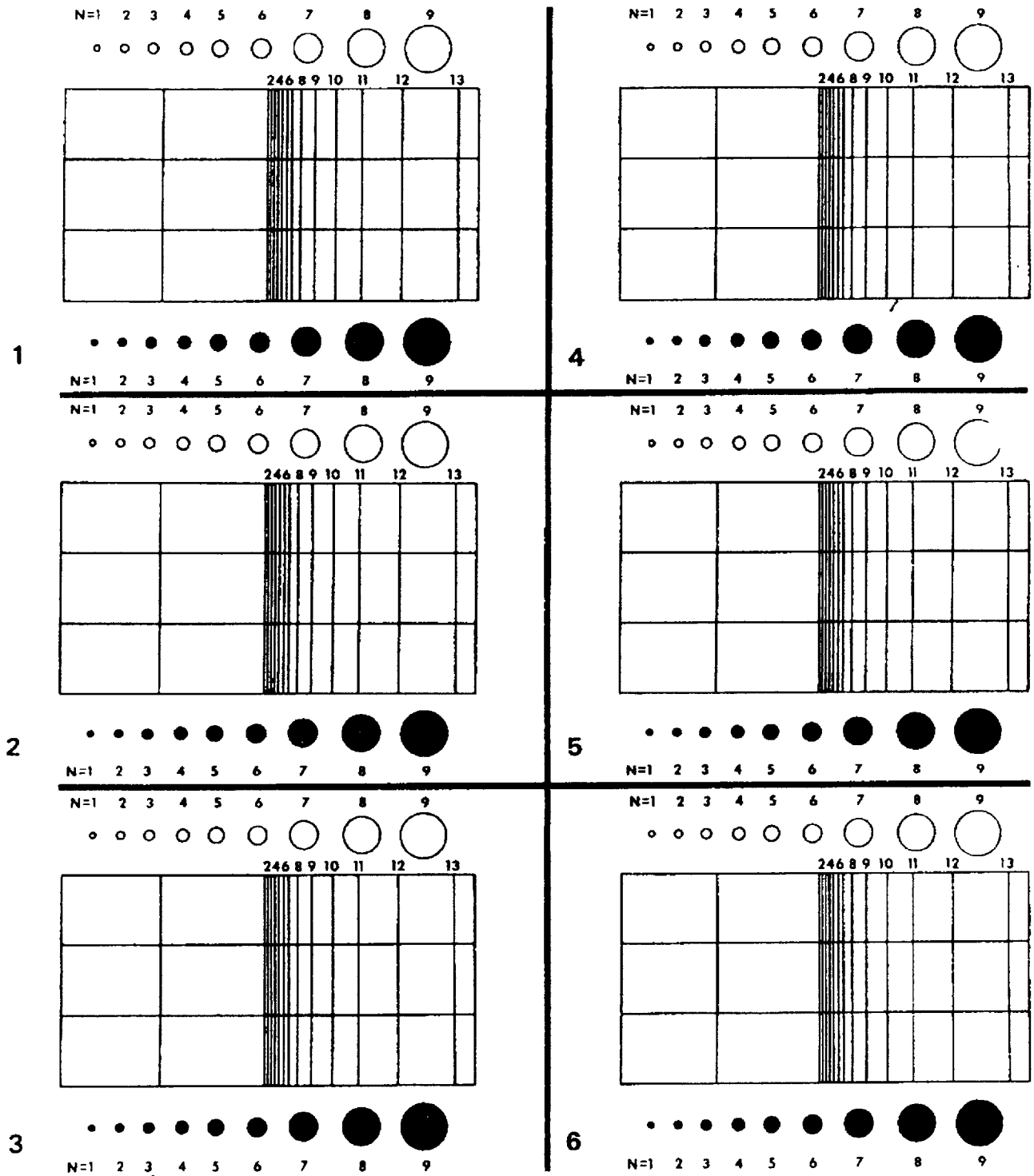


Figure 8

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ADDRESSES

Millipore Field Monitor Cases 50/box. Complete with filters. Catalog # MAWP 037AO

Millipore Filter and pads 100/box.
Catalog # AAWP 03700

Field Monitor Cases for 50/box, 37 mm filters - empty
Catalog # M00037AO

Millipore Corporation
Bedford, Massachusetts 07130

Wheaton Balsam Bottle. Catalog # 2244

Arthur H. Thomas & Company
Post Office Box 779
Philadelphia, Pennsylvania 19105

Porton Reticle, Catalog # 30084

Microscope Stage Micrometer, 0.1 & 0.01 mm divisions

Edmund Scientific Company
701 Edscorp Building
Barrevgton, New Jersey 08007

Rubber Tubing, 1/4" bore, 3/32" wall. Catalog # 57970-25

Matheson Scientific
12101 Centron Place
Cincinnati, Ohio

Adapters, hose end for 1/4" tubing to male luer slip
Catalog # LH/L

Becton, Dickinson & Company
Rutherford, New Jersey

White, opaque, cellulose bands, 41 x 25, #28

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

Spring Clip, #1140

John F. Maguire Company
121 Bacon Street
Pawtucket, Rhode Island 02860

UCC 006981

Union Carbide trial exhibit UC-2174: S. G. Bayer and R. D. Zumwalde, Evaluating Airborne Asbestos Dust: Membr… Published by AsbestosClaims.Law
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Nylon Band 1/2"

Plastic Services & Supply Company
Alexandria, Virginia

PERSONAL PUMPS:

1 Wilson Casella, 13030/1 MKII

Wilson Products Division
Reading, Pennsylvania

2 Monitaire Sampler, Model G 456058

Mine Safety Appliances Company
Pittsburgh, Pennsylvania

3 UNICO Telematie Model C-110 or 3900-10

UNICO Environmental Industries
Fall River, Massachusetts

4 Model 3600-10

Bendix Environmental Science Division

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.

UCC 006982

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asbestosclaims.law/library/17188/19

WV-0088 # 18

TABLE I

RESULTS OF AIR SAMPLING FOR ASBESTOS FIBERS DURING ADDITION OF ASBESTOS TO POLYSULFONE RESIN

Sample	Location	Sampling Time, Min.	Time Start	fiber/ml. >5μ in length
B-1	On platform in front of exhaust hood for feed hopper	10	10:55 A.M.	>0.1
B-2	Same location as B-1	20	10:55 A.M.	>0.1
S-1	Directly in front of screw conveyor approximately 20" from conveyor exit, 3' above floor level	12	3:47 P.M.	>0.1
S-2	General area around the feed hopper	15	4:25 P.M.	0.2
S-3	Operators breathing level while opening 2 bags of asbestos and dumping into the fiber pack	3	4:31 P.M.	3.4
S-4	Side of screw conveyor where dust has been deposited on equipment due to draft from open doorway	3	4:51 P.M.	>0.1
S-5	General area around feed hopper and fiber pack	23	5:02 P.M.	0.3
S-6	Same as S-5	10	5:02 P.M.	>0.1