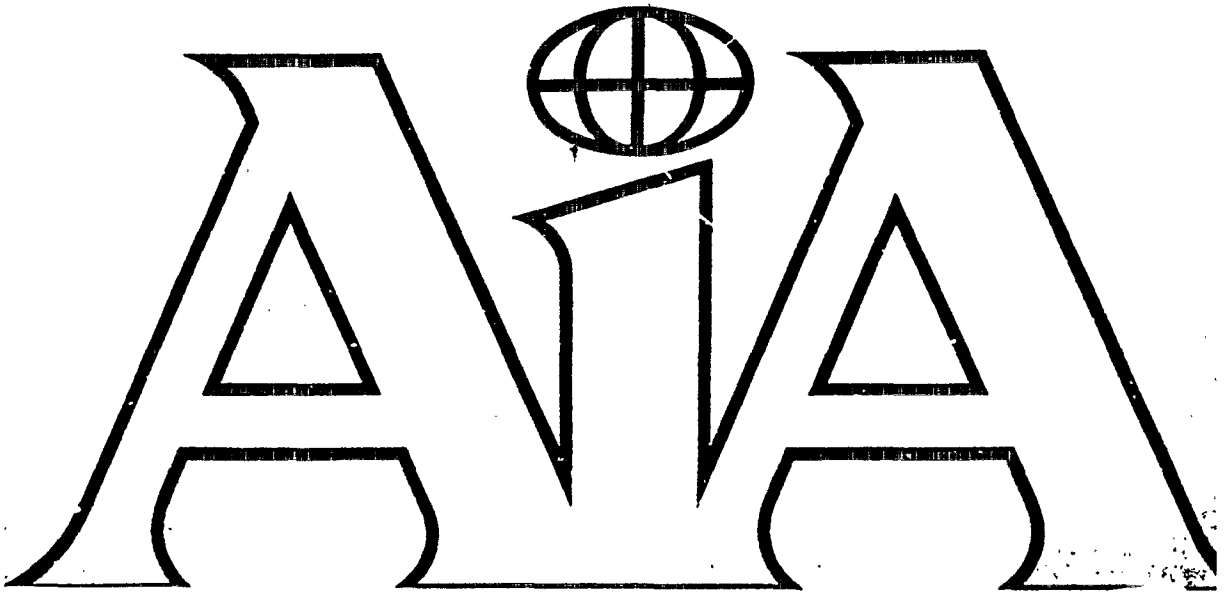
REFERENCE METHOD for the determination of Airborne Asbestos Fibre Concentrations at workplaces by light microscopy (Membrane Filter Method)



INTRODUCTION

The prime object of this Association is to encourage and facilitate the endeavours of its members to eliminate risks to health, occupational and environmental, arising from the use of asbestos.

Many countries have official regulations and guide lines which producers, manufacturers and consumers are required to observe in order to prevent such risks occurring, and progressively the standards stipulated are being achieved. In the course of applying these requirements much practical experience has been acquired, and the interchange of such knowledge and the maximising of control techniques is seen as the principle means by which our members can attain our prime objective.

There are still areas where official guidance has not been provided, and others where the problems of applying statutory requirements are new and may appear formidable. The Asbestos International Association believes that it has an opportunity and a responsibility to provide what help it can to those concerned with this problem from the wide experience of its members, and has decided therefore to produce a series of advisory publications for this purpose.

We wish to remind readers of two important points. First, in considering any recommendations in the AIA publications these should be related to the specific legal requirements in the country concerned. It is clearly not possible in such publications to relate the recommendations in every respect to the specific detailed regulations in each state. Nevertheless, the greater part of existing laws on the subject calls for similar forms of control and where no official regulation exists we advise that action should be based on the recommendation of the ILO meeting of experts on the safe use of asbestos, December 1973.
Secondly, the development of techniques of control is a continuous process, and we hope that the efforts we are undertaking will help to accelerate the process. Techniques which are recommended have reached their present stage as a result of interchange of ideas and practical experience between international experts in the asbestos industry, plant manufacturers, government agencies and many others. It will certainly be necessary regularly to up-date and amend these publications in the light of new ideas and criticisms. All such will be welcomed and will be given full consideration during revision stages.

Asbestos International Association
68 Gloucester Place,
London W1H 3HL, England.
Telephone: 01-486 3528
Telex: 298618 INTA G

7 September 1979

AIA Health and Safety Publication
Recommended Technical Method No.1 (RTM1)

SUPPLEMENT

It is intended that this Supplement will give guidance on the availability of the various items of equipment necessary to implement the AIA asbestos dust measurement procedures. This Supplement will be reprinted at certain intervals so that information on the equipment can be updated.

FILTER

— Membrane filter (mixed ester cellulose) — 25 mm diameter — pore width 1.2 µm — with grid
Suppliers: Gelman Instrument Company, Laboratory Products Division, 600 South Wagner Road, Ann Arbour, Michigan 48106, U.S.A. Product-no. 46000

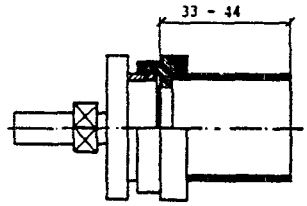
Millipore Corporation, Bedford, Massachusetts 01730, U.S.A. Order-no. RAWG 02500

FILTER HOLDER AND COWL

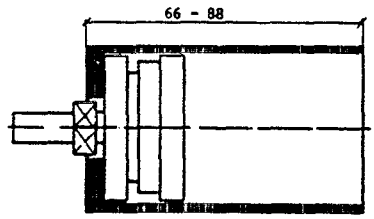
— Filter holder — 25 mm diameter
Supplier: Gelman Instrument Company, Laboratory Products Division, 600 South Wagner Road, Ann Arbour, Michigan 48106, U.S.A. Product-no. 1107

For measurement procedure apply cowl. Cowl for above filter holder is not available. Manufacture is possible according to following sketches:

Sketch 1



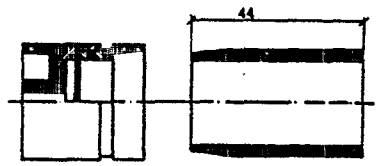
or Sketch 2



— Filter holder (monitor) — 25 mm diameter
Supplier: Millipore Corporation, Bedford, Massachusetts 01730, U.S.A. Order-no. M 0000 25 AO (without filter) Order-no. MRWG 025 AO (with filter; specification see Section FILTER) Available from 1 January 1980

For measurement procedure apply cowl. Cowl for above filter holder is not available. Manufacture is possible according to following sketch:

Sketch 3



PUMPS

Due to pulsation-free operation and easy portability, preference is given to

— Personal Air Sampler Type C 2000
Supplier: Rotheroe & Mitchell Ltd., 14 Aintree Road, Perivale, Middlesex, UB6 7LJ, England

Further acceptable pumps are:

— Super Sampler BDX 44 as well as BDX 30
Supplier: Bendix Corporation, Lewisburg Plant, Drawer 831, Lewisburg, West Virginia, U.S.A.

— Personal Dust Sampler T 13051/2
Supplier: C. F. Casella & Co. Ltd., Regent House, Britannia Walk, London N1 7ND, England

— High Flow Sampler Model P 2500
Supplier: E. I. du Pont de Nemours & Co. (Inc.), Fabrics and Finishes Department Applied Technology Division, Brandywine Building 4300, Wilmington, Delaware 19898, U.S.A.

— MSA-Pump Type G
Supplier: Mine Safety Appliances Company, 400 Penn Center Boulevard, Pittsburgh, Pennsylvania, U.S.A. Catalogue-no. 456058

Asbestos International Association
68 Gloucester Place,
London W1H 3HL, England.
Telephone: 01-486 3528
Telex: 298618 INTA G

22 October 1979

— ERRATA

Section

Contents: Appendix G should read: "Microscope Adjustment Procedure"

4.2.2: Last two lines of 1st Paragraph should read: "cautions presented in sections 4.2.3 and 4.2.4."

4.3.5: 2nd paragraph, 2nd sentence should read: "If the difference is greater than 10 per cent from the initial flowrate, the sample must be rejected."

5.4.1: 12th line (a): "see Appendix G" should be "see Appendix E"

5.4.2: — 6th line: C_{TW} not G_{TW}

— 13th line should read: "If the Single Sample Durations (t_i) . . ."

5.4.3: Before Example 1 should be inserted (indent from margin): "where C_{TW} (full shift) is the time weighted average concentration for the full working shift. This is equal to the calculated C_{TW}, provided that representative conditions apply as described in Section 4.2.2."

5.4.3.2, TYPE E, 3.:

— 1st and 2nd lines should read: "Calculate the empirical logarithmic standard deviation (s_l) of the . . ."

— both formulas should read:

$$s_l = \sqrt{\frac{1}{n-1}\left[\sum y_i^2 - \frac{1}{n}(\Sigma y_i)^2\right]}$$

or

$$s_l = \sqrt{\frac{1}{n-1}\left[y_1^2 + y_2^2 + \ldots + y_n^2 - n(\bar{y})^2\right]}$$

5.4.3.2, TYPE E, 4:

Formula should read:

$$C_{TW} = \text{Exp}\left[\bar{y} + \frac{s_l^2}{2}\right]$$

5.4.3.3: TYPE F on next column belongs in its contents to this section

6.5: First paragraph, 4th line "theoretically" should be changed to "theoretical"

Appendix B:

— Insert at the end of Step 9:

"*Note:* Theoretically, the water vapour content in the soap film flow meter air should be taken into consideration in determining the 'true' flowrate. However, for practical purposes acceptable accuracy is maintained without this correction."

— Change formula in last paragraph as follows:

$$Q_c = \frac{V}{\bar{t}} = \frac{1000}{63{\cdot}4/60} = 946 \text{ ml/min.}$$

Acknowledgements:

— CANADA, 3rd address should read:

Mr. Jean Marc Lalancette
Bureau de L'Amiante
845 ouest, Boul. St. Cyrille,
Quebec

— UNITED KINGDOM, 6th address should read:

Mr. A. L. Rickards*
Turner & Newall Ltd.
Asbestos Fibre Laboratory
P.O. Box 22
Trafford Park
Manchester M17 1RU

AIA Health and Safety Publication
Recommended Technical Method No.1 (RTM1)

REFERENCE METHOD for the determination of Airborne Asbestos Fibre Concentrations at workplaces by light microscopy (Membrane Filter Method)

CONTENTS

Prepared by the Dust Measurement Advisory Panel of the Asbestos International Association

1. PREFACE

Airborne asbestos fibre concentrations of all types* in the working environment are generally determined by the Membrane Filter Method but experience has shown that this method does not always produce comparable results when used by different laboratories and by different workers. Differences can arise due to variations in sampling, preparation of the slide, optical counting, the calculation of the results and other influential factors. International comparisons of dust measurements for epidemiological studies are only feasible if agreement can be reached concerning all details of the method.

The "Reference Method for the Determination of Exposure to Airborne Asbestos Fibre Concentration at Workplaces by Light Microscopy" set out in the following pages is an attempt by the Asbestos industry to reach international agreement. It is hoped that the new technical information presented in this document will motivate a review of the various national methods so that results from different countries become more comparable.

*As defined in the United States Department of the Interior's Bureau of Mines information circular 1977 IC 8751 "Selected Silicate Minerals and Their Asbestiform Varieties — Mineralogical Definitions and Identification-characterisations".

2. SCOPE

This method describes the equipment and procedures required for sampling and sample evaluation, necessary to assess personal exposure and the control of occupational environments to airborne fibres which are known to be predominantly asbestos. It should be emphasised that in mixed dust situations the presence of other fibres and fibre-like particles may interfere with the accuracy of counting.

It must also be recognised that the use of this method has limitations when applied to samples containing acicular particles (e.g. talc, gypsum) and consequently should not be implemented without a full qualitative understanding of the sample. There are a variety of analytical methods which can be used to develop a full understanding of complex samples, e.g. polarizing light microscopy, electron microscopy, etc.

All particles complying with the defined geometric conditions (see 5.3.5) are, in the absence of other convincing information, to be considered as asbestos fibres and counted as such, thus ensuring that underestimates of asbestos exposure are minimized.
It is also intended that the procedures described in this document should be used for epidemiology. However, for epidemiological purposes additional methods such as gravimetric, electron microscopic procedures, etc. are required to achieve a complete understanding of occupational exposure.

3. GENERAL METHOD DESCRIPTION

A sample is collected by drawing a measured quantity of air through a membrane filter by means of a battery powered sampling pump. The filter is later transformed from an opaque membrane into a transparent optically homogeneous specimen. The fibres are then sized and counted using a phase contrast microscope. The result is expressed as fibres per millilitre of air, calculated from the number of fibres on the filter and the measured volume of air sampled.

4. SAMPLING

4.1 Terminology

4.1.1 Occupational Sampling
All sampling must be so conducted that the results are representative of the worker exposure to asbestos fibres under typical working conditions for a full shift. Sampling procedures must not interfere with the activities of the worker.

4.1.2 Worker Breathing Zone
In order to estimate worker exposure, samples must be taken in the workers' breathing zone.

The workers' breathing zone consists of a hemisphere of 300 mm radius extending in front of the face, and measured from a line bisecting the ears.

4.1.3 Personal Samples
Personal samples are taken within the workers' breathing zone. Usually the filter is fastened to the jacket lapel of the worker with the cowl (see Supplement) pointing downwards. The worker carries the pump in a belt or a pocket.

4.1.4 Static Samples
Static samples are samples taken at fixed locations. They are not recommended for the measurement of personal occupational exposure to asbestos dust.

Point sources create considerable concentration gradients thus causing the results of static samples to vary considerably over short distances. However, static sampling can be useful if the dust is proven to be uniformly distributed over large areas.

4.1.5 Single Sample Duration
Single Sample Duration is the actual time during which a single sample is collected.

This duration is usually dependent upon analytical requirements (see 4.3.8).

4.1.6 Total Sample Duration
Total Sample Duration is the sum of Single Sample Durations taken during one day (see 4.2.3).

4.1.7 Reference Period
For the purpose of this method, estimates of exposure will be reported on the basis of an eight hour reference period. It is intended that exposure should be calculated as if it had taken place over eight hours.

If a worker is exposed to airborne asbestos dust for more than or less than eight hours, the measured concentration during his working period must be scaled to relate to an eight hour exposure (see 5.4.3), in order to arrive at an estimate of the workers' equivalent eight hour exposure.

4.1.8 Short Term Samples
The Single Sample Duration for a short term sample is less than one hour (see 4.3.8).

The short term sample has been defined because it is necessary to refer to that special case. Unless specified as short term, the samples are assumed to be of at least one hour duration.

4.2 Strategy

4.2.1 General Principles
Occupational exposure measurements are carried out to meet one or both of two major objectives:

1. To assess exposure relative to an occupational hygiene standard and to enable better control measures to be implemented.
2. To provide estimates of exposure for morbidity and mortality epidemiological investigations.

It is well known that dust concentrations vary widely both within a single day and from day to day. Most regulations and hygiene standards require a reliable estimate of exposure on a particular day. It is more useful for epidemiology to spread the sampling effort over a number of days, i.e. less will be known about a single day, but more about the average exposure over a working lifetime. Since sampling must often serve both purposes, the sampling schemes presented in this method emphasize the single day estimate.

It must also be recognised that variations in individual working practices result in a distribution of exposure values within any job group. Consequently data from one person cannot be assumed to be representative of the total job group. Any transfer of data must, therefore, be validated by appropriate relative measurements.

4.2.2 Sampling Schemes
There are a number of different sampling possibilities, some of which are listed for guidance in the following table. As they vary in the degree of usefulness and precision in estimating exposure, the table *must* be interpreted in association with the qualifying conditions and cautions presented in sections 4.2.3, 4.2.4, and 4.2.5.

In planning a sampling scheme, it is important to determine:

- the Estimation Period during which the exposure is estimated,
- the total Sample Duration,
- the number of samples.

To assess a worker's full shift exposure every effort must be made for the samples to relate to a whole working day. Care must be taken to ensure that the sampling period is not biased by abnormal conditions.

Short term samples should be taken at random (statistically) throughout the whole working day. If samples cannot be selected from the entire working day, the measurement results are valid only for the duration of the period from which the measurements were selected. However, relative measurements and reliable professional judgement can sometimes be used to make inferences about concentrations during other portions of the day. Reliable knowledge concerning the operation is essential to make such extrapolations.

Sampling Scheme	No. of Samples per shift	Total Sampling Duration
LONG TERM		
Full-shift consecutive sample(s)		
Type A	2 or more	approximately full shift
Type B	1	approximately full shift.
Partial-shift consecutive sample(s)		
Type C	2 or more	2 hours or greater
Type D	1	1 hour or greater
SHORT TERM		
Random Samples		
Type E	5 or more taken randomly throughout the working day	1 hour or greater
Systematic Samples		
Type F	1 or more plus continuous relative measurement, or 2 or more taken during each separate phase of a cyclical operation	1 hour or greater

4.2.3 Total Sampling Duration and Number of Samples

Sample duration is influenced primarily by the reason for sampling, the level of fibre concentration to be measured, the concentration of non-fibrous dust and the requirements of the analytical method. This may result in more than one single sample being required. The total sample duration should never be less than one hour.

Sections 4.3.6 and 4.3.8 detail acceptable minimum and maximum loadings of fibres on the filter, which dictate the range of possible sampling times for different airborne fibre concentrations.

Samples of short duration may be necessary if high background levels of particulate matter or fibres are present which would prevent accurate analysis.

4.2.4 Reliability of Sampling Schemes

The main strengths and limitations of the various sampling schemes, types A to F listed before, are as follows:

- **Type A Sampling Scheme** (two or more samples covering the full working shift) permits the most reliable estimate of exposure to be made. When several samples are taken, the average of the errors is usually less than the single (percentage) error in a single full shift sample. Sporadic gross errors such as miscalculations, contamination, incorrect sample timing, etc. are more likely to be detected by type A than type B.

  NOTE: Systematic errors must still be taken into account in the normal manner — e.g. flowrate inaccuracy, etc.

- **Type B Sampling Scheme** (one full shift sample) is not as reliable as type A because gross errors can escape detection unless evidence from previous sampling is available on which to base a judgement.
- **Type C Sampling Scheme** (two or more samples covering part of the full shift, i.e. two or more hours but less than full shift) can be satisfactory if the partial shift is representative of the full shift.
- **Type D Sampling Scheme** (one sample, one or more hours but less than full shift) similar to type C except that gross errors may escape detection.
- **Type E Sampling Scheme** (5 or more short term samples, taken randomly throughout the full shift) may give an acceptable indication of exposure but is generally more wasteful of resources and is the least precise of the above schemes. Note that an even poorer estimate results when the "average" dust concentration increases or decreases markedly throughout the day. This scheme should be applied with caution.
- **Type F Sampling Scheme** (several short term systematic samples taken during each separate phase of an operation) can be used by experienced industrial hygienists to characterise a workplace. This approach should not be used indiscriminately, particularly by persons not completely familiar with the process. Nor should it be used to estimate time-weighted-average exposure unless the results are verified by continuous relative measurements or other methods (see 4.2.2).

4.3 Technique

4.3.1 Filter

Membrane filters (mixed esters of cellulose or cellulose nitrate) of 1.2 micrometre pore size with printed grids and a diameter of 25 mm should be used. See Supplement for specifications of suitable filters.

4.3.2 Filter Holder

It is necessary to use an open faced filter holder fitted with a protective cowl (see Supplement).

The cowl helps to protect the filter from accidental contamination. A metallic cowl is preferred to a plastic one because of the possible risk of fibre loss due to electrostatic charge. Filter holders must be thoroughly washed between use.

Due to the design of the filter support utilized in some filter holders a secondary supporting membrane should be used.

The purpose of this secondary membrane is to ensure an even distribution of air passing through the primary membrane.

4.3.3 Storage and Transport

Fixatives must not be used.

Experience has shown that fixing fibres to the filter surface with cytological or other types of fixatives is unnecessary and should not be done.

Filters should be transported in closed holders which should only be opened immediately before use and sealed immediately after.

An alternative is to transfer the filter to a petri dish in the following way: In a dust-free area, using forceps, carefully remove each used filter from its holder taking care to grasp it on its unexposed edge. Place the filter, dust side up, in a plastic petri dish or similar container. Fasten the filter to the bottom of the dish with one or two pieces of adhesive tape attached to the unexposed edge. After transporation, the filter can be removed easily from the dish with a surgical scalpel.

Pack the filter holders or petri dishes into a rigid container with sufficient soft packing material to prevent both crushing and vibration of the filter. Samples should be unambiguously labelled and caution is necessary to ensure that filters cannot be accidentally reused. The filters should not be marked for this purpose because of the risk of damaging the filter.

4.3.4 Sampling Pump

A portable battery operated pump must be used for personal sampling. The capacity of the battery must be sufficient to operate continuously over the chosen sampling time. The flow must be free from pulsation.

As a minimum and tentative criteria there must be no visible vibration of a rotameter float when this flowmeter is connected to the filter holder.

Although some pumps are equipped with pulsation dampers, an external damper may have to be installed between the pump and the filter.

Never run the pump without filter.

Connecting tubing must be constriction-proof and the connections leakproof.

4.3.5 Flow Rate

The flowrate should be adjusted to one litre/minute, i.e. approximately 4 cm/s face velocity.

The flowrate should be checked at least before and after sampling. If the difference is greater than 10 per cent, the sample must be rejected.

If an external flowmeter is used to determine the flowrate of the pump, care must be taken to ensure that the flowmeter does not cause *unknown* changes to the flowrate. Measurement of the "sampling train" flowrate using a soap-film flowmeter, with and without the external flowmeter, is one satisfactory method of determining any change in flowrate.

The flowmeter used should be able to measure flowrate to an accuracy within ± five per cent of the true flow (95 per cent confidence limits).

See Appendix B for flowrate calibration.

4.3.6 Acceptable Fibre Loadings on Filters

- **Minimum Loading**
  The minimum filter loading should exceed 50 fibres/mm² (i.e. approximately 40 fibres/100 Walton-Beckett graticule areas). In special circumstances (e.g. when an indication of concentration with low precision is acceptable) it is permissible to lower the acceptable fibre loading to 20 fibres/mm² (i.e. approximately 15 fibres/100 Walton-Beckett graticule are

  The lowering of the acceptable fibre loading gives, at best, barely acceptable coefficients of variation. The limitations as described in section 6.5 should also be considered when measuring very low fibre concentrations.

- **Maximum Loading**
  Experience shows that the filter loading should not exceed a maximum of five fibres/graticule area (average value for all counted fields) for the majority of sampling situations.

  This may need to be reduced to an average of about one fibre per graticule area when mixed dusts or agglomerates are present, and can sometimes be doubled when only fibres are present. Average filter loadings exceeding 10 fibres/graticule area should be rejected.

4.3.7 Blanks

For each batch of filters used for sampling, and for every 25 filters in the batch, select one unused filter which has been subjected to the same treatment as for normal samples, but without having had air drawn through it, or been attached to the worker. If this "blank" yields fibre counts greater than three fibres/100 graticule areas, the entire sampling and analytical procedure should be examined carefully to find the cause of the contamination. When the blank count exceeds three fibres/100 graticule areas, and also exceeds 10 per cent of the actual sample fibre count/100 graticule areas, the samples represented by the blank are not considered acceptable for assessment of worker exposure. However, the determination may still be useful for indicating compliance with the hygiene standard (e.g. if the estimated exposure is less than that permitted by regulations even with the contamination then this is a conservative estimate of compliance).

For example — the fibre count of a blank filter was 15 fibres/100 graticule areas (i.e. 0.15 fibres/area) while the sample yielded 108 fibres in 90 graticule areas (i.e. 1.20 fibres/area).

$$\frac{\text{Blank count}}{\text{Sample count}} \% = \frac{.15}{1.20} \times 100 = 12.5\%$$

As this percentage exceeds 10 per cent, the sample is rejected. Furthermore, because the blank count exceeded three fibres/graticule area the cause of contamination must be found and corrected.

4.3.8 Recommended Single Sample Duration

Taking into account the filter loading considerations as detailed in section 4.3.6, the sampling duration for each sample may be determined by application of the following simple formula:

$$t = \frac{A}{a} \cdot \frac{L}{c_{exp.}} \cdot \frac{1}{r}$$

t = Single Sample Duration
L = required filter loading in fibres/graticule area
A = effective filter area mm²
a = graticule area mm²
r = flow rate ml/min.
$c_{exp.}$ = average fibre concentration expected to occur during the Single Sample Duration (fibre/ml)

To provide guidance in the selection of Single Sample Duration, the following table lists recommended durations based on two fibres/graticule area. If it is not possible to use these values, the minimum and maximum durations allow a choice to be made whilst still remaining within the constraints of 4.3.6.

	Single Sample Duration		
$c_{expected}$ fibres/ml	$t_{recommended}$(1)	$t_{maximum}$(2)	$t_{minimum}$(3)
0.5	3 hours	8 hours	40 minutes
1	1.5 hours	4 hours	20 minutes
2	45 minutes	2 hours	10 minutes
5	20 minutes	1 hour	4 minutes*
10	10 minutes	30 minutes	2 minutes*
20	4 minutes*	10 minutes	1 minute*

Note: (1) 2 fibres/graticule area
(2) 5 fibres/graticule area
(3) 0.4 fibres/graticule area equivalent to 50 fibres/mm²

**A measured concentration of less than 20 fibres/ml should be discarded because it has little significance if the sampling time is less than 10 minutes.*

Sampling time should be measured accurately.

The timers or counters installed in some pumps are not always reliable.

4.3.9 Sampling Record

All data necessary for the determination of the fibre concentration must be recorded, along with the sampling details. Furthermore, as much data as is available, which can be of value for epidemiological studies, should be included (see Appendix D).

5. EVALUATION

5.1 Sample Preparation

5.1.1 Cleaning Slides and Equipment

Clean conditions should be maintained at all times.

A dirty preparation area may result in sample contamination and erroneous results.

- *Clean slides with lens tissue or industrial paper tissue and lay them on a clean surface, e.g. lens tissue sheet. It is good practice to clean each coverslip with lens tissue immediately before use to ensure that the surfaces are free from contamination.*
- *Wipe scalpel and forceps with lens tissue and place them on a clean surface, e.g. lens tissue. When mounting a series of filters, the mounting tools must be wiped clean before dealing with each sample.*

5.1.2 Filter Sample Cutting

Mounting of the total filter is preferred.

If it is necessary to cut the filter, all cutting should be done with a scalpel using a rolling action. Do not use scissors. It is recommended that the smallest piece mounted be wedge-shaped, approximating to one quarter or one third of the filter.

5.1.3 Mounting the Sample

For mounting use the acetone-triacetin method only as described in Appendix A.

WARNING

Acetone mounting should be carried out only in a fume hood or fume cupboard. On no occasion should it be used in the vicinity of an open flame.

5.2 Optical Requirements

5.2.1 Microscope Equipment

It is recommended that the following specification be used to select a microscope suitable for asbestos dust counting. Because microscopes with identical "specifications" can give quite different performances, it is necessary that the performance of proposed and existing microscopes be assessed by means of "Detection Limit Test Slides" (see Appendix F). It is also important that newcomers consult with experienced workers before selecting microscopes for asbestos dust determination.

- Light Source — Koehler illumination is required.

  It is preferable for the illuminator to be built-in but an external lamp with a plain mirror can be satisfactory. A variable light intensity control is necessary for both methods of illumination.

- Substage Assembly — An Abbé or achromatic phase-contrast condenser incorporated into a substage unit is required.

  There must be a means of centring each condenser annulus with respect to the phase plate in the corresponding objective and a means of focussing the condenser.

- Stage — A built-in mechanical specimen stage fitted with slide clamps and x-y-displacement is required.

- Objectives — A rotating nose-piece fitted with 10× and 40× parfocal phase-contrast achromatic objectives is required.

  The 40× objective must have a numerical aperture (NA) of 0.65, achromatic. It should have a phase ring of not less than 65 per cent and not greater than 85 per cent absorption. Either positive or negative phase-contrast is suitable.

- Eyepiece — Binocular eyepieces of the compensating type are recommended. They should be chosen to give a total magnification of between 450× and 500×, preferably 500×. At least one eyepiece must permit the insertion of a graticule and preferably be of the focussing type. The use of body magnification changers is not recommended.

- Graticule — The graticule recommended for this method is the Walton-Beckett circular eyepiece graticule.

  Its actual diameter when using the 40× phase objective and an appropriate eyepiece should be 100 micrometers plus or minus 2 micrometers. See Appendix E for graticule specification, source of supply and ordering information.

Accessories

- *CENTRING TELESCOPE or Bertrand Lens is essential for checking that the phase rings in the condenser are centred with respect to those in the objective.*
  A green filter is necessary to ensure the best phase contrast conditions because the optics are designed for this wavelength.
- *STAGE MICROMETER — Must be subdivided into 10 micrometer intervals and preferably be one millimeter long.*
  Microscope Slides — Should be of the best quality.
- *COVERSLIPS of thickness to which the microscope is designed (normally 0.17 mm thickness) are essential. Incorrect coverslip thickness will detract from the quality of the final image.*

5.2.2 Microscope Adjustment Principles
Follow the manufacturer's instructions while observing the following guidelines:

- *The image of the light source must be in focus and centred on the condenser iris or annular diaphragm for true Koehler illumination.*
- *The object for examination must be in focus.*
- *The illuminator field iris must be in focus, centred on the sample and opened only to the point where the field of view is illuminated.*
- *The phase rings (annular diaphragm and phase shifting elements) must be concentric.*
- *The eyepiece graticule must be in focus.*

For more detailed information see Appendix G.

Microscope adjustments must be a daily routine.

5.2.3 Eyepiece Graticule Calibration
Each combination of eyepiece, objective and graticule must be calibrated with a stage micrometer. Should any of the three be changed, the combination must be recalibrated. For some microscopes, calibrations will change for observers with different interpupillary distances (see Appendix E for eyepiece graticule calibration procedures).

5.2.4 Microscope/Observer Performance Assessment
Because past experience has shown that significant differences in counts occur due to differences in microscope quality, setting up and cleanliness, it is necessary that laboratories following this method should maintain contact with the AIA.

As mentioned in section 5.2.1, sets of detection limit test slides are available which will assist in the regular assessment of microscope and observer performance. A practical detection limit relative to the test slides, Code-No. 5 or 6 (0.26 or 0.22 µm spheres) should be achieved.

Exchange of microscope slides for comparison with experienced laboratories will help to ensure that valid results are being generated.

5.3 Counting and Sizing Fibres

5.3.1 General
Airborne asbestos dust collected on membrane filters appears in a wide variety of forms ranging from simple single fibres to very complex configurations of fibres or aggregates. When presented with these, the microscopist could experience difficulty in defining and counting the fibre content of a dust sample. The following notes (and drawings in Appendix H) have been prepared to assist and guide the observer in the assessment and interpretation of asbestos dusts collected on membrane filters.

5.3.2 Low Power Scanning
With a total magnification of 100× to 150× (i.e. 10× objective) scan the entire filter area.

The margin normally covered by the filter holder gasket should be free of dust and fibres. All viewing fields should have similar appearances with respect to total dust loading. If the observed fields show marked differences in loading, gross aggregation of fibres or dust, the filter must be rejected.

5.3.3 Graticule Field Selection
After a satisfactory low power scan, change the microscope objective to 40× phase and focus on the dust plane.

Ensure that the phase rings remain concentric. While most of the fibres and dust will be found on the upper surface of the filter, it will be necessary to focus below (say up to 10 micrometers) and slightly above the surface.

When counting and sizing, constant use of the fine focus is necessary because of the small depth of focus of a 40× objective (i.e. two to three micrometers).

Counting fields should be chosen at random throughout the *entire* area of the filter or filter segments.

If the grid of a filter obstructs the view, move the stage to another field.

Do not count fields that lie within 3 mm of the filter edge and within 2 mm of the cutting line.

5.3.4 Laboratory Working Conditions
The working practices and the working environment in a laboratory may influence systematically the accuracy of the actual counting. Some differences may appear when inter-laboratory comparisons are made which are due merely to different laboratory lighting conditions, different seating and computing arrangements, etc. Different practices of recording data may also cause some disagreement between the counters, due to the rate of fatigue of the eyes.

The detailed writing of data involves the re-focussing of the eyes after each field, whereas continuous registering with electrical or mechanical counters involves only a single period of continuous concentration.

This problem of ergonomics briefly stated here can only be dealt with when all the other parameters of the method are fixed.

5.3.5 Counting Criteria

- Designate all particles having the following geometric dimensions as fibres:
  - length greater than five micrometers, and
  - diameter less than three micrometers, and
  - length to diameter ratio greater than 3 : 1.

  Accuracy is important, and full use should be made of known dimensional standards. Estimate the length of curved fibres along the curve of the fibre (i.e. true length).
- When examined microscopically, asbestos fibres fall into four basic groups as follows:
  - Single fibres can be directly classified according to their geometric dimensions.
  - Split fibres are counted as one fibre, according to their geometric dimensions. The diameter of a split fibre is measured across the compact part of the fibre, not across the split part.
  - Grouped fibres are counted individually where individual fibres can be distinguished. Where they cannot be distinguished as individual fibres they are counted as equivalent to one fibre if the bundle has a total diameter less than three micrometers.
  - Fibres attached to particulate matter are counted as one fibre if the diameter of the particle is less than three micrometers, otherwise not.

  Refer to Appendix H for full details.
- The counting rules are based on the principle of counting fibre ends visible within the graticule area and dividing by two to obtain the number of fibres observed.
  - *Count any fibre that lies entirely within the counting area.*
  - *Count as "half fibre" any fibre with only one end lying within the counting area.*
  - *If a single curved fibre has each end inside the counting area having crossed the area twice, each end is still counted as half a fibre.*
- If more than one eighth of the counting field contains an agglomerate of fibres and/or dust, reject the field and select another. Always record such occurrences.
- Count as many fields as are necessary to give a total fibre count of 100. A minimum of 20 fields must be counted, even if more than 100 fibres have been observed. It is not necessary to count more than 100 fields. However, errors will be large when the minimum fibres or fields are not counted (see 4.3.6 for minimum loading requirements).
- All relevant information must be recorded (see Appendix I for an example of a dust counting form).

5.4 Calculation of Dust Concentration and Worker Exposure

When the following calculations are applied, the limitation imposed upon the data by the sampling and fibre counting methods must not be disregarded. Results should not be interpreted or reported with false precision.

5.4.1 Single Values

The fibre concentration for each Single Sample Duration is determined according to the following formula:

$$c = \frac{A}{a} \cdot \frac{N}{n} \cdot \frac{1}{r} \cdot \frac{1}{t} \qquad (1)$$

where:

- c = concentration (fibres/ml)
- N = total number of fibres counted
- n = number of graticule areas observed
- A = effective filter area (mm^2) (see Appendix C)
- a = graticule counting area (mm^2) (see Appendix G)
- r = flowrate of air through filter (ml/min)
- t = Single Sample Duration (minutes)

5.4.2 Time Weighted Average Values

When several samples of different sampling durations are taken calculate the time weighted average values from the single values as follows:

$$C_{TW} = \frac{\sum c_i \cdot t_i}{\sum t_i} = \frac{c_1t_1 + c_2t_2 + \ldots + c_nt_n}{t_1 + t_2 + \ldots + t_n} \qquad (2)$$

- C_{TW} = time weighted average concentration (fibres/ml)
- c_i = single value of concentration (fibres/ml)
- t_i = Single Sample Duration (minutes)
- Σt_i = Total Sample Duration
- n = total number of samples

If the Single Sample Duration (t_i) referred to above are of equal duration, then equation (2) is simplified as follows:

$$C_{TW} = \frac{\sum c_i}{n} = \frac{c_1 + c_2 + \ldots + c_n}{n} \qquad (3)$$

5.4.3 Equivalent eight hour Exposure Value

If the shift of the worker exposed to airborne asbestos dust is more than or less than eight hours, the average concentration during the full shift must be multiplied by a factor (f) to yield the Equivalent eight hour Exposure Concentration (C_{eq}), as follows:

$$f = \frac{\text{full shift time (hours)}}{8 \text{ hours}} \qquad (4)$$

$$C_{eq} = f.C_{TW} \text{ (full shift)} \qquad (5)$$

Example 1:
Daily shift duration 12 hours
Time-weighted-average for the full shift of 1.2 fibres/ml.

Using equation (4): $f = \frac{12}{8} = 1.5$

Using equation (5): $C_{eq} = 1.5 \times 1.2 = 1.8$ fibres/ml

Example 2:
Daily shift duration of 5 hours* with a corresponding shift average of 1.2 fibres/ml.

Using equation (4): $f = \frac{5}{8} = 0.625$

Using equation (5): $C_{eq} = 0.625 \times 1.2 = 0.8$ fibres/ml

*This means that the worker was known to have zero exposure to asbestos outside of his 5-hour shift.

5.4.3.1 Calculation of "C_{eq}" for various Sampling Schemes

Types A, B, C and D

1. Calculate single value concentration(s) for the sample(s) using equation (1).
2. Calculate time-weighted-average (C_{TW}) concentration using the above single value(s) and respective Single Sample Duration(s) in equation (2) (or (3) if applicable).
3. Calculate C_{eq} by using the procedure at 5.4.3.

5.4.3.2 Calculation of "C_{eq}" for Sampling Scheme E

Type E

When 5 or more short term samples are taken randomly throughout a full shift, the time-weighted-average concentration can be estimated as follows:

1. Calculate the natural logarithm of each concentration: $y_i = \ln c_i$, i.e. $y_1 = \ln c_1$, $y_2 = \ln c_2$ and so on. If any concentration is less than 0.1 fibres/ml, replace it with 0.1 fibres/ml for the above calculation.
2. Calculate the arithmetic average of the logarithmic concentrations:

$$\bar{y} = \frac{\sum y_i}{n} = \frac{y_1 + y_2 + \ldots + y_n}{n}$$

3. Calculate the empiral logarithmic standard deviation (s_e) of the logarithmic concentrations (sampling/analytical random errors and environmental fluctuations are included)

$$s_e = \sqrt{\frac{1}{n-1}\left[\sum y_i^2 - \frac{1}{n}(y_i)^2\right]}$$

or

$$s_e = \sqrt{\frac{1}{n-1}\left[y_1^2 + y_2^2 + \ldots + y_n^2 - n(\bar{y})^2\right]}$$

4. The estimate of the average airborne concentration is calculated as follows:

$$C_{TW} = \text{Exp}\left[\bar{y} - \frac{s_e^2}{2}\right]$$

Note: The above calculations are used because available evidence shows that random intra-day variations are best described by a log-normal distribution.

5. Using C_{TW} from above, calculate C_{eq} as in section 5.4.3.

5.4.3.3 Calculation of "C_{eq}" for Sampling Scheme F

Type F

1. Calculate single value concentrations for the samples using equation (1).
2. Calculate the times (T_i) for each individual working phase ensuring that the sum of these phase times equals a full shift.
3. Calculate the time-weighted-average concentration using the phase times (T_i) instead of the Single Sample Duration (t_i) in equation (2).
4. Calculate C_{eq} as in Section 5.4.3.

Note: The above calculations for the different sampling schemes do not imply identical reliability in the estimation of the equivalent 8 hour exposure value (C_{eq}), (see 4.2.3 and 4.2.4).

6. SAMPLING AND ANALYTICAL ERRORS

6.1 General

Errors introduced into the estimation of airborne asbestos dust comprise sampling and analytical errors, each of which has a systematic and random component. The application of standard procedures and a reproducible routine is the only way of controlling most of the many sources of error inherent in the membrane filter method. The following list describes some of the common sources of error.

6.2 Systematic Errors

6.2.1 Sampling

- Flowrate.
- Sampling time.
- Non-representative or biased sampling.
- Contamination — deliberate or accidental.

6.2.2 Analytical

- Effective filter area.
- Counting area.
- Filter mounting.
- Microscope and observers.
- Contamination.

6.3 Random Errors

6.3.1 Sampling

- Flowrate variability.
- Random fluctuations of the airborne dust cloud.

6.3.2 Analytical

- Fibre distribution on the filter.

Non-random deposition of dust on the filter leads to gross errors, the magnitude of which cannot be estimated. Twenty or more fields must be counted to ensure that minor divergence from randomness does not bias the result.

- Poisson errors.

As only small samples of the fibres deposited on the filter are counted, errors arise in the estimation of the total number of fibres on the entire filter face. Theoretically, the Poisson distribution defines the variation in fibre counts resulting from viewing randomly selected counting fields on the filter. If a minimum of 100 fibres is counted, and if a Poisson distribution were appropriate to the counting results, the relative standard deviation of the fibre counts would be ± 10 per cent. It has been shown experimentally that the actual distribution of fibre counts can depart from that of Poisson, in which case the standard deviation may be greater.

6.4 Overall Accuracy

Because of the nature of the membrane filter method, it is not possible to know the "true" airborne fibre concentration of a given dust cloud. For this reason it is not possible to assess the likely accuracy of the method. Even the precision (or repeatability) of the method is difficult to quantify because of systematic errors which tend to arise both intra- and inter-laboratory. Taken as a whole by "randomly" selecting observers and laboratories, these systematic errors take on a random nature such that it may be possible in future to provide estimates of empirical precision (i.e. the closest approach possible to a statement of accuracy for a method with no known "true" values).

Much work has been done in an attempt to arrive at these estimates, and to date only partial conclusions have been reached. One of these describes the theoretical Poisson distribution (see section 6.3.2) as contributing a 95 per cent confidence interval of ± 20 per cent for a total of 100 fibres counted, up to about ± 35 per cent for only 40 fibres counted in 100 graticule areas.

Other sources of random and systematic errors add significantly to the uncertainty in estimating the airborne asbestos dust concentration.

6.5 Limitations of the Membrane Filter Method and Presentation of Results

With the parameters specified in this method, i.e. one litre/minute flowrate and a minimum filter loading of 15 fibres per 100 graticule areas, the theoretically lower detection limit for an eight hour sample is 0.02 fibres/ml; however, the practical limit is much higher.

It is generally accepted that blank, unused filters can frequently give a reading of several countable fibres per 100 graticule areas. These "fibres" may be unidentified contaminents on the filter, or artifacts from the clearing process which have the appearance of fibres.

It must be recognised that neither counting more fields nor increasing sampling duration overcomes the problem of background dust, when asbestos is a minimum constituent in the overall dust cloud.

There is at present insufficient information available to determine at what level the reliability of the method becomes so poor that results have little meaning. It is clear that this will not be a single value, but will be a range depending upon at least the relative and absolute fibre concentration. There appears to be general agreement amongst those experienced in the field, that these limits lie somewhere in the range of 0.1 to 0.5 fibres/ml depending on a variety of conditions. In view of this situation, and the inherent variability of the method, all calculated values of less than 0.1 f/ml should be reported only as "less than 0.1 fibre/ml". All higher values should be rounded off to the first decimal place, and to two significant figures.

Appendix A

Acetone-Triacetin-Mounting Procedure

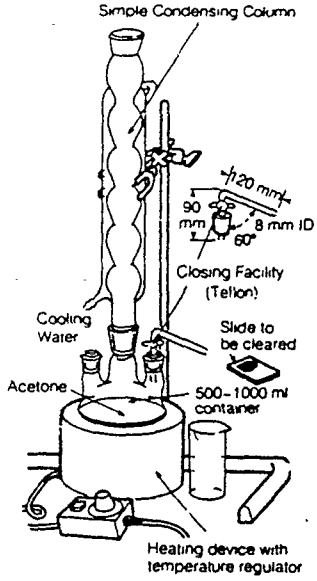
WARNING

Acetone mounting should be carried out only in a fume hood or fume cupboard. On no occasion should it be used in the vicinity of an open flame.

- A hot plate, or waterbath, or heating mantle, complete with energy regulator, or even an infant's bottle warmer can be used to heat the acetone. An effective method is an infra-red lamp. The lamp can be moved closer to, or further from the flask so that the acetone can be boiled gently.
- As illustrated in the diagram below, it is advisable to use a simple condensing column to ensure that a bare minimum of acetone vapour escapes.

  When not in use, the acetone vapour outlet should be plugged.
- Heat the acetone to boiling and wait until a moderate quantity of acetone vapour is emerging from the outlet.
- Place the filter dust side up on a clean microscope slide at room temperature — electrostatic forces usually keep the filter on the slide.
- Ensuring that no liquid acetone drops on the filter (by wiping the outlet periodically with a tissue), hold the slide with clean forceps directly in the acetone vapour stream approximately 15 to 25 mm from the outlet for three to five seconds. At the same time move the filter slowly across the outlet to ensure even coverage until the filter is transparent. Too little vapour will fail to render the filter transparent, while too much vapour (especially drops of liquid acetone) will destroy the filter by dissolving it or shrinking it beyond use. The slide must not be prewarmed, as the acetone vapour must condense on the slide for correct clearing.
- Using a hypodermic syringe with a 22 gauge needle, place one to three drops of glycerol triacetate (Triacetin) on the acetone cleared filter. To avoid the development of a "skin" over the Triacetin, immediately lower at an angle (see diagram below) a clean coverslip onto the Triacetin. The coverslip should not be pressed onto the membrane.

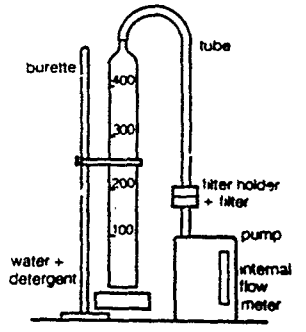
- Too much Triacetin (as indicated by excess liquid emerging from the edges of the coverslip) can cause the outside edge of the filter eventually to disintegrate to some degree. Insufficient Triacetin will result in uneven clearing of the granularity left from the acetone vapour clearing. Further, the refractive index of the mounted sample will not be suitable for optimum visibility of very fine Chrysotile fibres.
- Heating the cleared filter to approximately 50°C for fifteen minutes accelerates the clearing process and enables analysis to proceed almost immediately thereafter. Otherwise it is necessary to delay counting for up to 24 hours until the entire filter has dissolved under the action of the Triacetin. The finished product will be stable, will not disintegrate, nor be subject to particle migration.
- It is desirable to paint nail polish, or similar lacquer around the edge of the coverslip if the slide is to be kept indefinitely.



Appendix B

Flow Rate Calibration and Corrections

Internal and external flow meters must be calibrated with a primary calibration device. One suitable calibration procedure makes use of a soap film flow meter. The flow meters described in this section are of the variable area type (i.e. "rotameters").



1. Choose an accurate burette (or similar) of 300–500 ml capacity. Attach a tube to the bottom of the burette, and then clamp it in an inverted vertical position into a stand.
2. Set up the sampling pump complete with connecting tube, filter holder and filter as that used in the field.
3. Connect the soap film flow meter. Ensure that the system is leakproof. It is advisable to rinse the burette thoroughly in water immediately prior to the test — this removes accumulated detergent and also assists in wetting the inside of the burette.
4. Switch on the pump and adjust the flowrate to 1 l/min. according to the internal flow meter (if fitted).
5. Partly fill a beaker or petri dish with water plus the minimum amount of detergent necessary to permit bubbles to be formed.
6. By momentarily placing the beaker against the bottom of the soap film flow meter create a bubble such that it will travel the entire length of the burette without bursting.

7. With a stop watch, measure accurately the time that the bubble requires to traverse the tube between its extreme graduated ends.
8. Repeat steps 6 and 7 at least twice, or more, until good repeatability of the times is achieved.
9. Average the times, and calculate the true flow (Q_c) as follows:

$$Q_c = \frac{V}{\bar{\tau}}$$

Where Q_c = True volumetric flowrate (ml/min.) at calibration conditions.
V = Volume of burette (ml).
$\bar{\tau}$ = Average time required for bubble to traverse the tube (minutes).

10. If the external or internal rotameter is used under different temperature conditions than those during calibration, it is generally *not* possible to calculate the different flowrate that will inevitably result.

As all air sampling measurements are concerned only with volumetric flowrate (i.e. flowrate measured and expressed at the prevailing temperature and pressure) and not mass flowrate (i.e. flowrate corrected to standard temperature and pressure conditions), recalibration of the pump flowrate is essential if it is operated under conditions substantially different to those of calibration. Substantial implies a difference in altitude or temperature by more than 500 m or 15°C respectively compared to the calibration conditions. For field calibration, whilst a 1 litre soap film flow meter is preferred, a 500 ml unit is more convenient and has been found satisfactory.

Example: During the calibration of a pump with an internal flow meter a soap film flow metor of 1000 ml volume gave an average of 63.4 seconds for the bubble to traverse its length.
What is the flowrate under these conditions?
Using the equation in this Appendix:

$$Q_c = \frac{V}{\bar{\tau}} = \frac{1000}{63.4/60} \quad 946 \text{ ml/min.}$$

The flowrate, under the temperature and pressure conditions as stated above was 946 ml/min.

Appendix C

Measurement of Effective Filter Area

One convenient way in which to determine the area of the dust deposit (i.e. the effective filter area) is as follows:

1. Place a small quantity of dark coloured dust (e.g. carbon, cement or road dust) into a 2 to 5-litre container with a lid.
2. Shake the container, remove the lid and draw air through a membrane filter and its holder until the airborne dust in the container forms an obvious deposit on the filter.
3. Remove the filter from the holder, and mount onto a microscope slide in the normal manner as described in the Reference Method.
4. Measure at least four different diameters of the resultant dust spot to within ± 0.2 mm. Amongst other methods, microprojection measurement, or the use of microscope object stage verniers have been found satisfactory.
5. Provided that the measured diameters differ by no more than 1 mm, a simple arithmetic average is sufficient to provide a good estimate of the effective filter diameter.
6. At least three individual filters must be prepared and measured as described above to give assurance that the finally calculated area is sufficiently accurate.
7. Provided that the three filter diameters differ no more than 1 mm, an arithmetic average should be taken and the area calculated in the usual manner. This area is then the Effective Filter Area to be used for calculations in this method.
8. If steps 5 or 7 produce differences greater than 1 mm, close attention should be paid to the sampling of the dust or to the filter clearing technique.
9. It is necessary to repeat the measurement of the effective filter area if the type of filter or holder, or if any aspect relating to filter clearing is changed.
10. It is advisable to repeat the entire measurement procedure every 12 months to ensure that the correct effective filter area is known.

Appendix D

Dust Sampling Record

All data necessary for the determination of the fibre concentration must be recorded in a sampling record. Furthermore as much data as available which can be of value for epidemiological studies should be included.

Sampling Details
- Instrument Type and No.
- Flowrate, initial, intermediate and final
- Duration
- Sampling scheme used
- Date, Hour
- Sampled by

Sampling Place Details
- Designation
- Harmful substances — types of asbestos, quartz, etc.
- Brief description of working process
- Variable parameters which can exercise an influence on dust formation
- Work practices
  - Working conditions: normal abnormal
  - Material: type, size, condition, etc.
  - Airflow: worker in dust airflow yes/no obvious influence on adjoining working places
- Methods of dust control
  - Exhaust ventilation
  - Other methods
  - Visual impression
- Number of employees for which the measuring value is representative
- Personal protection yes/no Type:
- Hours per shift
- Days per week

See opposite for Dust Sampling Record

Appendix E

PART 1

Specifications of Eyepiece Graticule, Ordering Information and Calibration

The "Walton/Beckett" graticule described in this method is available from Graticules Limited, Sovereign Way, Botany Trading Estate, Tonbridge, Kent, England, TN9 1RN.

The desired diameter (D) of the circle (100 ± 2 micrometers) and the overall diameter of the glass disc should both be specified in millimetres when ordering. The graticule can be referred to by the Graticules Ltd. Reference No. G22. The following procedure is one of several methods for determining the diameter (d) of the circular counting area.

1. Insert any available graticule into the eyepiece and focus so that the graticule grid is sharply in focus.
2. Set the appropriate interpupillary distance, and if applicable reset the binocular head adjustment so that the "tube" length (and thus magnification) remains constant.
3. Ensure that the 40 × phase objective is in place, and that the magnification changer position (if used) is known and recorded.
4. Place a stage micrometer on the microscope object stage and focus the microscope onto the graduated lines.
5. Measure the overall object length (l_o) of the graticule grid using the stage micrometer.
6. Remove the graticule from the microscope and measure its actual overall grid length (l_a). This can be done by using a stage fitted with verniers.
7. Use the following equation:

$$\frac{l_a}{l_o} \cdot D = d = \text{diameter to be specified}$$

It is also necessary to measure the overall diameter of the glass disc.

Example: Step 5 produced an object length of a Porton graticule of 108 micrometers.
Step 6 produced an actual length of 4.50 mm
Step 7 $\frac{4.50 \text{ mm}}{0.108 \text{ mm}} \times 0.1 =$
$= 4.17$ mm

For this example the graticule diameter was found to be 17 mm. Thus a 17 mm diameter, Type G22 "Walton/Beckett" graticule of circle diameter 4.17 mm should be specified for the above example.

To expedite manufacture of "made to order" graticules so as to avoid delay and keep down prices, graticules should be ordered in bulk if at all possible.

Graticules Limited have stated that a number of graticules requested on a single order can be invoiced separately to individual companies, and delivered separately to the same or any other set of addresses.

PART 2

Calibration of Eyepiece Graticules

1. Obtain a stage micrometer, preferably with a scale having two or 10 micrometer divisions and place on the object stage of the microscope.
2. Make sure interpupillary distance of eyepieces is set correctly.
3. Note the objective magnification and any intermediate magnification used.
4. Focus the microscope onto the graduated marks of the stage micrometer.

EXAMPLE ONLY

DUST MEASURING RECORD

Place of measurement ☐ date ☐

Measuring point/Name ☐ Code-No. _____ text in clear

Dimension of workplace ☐ < 50 m³ ☐ 50–500 m³ ☐ 500–5000 m³ ☐ > 5000 m³

Exhaust ventilation ☐ yes ☐ no

Situation representative? ☐ yes ☐ no

Dust concentration ☐ above average ☐ below average

Visual impression ☐ good ☐ quite good ☐ bad

Number of employees working at this working place: _____

Respirators are worn ☐ yes ☐ no ☐ sometimes Type: _____

Draught during measurement ☐ no ☐ yes _____

Measured in the dustladen air flow ☐ yes ☐ no

Adjoining working places are influenced ☐ no ☐ yes Measuring point No. _____

Measurement was done ☐ personal ☐ static

Sampling device ☐ atmospheric pressure ☐ mbar

Air flow rate ☐ time started ☐ time ended ☐

Sampling scheme used

Sample No.	Sampling time (min.)	Total Flow	Working phase	Fibres/ml
☐				☐
☐				☐
☐				☐
☐				☐
☐				☐
☐				☐
			Average value	☐

Harmful substances ☐ Chrysotile ☐ Crocidolite ☐ Amosite ☐ Quartz ☐ _____ (other)

Other fibres ☐ Fibreglass ☐ Mineral wool ☐ _____ (other)

DUP 0821090

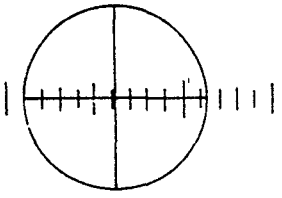
DU 011515

5. Line up the eyepiece graticule with the graduated divisions on the micrometer so that the number of whole micrometer divisions can be counted from one side of the eyepiece graticule graduations to the other.
6. If less than a whole division remains, estimate this fraction to the nearest micrometer and add to the number of whole divisions of the stage micrometer after converting to micrometers.

This totalled result is the projected or object dimension of the eyepiece graticule.

Example:

1. A stage micrometer with 10 micrometer divisions was placed on the stage of a microscope.
2. The following diagram depicts the view of the superimposed eyepiece graticule and stage micrometer.



Note that 10 whole divisions span across the graticule; i.e. 10 × 10 micrometers.

3. The remainder of the 11th division is estimated as being one third of a whole division, i.e. three micrometers.

Adding these together yields 103 micrometers which is the object dimension of the eyepiece graticule.

Note that if the interpupillary distance, objective, intermediate magnification, or even in some microscopes the eyepiece is changed then this usually changes the object dimension of the eyepiece graticule — thus necessitating recalibration.

Appendix F

Test Slides for the Determination of the Detection Limit during Phase Contrast Microscopy

Source of Supply (until commercial marketing has started):

Asbestos Institute for Occupational and Environmental Safety and Health
Görlitzer Str. 1
4040 Neuss
Germany

Mounting of Test Slides

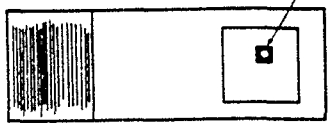
A membrane filter, positioned on a microscopic slide, was treated with acetone vapour in order to produce a transparent film. Spherical Latex Particles, with a refractive index of 1.56 (similar to that of chrysotile) were diluted with alcohol. Agglomeration of the particles was minimised by ultrasonic agitation. After evaporation of the liquid, a drop of triacetine was added to the film containing the Latex Particles and a coverslip was added to produce a normal microscope specimen slide. This process was carried out in the same manner as would be applied to a dust slide membrane filter; consequently the slide has the same optical characteristics under phase contrast microscopy as a normal Chrysotile slide.

Only particles of one size were deposited on slides 1 and 2. Due to difficulty of detecting the smaller particles contained on slides 3 to 8, particles of 0.6 µm were also added to these slides, representing approximately 10 per cent of the particulates. The larger particles are intended to assist in locating the correct specimen plane.

The slides available are as follows:

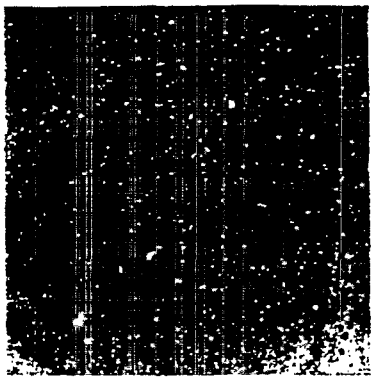
Code-No	Particle sizes
1	0.6 µm
2	0.48 µm
3	0.36 µm + 10 per cent 0.6 µm
4	0.31 µm + 10 per cent 0.6 µm
5	0.26 µm + 10 per cent 0.6 µm
6	0.22 µm + 10 per cent 0.6 µm
7	0.18 µm + 10 per cent 0.6 µm
8	0.11 µm + 10 per cent 0.6 µm

The area most suitable for use has been delineated by a mask outline. This area only should be used for evaluation.



Application

Test observation should commence by observing slide No. 1 (0.6 µm diameter). The slide is positioned on the microscope in the the normal way and positioned for observation of the marked area. When the sample is correctly placed a dense distribution of Latex Particles (points of light) will be observed similar to the following picture:



Only the particles which are densely distributed and of the appropriate size are the test particles. It is not intended that the particles should be counted but a dense distribution should be detected. The same procedure is applied to each of the slides in numerical order. To assist in locating the correct specimen planes in slides 3 to 8, the microscope is first focussed on to the 0.6 µm diameter particles. A dense distribution of the test particles should be observed once the *correct focus has been achieved.*

The process is repeated with each slide until the slide where the test particles are no longer visible. The working detection limit is defined by the slide value on which the particles are just detectable.

NOTE: The particle loading of the slide is high. If only a small number of particles is detected in a field of view, the particles being observed *are not* the test particles.

Appendix G

Microscope Adjustment Procedure

Good quality phase contrast microscope equipment should be used as detailed in Section 5.2.1. The equipment should be maintained in first-class condition and most manufacturers operate a routine maintenance service which includes the stripping down and cleaning of all optical components and the replacement of worn traverse mechanisms. Such services should be used unless skilled maintenance services can be provided by counting-laboratory staff.

In general the following setting-up procedure should be adopted to obtain Koehler illumination and good phase contrast conditions but the detail may vary according to manufacturer's instructions and the type of equipment.

1. Place membrane filter specimen slide on microscope stage.
2. Open both the illuminator diaphragm (often referred to as the field iris) and the substage condenser diaphragm. (Note — at this stage the phase annuli should not be inserted. These are usually based in a rotating drum fitted into the substage condenser unit.)
3. Raise condenser to its upper limit, usually within 1 mm of lower face of specimen slide.
4. Using a convenient level of illumination and 10× objective focus the specimen.
5. Close down the illuminator diaphragm and focus this in the field of view by lowering and raising the condenser. Centre the diaphragm and re-open to fill the field of view.
6. Observe the back focal plane of the objective, using either a Bertrand lens fitted to the body of the microscope or by removing the eyepiece and using an auxiliary telescope.
7. Observe image of bulb (removing the diffusing disc if one is fitted) and centre the bulb filament — *focussing the bulb if* possible with the adjustment provided. The image of the bulb filament should fill the back focal plane of the objective. Re-insert the diffusing disc if appropriate. (Note — if the bulb cannot be focussed *adjust to give uniform bright illumination.*)
8. Insert the correct phase annulus into the condenser system and centre this using the appropriate adjusting screws so that the phase plate in the objective and the image of the annulus coincide exactly. *Adjust slightly the condenser focussing* if this is necessary. Ensure that the bright annulus image does not extend beyond the phase ring.
9. Revert to normal viewing and change to 40× objective with no phase annuli in *the condenser system. Close down the* field diaphragm and refocus this by appropriate adjustment of the condenser. Re-centre if necessary and re-open to fill field of view.
10. Repeat stages 6 and 8 after inserting the phase annulus appropriate to the 40× objective.
11. Revert to normal viewing.

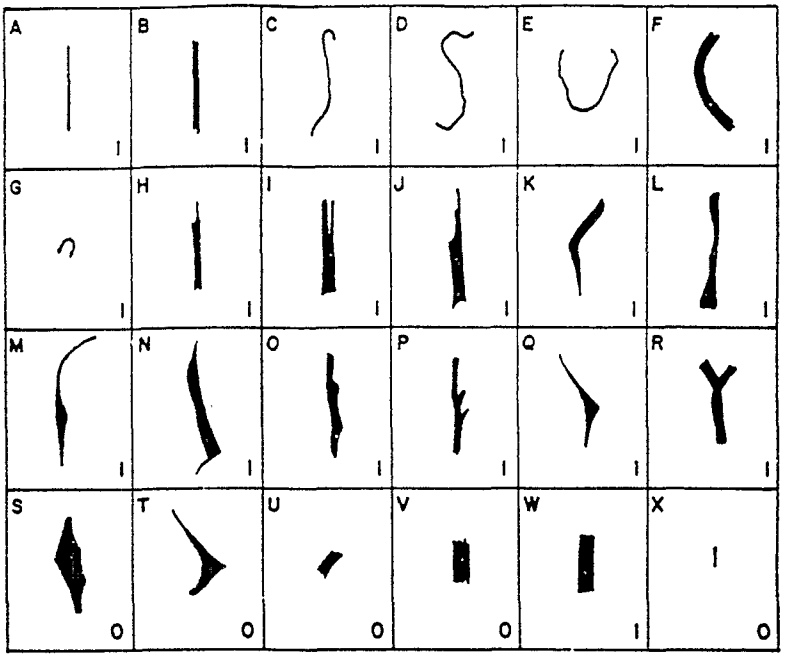
Appendix H

Drawings of Various Asbestos Fibres

NOTE: All drawings are the same scale i.e. one micrometer = 1 mm. The number in the right bottom corner of each drawing indicates the number of fibres (as defined) counted.

(a) Single fibres

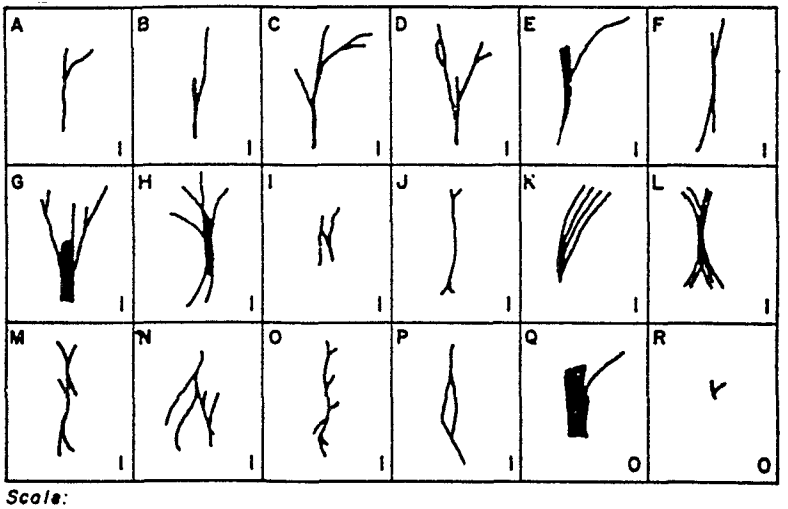
These are the simplest of the fibres to identify and count. They are the most common of measurable fibres as seen on the membrane filter. Amosite and crocidolite fibres generally assume a straight needlelike form. Chrysotile fibres, while sometimes straight, often assume a curved or curly outline. Fibres which appear irregular and perhaps "unfibre-like" are counted if they conform to the basic requirements of fibre definition.



Scale: 5µm

(b) Split fibres

These appear generally as a fibre or fibres splitting away from a single stem. Provided that the fibre conforms to the definition at its longest length and greatest thickness, any particular fibre configuration should be counted as one fibre only.

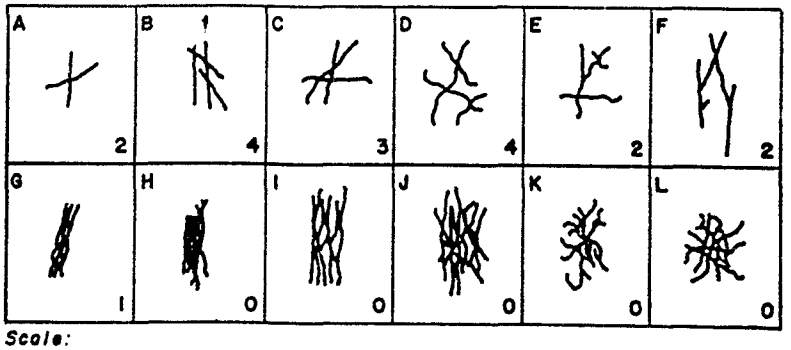


Scale: 5µm

(c) Grouped fibres

These are formed when fibres overlap, intertwine or pack together. The simplest form is when two fibres overlap and cross each other. In this case each fibre in the group appears as a discrete entity. In more complex form fibres lie nearly parallel and appear to originate from the same bundle. The latter should be counted as one fibre only, provided the bundle has a total width not greater than three micrometers and conforms to the other criteria.

Occasionally groups of fibres are seen as an indeterminate number of fibre entanglements which appear to originate from the same fibrous bundle. These should not be counted as fibres.



Scale: 5µm

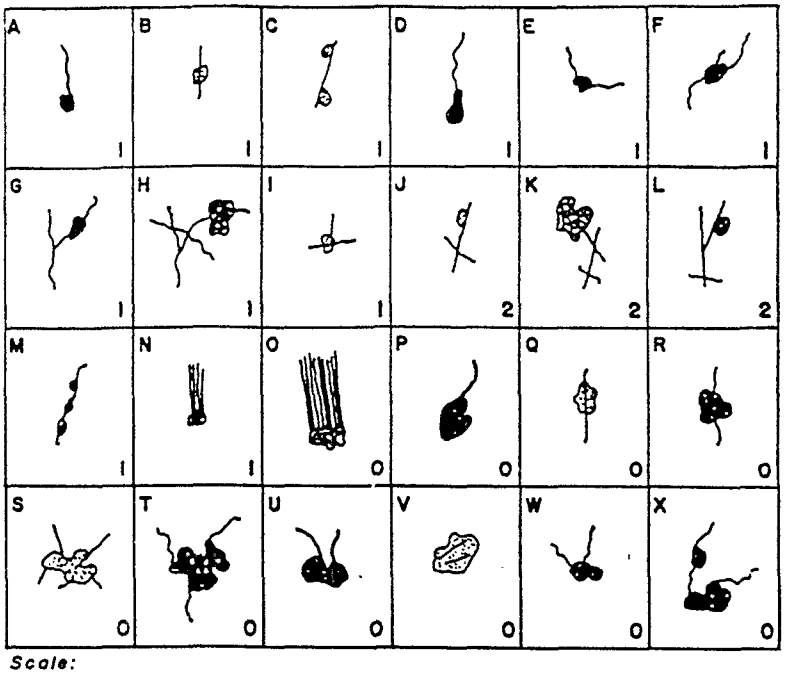
(d) Fibres with other Particles

This group consists of fibres attached to, or embedded in particulate matter. This latter material could be parent asbestos rock, or resins, cement, silicates, etc. as used in manufactured products. Under the microscope some fibre, especially chrysotile, appears to project from the particulate matter with only part of the fibre seen. Other fibres (often amosite) are seen as embedded in the particulate matter.

If the particulate matter is not more than three micrometers wide, all fibres which conform to the definition should be counted.

NOTE: Once a particle appears with a fibre, the particle is considered to be attached to it.

General Note: Even after meticulous application of the above criteria and guides, there will still be times when it is difficult to make a decision. At these times it is important to ensure that the best conditions of microscopy have been achieved because the fine details of the image are often the determining factors.



Appendix I

Dust C unting Record (Example only)

Counted by :
Date :
Microscope No.:
Graticule Type : Area: mm²

number of fibres	number of fields

0-bundles
X-background not okay

$$c = \frac{\Sigma n_f}{\Sigma n_{cf}} \cdot \frac{1}{V} \cdot F = \frac{\quad}{\quad} = \boxed{\quad} \ \frac{\text{fibres}}{\text{ml}}$$

In special circumstances it is of value to record the number of fibres contained in individual fields of counting.

Example:

n_f Sample No.:

	1																		

$$c = \frac{\Sigma n_f}{\Sigma n_{cf}} \cdot \frac{1}{V} \cdot F = \frac{\quad}{\quad} = \boxed{\quad} \ \frac{\text{fibres}}{\text{ml}}$$

c = concentration in fibres ml
N = Σn_f = total number of fibres counted
n = Σn_{cf} = number of fields counted
A = effective filter area (mm²)
a = area of the counting field (mm²)
V = total flow (ml)
F = $\frac{A}{a}$ (constant factor)

DUP 0821093

DU 011518

BIBLIOGRAPHY

1.
Edwards, G. H. and J. R. Lynch
The Method used by the U.S. Public Health Service for Enumeration of Asbestos Dust on Membrane Filters.
Ann. Occ. Hyg., Vol. 11, 1–6 (1968)

2.
Asbestosis Research Council
(a) Technical Note 1 (1971)
The Measurement of Airborne Asbestos Dust by the Membrane Filter Method (Rev.).
(b) Technical Note 2 (1971)
Dust Sampling Procedures for use with the Asbestos Regulations 1969.
Rochdale, Lancs.

3.
U.S. Dept. of Health, Education and Welfare, Public Health Service, National Institute of Occupational Safety and Health.
Criteria for a Recommended Standard — Occupational Exposure to Asbestos.
HSM–72–10267 (1972)

4.
Leidel, N.A., S. G. Bayer and R. D. Zumwalde
USPHS/NIOSH Membrane Filter Method for Evaluating Airborne Asbestos Fibres.
NIOSH Unpublished In-House Report TR–84 (1973)

5.
Beckett, S. T. and M. D. Attfield
Inter-Laboratory Comparison of the Counting of Asbestos Fibres sampled on Membrane Filters.
Ann. Occ. Hyg., Vol. 17, 85–96 (1974)

6.
AIHA–ACGIH Aerosol Hazards Evaluation Committee
Recommended Procedures for Sampling and Counting Asbestos Fibres.
Am. Ind. Hyg. Ass. J., Vol. 36, 83–90 (1975)

7.
AIHA–ACGIH Aerosol Hazards Evaluation Committee
Background Documentation on Evaluation of Occupational Exposure to Airborne Asbestos.
Am. Ind. Hyg. Ass. J., Vol. 36, 91–103 (1975)

8.
Gabriel, J. M. and D. Bouige
Prelevement et Numeration des Fibres D'Amiante
Cahiers de Notes Documentaires, No. 79, 2e Trimestre, 207–211 (1975)

9.
Australian Department of Health
Membrane Filter Method for Estimating Airborne Asbestos Dust.
Canberra (1976)

10.
Beckett, S. T., R. K. Hey, R. Hirst, R. D. Hunt, J. L. Jarvis and A. L. Rickards
A Comparison of Airborne Asbestos Fibre Counting With and Without Eyepiece Graticule.
Ann. Occ. Hyg., Vol. 19, 69–76 (1976)

11.
Walton, W. H., M. D. Attfield and S. T. Beckett
An International Comparison of Counts of Airborne Asbestos Fibres Sampled on Membrane Filters.
Ann. Occ. Hyg., Vol. 19, 215–224 (1976)

12.
Gibbs, G. W., P. Baron, S. T. Beckett, R. Dillan, R. S. J. du Toit, M. Koponen and K. Robock
A Summary of Asbestos Fibre Counting Experience in Seven Countries.
Ann. Occ. Hyg., Vol. 20, 321–332 (1977)

13.
Leidel, N. A., K. A. Busch and J. R. Lynch
Occupational Exposure Sampling Strategy Manual.
NIOSH Technical Information Report, 77–173 (Jan. 1977)

14.
Robock, K. and U. Teichert
Techniques, Strategies and Results of Dust Measurements in the Asbestos Industries.
Vth International Conference on Pneumoconiosis/ILO, Caracas, Venezuela (1978)

15.
Advisory Committee on Asbestos
Asbestos measurements and monitoring of asbestos in air (2nd Report).
Health and Safety Commission (UK), 3–28 (1978)

16.
Rickards, A. L.
The Routine Monitoring of Airborne Asbestos in an Occupational Environment.
Ann. Occ. Hyg., Vol. 21, 315–322 (1978)

17.
Cooper, D. W., H. A. Feldman and G. R. Chase
Fibre Counting: A Source of Error Corrected.
Am. Ind. Hyg. Ass. J., Vol. 39, 362–367 (1978)

18.
Leidel, N. A., S. G. Bayer, R. D. Zumwalde and K. A. Busch
USPHS/NIOSH Membrane Filter Method for Evaluating Airborne Asbestos Fibres.
NIOSH Technical Report, 1–89 (Feb. 1979)

ACKNOWLEDGEMENTS

The Dust Measurement Advisory Panel (DMAP) has been greatly assisted in its work by contributions from the following institutions and their representatives who took part in the International Colloquia on Dust Measuring Technique and Strategy organised by the Asbestos International Association (Warmensteinach, August 1977; Washington, October 1978).

* member of DMAP

AUSTRALIA
Mr. G. Major
School of Public Health and Tropical Medicine
The University of Sydney
Building A 27
New South Wales 2006

Mr. G. Pickford*
James Hardie & Co. P/L Ltd.
R & E Centre
Grand Avenue Camellia
New South Wales 2142

Mr. J. W. Winters
James Hardie & Coy. Pty. Ltd.
65 York Street
Sydney

AUSTRIA
Mr. Bigga
Österreichische Staub (Silikose) — Bekämpfungsstelle
Technische Abteilung
Postfach 72
a-8700 Leoben

Mr. Schmiedinger
Eternit-Werke Ludwig Hatschek
A-4840 Vöcklabruck

BELGIUM
Mr. Roger Meunier
REDCO
Kuiermansstraat
B-2920 Kapelle op den Bos

Mr. Vanherle
EEC Advisory Council of the AIA
WTC 1 – P.O. Box 37
Boulevard E. Jacqmain 162
B-1000 Bruxelles

CANADA
Mr. G. Gibbs, M.Sc., Ph.D.
Occupational Health and Safety Unit
Institute for Mineral Industry Research, Gault Estate
McGill University
Mount St. Hilaire
Montreal, Que. J3G 4S6

Mr. Marc Trudeau*
Technical Advisor
Quebec Asbestos Mining Association
Thetford Mines
P.O. Box 624
Quebec G6G 1J4

Mr. Jean Marc Lalancette
Bureau de Lauinate
845 ouest, Boul. St.
Cyville, Quebec

DENMARK

Mr. Thomas Schneider
Arbejdstilsynet Statens Institut for Arbejdshygiejne
Institute for Working Environment
Baunegaardsvej 73 Du
DK-2900 Hellerup

Mr. K. Thiele
Dansk Eternit Fabrik A/S
DK-9100 Aalborg
P.O. Box 763

FINLAND

Mr. N. Arppe
Paraisten Kalkki Oy
SF-08580 Muijala

Mr. M. Koponen
Outokumpu Oy
Paakonttori
Toolonkatu 4
SF-00100 Helsinki 10

Mr. A. Palomäki
Paraisten Kalkki Oy
SF-08680 Muijala

FRANCE

Mr. Daniel Bouige*
LHCF Laboratoire d'Hygiene et de Contrôle des Fibres Minerales
10 Rue de la Pépiniére
F-75008 Paris

Mr. Bernard Carton
INRS Institut National De Recherche et de Securité
Avenue de Bourgogne
F-54500 Vandoeuvre

Mr. Clousier
Ferodo S.A.
B.P. 20
F-14.110 Conde/NO1 Reau

Mr. Patrick Sebastien
Laboratoire d'Étude des Particules Inhalées
37 Bd. Saint-Marcel
F-75013 Paris

Mr. Turpin
Eternit Industries
8 Rue de la Fontaine
F-59121 Prouvy

GERMANY

Dr. G. Riediger
Staubforschungsinstitut des Hauptverbandes der gewerblichen Berufsgenossenschaften
Postfach 50 40
5300 Bonn 5

Dr. Klaus Robock* (Chairmar DMAP)
Asbest-Institut
für Arbeits- und Umweltschutz e.V
Görlitzer Str. 1
4040 Neuss 1

Mr. Ullrich Teichert* (Secretary DMAP)
Asbest-Institut
für Arbeits- und Umweltschutz e.V
Görlitzer Str. 1
4040 Neuss 1

Mr. D. Weltle
Institut für Arbeits- und Sozialmedizin
Schillerstr. 29
8520 Erlagen

IRELAND

Mr. E. J. Fenelon
Tegral Building Prods. Ltd.
Athy,
Co. Kildare

ITALY

Prof. A. D. Bonsignore
Universita' di Genova
Istituto Medicina del Lavoro
10 Viale Benedetto XV
I-16132 Genova

Prof. G. Cecchetti
Universita' Cattolica del Sacro Cuore
Istituto Medicina del Lavoro
Centro di Igiene Industriale
Via della Pineta Sacchetti 644
I-00136 Roma

Dr. A. Marconi
Istituto Superiore di Sanita'
Laboratorio di Igiene del Lavoro
Viale Regina Elena 299
I-00136 Roma

NETHERLANDS

Mr. H. J. van't Haaff
Eternit B.V. Goor, Haven 12
Postrekening 10237

Mr. R. W. Lanting
Instituut voor Miliquhygiene en Gezondheidstechniek T.N.O.
Schoemakerstraat 97
Delft

Mr. Meppelder
Directorate General
Labour P.O. Box
Voorburg

Mr. P. B. Meyer
TNO-Institute for Envior Hygiene
P.O. Box 214
Delft

NORWAY

Mr. L. Knutsen
A/S Norcem
3470 Slemmestad

Mr. J. Jahr
Yrkeshygienisk Institutt
P.O. Box 8149
Dep. Oslo 1

REPUBLIC OF SOUTH AFRICA

Dr. R. S. J. Du Toit
P.O. Box 1132
Johannesburg 2000

SWEDEN

Mr. Folke Danstrand
C.A. Clase AB
Ruskvädersgatan 8
417 Göteborg

Mr. N. Hallin
Organisation for Industrial Safety and Health in the Construction Industry
Burgghälsam
Fack
10041 Stockholm

Dr. Staffan Krantz
Nat. Board Occ.
Safety and Health
Fack
100-26 Stockholm

Dr. S. Skyllberg
Swedish National Board of Industrial Safety
Fack
10026 Stockholm 39

UNITED KINGDOM

Dr. Steve Beckett
Institute of Occupational Medicine
8 Roxburgh Place
Edinburgh

Mr. A. A. Cross
Asbestos International Association
68 Gloucester Place
London W1H 3HL

Mr. John L. Jarvis
Cape Industries Ltd.
Environmental Services Lab.
Iver Lane, Cowley
Uxbridge, Middx.

Dr. G. Leguen
Research & Service Laboratory
Division Health & Safety Executive
403/405 Edgware Road
Cricklewood
London N.W.2

Dr. Trevor L. Ogden
Health & Safety Executive
403 Edgware Road
London N.W.2

Mr. A. L. Rickards*
Turner & Newall Ltd.
P.O. Box 22
Trafford Park
77 Fountain Street
Manchester M2 2EA

Mr. Reginald Sykes*
Asbestos Research Council
P.O. Box 40
Rochdale OL12 7EQ

Dr. Chris Taylor
Dept. Medical Biophysics
Stopford Building
University of Manchester
Oxford Road
Manchester M1 9PT

Mr. R. M. Wagg
Health & Safety Executive
403/405 Edgware Road
Cricklewood
London N.W.2

Dr. W. H. Walton
Institute of Occupational Medicine
Roxburgh Place
Edinburgh EH8 9SU

U.S.A.

Dr. Paul A. Baron
N.I.O.S.H.
Robert Taft Laboratory
4676 Columbia PDWY
Cincinnati, Ohio 45226

Dr. G. Chase*
Johns-Manville Corporation
Health, Safety and Environment
Greenwood Plaza
Ken-Caryl-Ranch
Denver, Colorado 80217

Mr. Ching Bien
Mr. Stephen Mallinger
Department of Labor OSHA
200 Constitution Avenue, NW
Washington, D.C. 20210

Dr. Samuel H. Goldberg
Dust Branch MSHA
4800 Forbes Avenue
Pittsburg Pa. 15213

Dr. Y. Hammad
Tulane University School of Medicine
Pulmonary Disease Section
New Orleans, La. 70112

Mr. James G. Heil
Certain Teed Corporation
Technical Center
P.O. Box 1100
1400 Union Meeting Road
Blue Bell, Pa. 19422

Mr. Jimmie Hodgeson
National Bureau of Standards
Chemistry Building Room A 345
Washington, D.C. 20234

Mr. F. A. Madsen
OSHA Occupational Safety and Health
Administration
390 Wakara Way
Salt Lake City, Utah 84108

Dr. Harrison B. Rhodes*
Union Carbide Corporation
P.O. Box 579
Niagara Falls, N.Y. 14302

Mr. Glen Sutton
Mine Safety and Health Administration
Denver Technical Support Center
P.O. Box 25 367
Denver, Colorado 80225

The DMAP acknowledges its special indebtedness to work already done in this field by:

Asbestosis Research Council
P.O. Box 40
Rochdale OL12 7EQ
U.K.

N.I.O.S.H.
Robert Taft Laboratory
4676 Columbia PDWY
Cincinnati, Ohio 45226
U.S.A.

National Health and Medical Research Council
P.O. Box 100
Woden
Canberra, A.C.T. 2606
Australia

Asbestos International Association

Member Associations

AUSTRALIA*

South Pacific Asbestos Association
c/o L W Farrar & Assoc Pty Ltd
129 York Street
Sydney 2000, NSW
Telephone 297946

AUSTRIA

Verein Der Oesterreichischen
Asbestzementfabrikanten
Prinz Eugen Strasse 8.
1041 Wien
Telephone 65 58 77

BENELUX

(Belgium-Netherlands-Luxembourg)

Comite d Information de l'Amiante
Benelux
W T C Boite 37
Boulevard E Jacqmain 162
B 1000 Bruxelles
Telephone (02) 218-6329
Telex 21 696

CANADA

Institute of Occupational &
Environmental Health (Association)
AMAQ Suite 320
560 est Grande Allee
Québec, Que
G1R 2K2
Telephone (418) 529-8168

DENMARK

Danish Asbestos Information Group
c/o Dansk Eternit Fabrik A/S
P O Box 763,
DK-9100 Aalborg.

FINLAND

Finnish Asbestos Information Group
c/o Paraisten Kalkki Oy,
SF-21600 Parainen
Telex 62220 Pkparsf

FRANCE

Chambre Syndicale de l'Amiante
10 Rue de la Pepiniere,
75008 Paris.
Telephone: 522 12-34

GERMANY

Wirtschaftsverband Asbestzement e.V.
Goerlitzer Strasse 1
D 4040 Neuss
Telephone: (0) 2101 13051
Telex: 851 7402 AUD

Wirtschaftsverband Asbest e.V.
Oberschelder Weg 2-4
6000 Frankfurt/Main 50
Telephone: (0611) 58 20 77

IRELAND

Irish Asbestos Council
6 South Leinster Street
Dublin 2
Telephone 01-763974
Telex 4281

ITALY

Associazione Nazionale Industriali
Amiantieri
Unione Industriale
Via Fanti 17
10128 Torino
Telephone 571 6239
Telex 230641 UNINDUTO

Assocemento
via di S Teresa 23
00198 Roma
Telephone 864 314/865 068

JAPAN

AIA Committee
Japan Asbestos Association
8-10-7 Ginza Chuo-ku
Tokyo

NORWAY

Norwegian Asbestos Information Group
Norcem AB
3470 Slemmestad

REPUBLIC OF SOUTH AFRICA

South African Asbestos Producers
Advisory Committee
P O Box 10505
Johannesburg 2000
Telephone 395458
Telex 87582

SPAIN

Asociacion Espanola de Fabricantes
de Productos de Amianto
Mª Diaz de Haro 38
Apartado 558
Bilbao (10)
Telephone 437 37 05
Telex 32125 Monsa E

Asociacion de Fabricantes de
Productos de Amianto-Cemento
Rafael Calvo 18,
Madrid (10)

SWEDEN

Swedish Asbestos Information Group
C.A Clase A.B.
Ruskvadersgatan 8,
41734 Gothenburg

SWITZERLAND

Arbeitskreis Asbest
c/o Stiffler & Nater
Dufour Strasse 101
8008 Zurich

UNITED KINGDOM

Asbestos Information Centre
Sackville House
40 Piccadilly
London W1V 9PA
Telephone 01-439 9231/2/3
Telex 21120 ref 2526

U.S.A.

Asbestos Information Association/NA
1745 Jefferson Davis Highway
Crystal Square, Suite 509
Arlington
Virginia 22202
Telephone (703) 979 1150
Telex

Additional Members since 31 May '78

GREECE

Hellenic Asbestos & Asbestos Cement
Association
8 Omirou Street
Athens (133)
Telephone 32 31 244
Telex 215871

* now includes Indonesia, Malaysia,
New Zealand and Singapore

Asbestos International Association
68 Gloucester Place,
London W1H 3HL, England.
Telephone: 01-486 3528
Telex: 298618 INTA G

31 May 1978
Amended 10 April 1979
Amended 7 September 1979