National Occupational Health and Safety Commission

ASBESTOS

Guide to the Control of Asbestos Hazards in Buildings and Structures [NOHSC:3002(1988)]

Code Of Practice for the Safe Removal of Asbestos [NOHSC:2002(1988)]

Guidance Note on the Membrane Filter Method For Estimating Airborne Asbestos Dust [NOHSC:3003(1988)]

AUGUST 1988

Australian Government Publishing Service
Canberra

ISBN 0 644 08619 X

ASBESTOS

GUIDE TO THE CONTROL OF ASBESTOS HAZARDS IN BUILDINGS AND STRUCTURES

CONTENTS **PAGE**

PREFACE

The National Occupational Health and Safety Commission is a tripartite body established by the Commonwealth Government to develop, facilitate and implement a national health and safety strategy.

This strategy includes standards development, research, training, information collection and dissemination, and the development of common approaches to occupational health and safety legislation.

The National Commission comprises representatives of the peak employee and employer bodies - Australian Council of Trade Unions and Confederation of Australian Industry - as well as the Commonwealth, State and Territory Governments.

In line with the Commission's philosophy of participation, standing committees and working parties are basically tripartite in nature, but also include persons with specialist knowledge and representatives of groups with special needs.

The National Occupational Health and Safety Commission is aware of the enormous extent of the asbestos hazard in Australia.

Asbestos was used extensively in structures such as buildings, processing plants, ships, trains and motor vehicles in the 1950s, 1960s and early 1970s. The use of sprayed asbestos is now banned in all States, and crocidolite and amosite have been declared customs prohibited imports.

The known adverse health consequences of asbestos exposure dictate that some control is required. The main methods of controlling asbestos in buildings and other structures are:

- administration
- enclosure
- encapsulation/sealing
- removal

The hazard posed by asbestos is determined by the nature of the product and its condition, and these dictate how it is to be treated. Various approaches for the treatment of asbestos are outlined in the course of this document, however, there may be specific applications where special approaches may be required.

Work involving asbestos removal, encapsulation, enclosure or work which involves the disturbance of asbestos must be carried out in conformity with this Guide and attached Code so that the level of contamination is kept as low as possible, and restricted to areas inaccessible to those persons not adequately protected.

Asbestos removal may not be immediately necessary but must be completed before a structure, or part of a structure, is demolished.

Immediate resources should be concentrated on asbestos that currently constitutes an elevated health risk or is in vulnerable or exposed locations.

Against a background of increased public concern over the health risks resulting from the presence of asbestos in buildings and other structures where people spend their working day, the National Consultative Committee on Occupational Health and Safety (NCCOHS) established a working party to examine the issue, with the following terms of reference:

- to examine the current occupational health and safety standards and guidelines on exposure to asbestos;

- where standards are found to be appropriate, to incorporate them in interim guidelines on handling asbestos occurrences;

- where deficiencies and gaps in standards and guidelines are identified, to develop interim guidelines to remedy these deficiencies;

- to report to the National Consultative Committee on these matters as a matter of urgency.

The NCCOHS Working Party produced two interim guides, *Controlling Asbestos Hazards: Interim National Guide to Identification, Evaluation and Control of Asbestos Hazards*; and *Asbestos Management; Interim National Guide to the Protection of Workers from the Health Effects of Asbestos*.

The National Commission established a Working Party on Asbestos, through its Standards Development Standing Committee, with the following terms of reference:

- to review the NCCOHS interim guides, *Asbestos Management and Controlling Asbestos Hazards*, taking account of the Department of Employment and Industrial Relations and A.C.T. Asbestos Advisory Committee Asbestos Management Plans, and public comments received on these documents;
- to identify those areas associated with asbestos management where additional standards may be required, and report on the need for such standards to the Standards Development Standing Committee;
- to undertake any other standards development work associated with asbestos as directed by the Standards Development Standing Committee.

Complementing the role of the Asbestos Working Party in developing the Asbestos Guide and Code of Practice, an additional Working Party has been reviewing the NH&MRC *Membrane Filter Method for Estimating Airborne Asbestos Dust*. This latter Working Party has retained the original NH&MRC membership of experienced occupational hygienists and, under the guidance of the tripartite Standards Development Standing Committee, has produced the *Guidance Note on the Membrane Filter Method for Estimating Airborne Asbestos Dust* which is appended to this document.

This document, in its draft form was released for public comment in April of 1987. Following a three month period of public comment all submissions were examined by either the Asbestos or Membrane Filter Method Working Parties, and the draft document amended as appropriate as a result of this review.

The National Commission, having considered the final documents prepared by its Working Parties, now declares a final code of practice pursuant to Section 38(1) of the National Occupational Health and Safety Commission Act.

23 MAY 1988

GLOSSARY OF TERMS

Approved	approved by the relevant State or Territory authority.
Asbestos	is defined as the fibrous form of mineral silicates belonging to the serpentine and amphibole groups of rock-forming minerals, including actinolite, amosite (brown asbestos), crocidolite (blue asbestos), chrysotile (white), tremolite, or any mixture containing one or more of these.
Code	for the purposes of this document, \`the Code' is the NOHSC *Code of Practice for the Safe Removal of Asbestos*.
Construction work	shall include all work performed in or in connection with the installation, erection, repair, cleaning, painting, renewal, renovation, dismantling, maintenance, ornamentation or demolition of buildings, ships, structures, pipes, plant, machinery, parts, artefacts, appliances, or tools or parts thereof.
Employee	any person who has entered into or works under a contract of service or apprenticeship with an employer, whether in a factory, commercial premises, office, ship, construction site or any other place of employment.
Employer	includes any person or body, whether incorporated or unincorporated, including self-employed, who employ one or more persons in industrial or commercial premises, office, ship, construction site or any other place of employment.
Friable material	is material which is easily crumbled or reduced to powder. This form of asbestos represents a particular hazardous state.
Guide	for the purposes of this document, \`the Guide' is the NOHSC *Guide to the Control of Asbestos Hazards in Buildings and Structures*.
Hazard	is potential for harm.
Membrane Filter Method	is the technique outlined in the NOHSC *Guidance Note on the Membrane Filter Method for Estimating Airborne Asbestos Dust*, which is appended to this document.
Fibre	is a particle of asbestos with a diameter of less than 3 um and greater than 5 um in length, with a length to diameter ratio of greater than 3:1.

Plenum	is a building term which means a space used as a pressure-equalising or mixing chamber in ventilation systems. It may be a plantroom, a space between the ceiling and roof of a building or a space below a false floor.
Practicable	practicable having regard to: • the severity of the hazard or risk in question; • the state of knowledge about the hazard or risk; • the availability and suitability of ways to remove or mitigate that hazard or risk; • the cost of removing or mitigating that hazard or risk.
Property owner	shall include the owner of buildings or other structures in which asbestos products may exist.
Registered removalist	is a removalist registered or licenced under the relevant State legislation to perform asbestos removal and maintenance work.
Regulations	includes all provisions given force of law by the competent authority or authorities.
Relevant authority	refers to the appropriate Local, Territorial, State or Commonwealth Government agency.
Removal area	is the region immediately surrounding the site of asbestos removal and is defined by either barriers or the plastic sheeting of the containment. For the purposes of this document, the removal area is assumed to be potentially contaminated with asbestos dust.
Removal site	is the region surrounding, and adjacent to, the asbestos removal area. In a building this may be an entire floor surrounding the removal area
Risk	is the probability that a potential harm may become actual.
State Authority	for the purposes of this document, all references to State legislation or authorities shall include those of Australian Territories.
Structure	includes any industrial plant, erection, edifice, wall, chimney, fence, bridge, dam, reservoir, wharf, jetty, earth works, reclamation, ship, floating structure and tunnelling.
Workplace	includes all places where employees need to be or to go by reason of their work.

1. INTRODUCTION

This Guide, endorsed by the tripartite National Occupational Health and Safety Commission provides the methods, procedures and work practices recommended for the identification, evaluation and control of hazards from *in situ* asbestos in the working environment.

The involvement of the Australian Council of Trade Unions, the Confederation of Australian Industry, and Commonwealth and State Governments in its preparation means that this Guide provides common ground for the development of effective plans of action to protect Australian workers from exposure to asbestos fibres, on a co-operative basis.

This Guide has been written for the use of employers (including government departments and statutory authorities), employees and their representative organisations, in dealing with the presence of asbestos, and for the use of governmental inspectors, asbestos removalists and other persons involved in the direct control of existing asbestos hazards.

Over the years, legislation has been developed and implemented in all States for the purpose of protecting workers who are occupationally exposed to asbestos.

THIS GUIDE AND ATTACHED CODE OF PRACTICE DO NOT DISPLACE STATUTORY REQUIREMENTS DETAILED IN EXISTING OR FUTURE STATE LEGISLATION.

The Guide deals with circumstances in which workers may be exposed to asbestos *in situ* in buildings or other structures, including:

- workers (for example, electricians, carpenters, plumbers and telephone technicians) who may disturb *in situ* asbestos products in the course of installation, maintenance and repair operations
- workers working near but not in contact with *in situ* asbestos products which are inadequately controlled, or are being enclosed, sealed or removed
- workers responsible for enclosure, sealing, encapsulation or removal of *in situ* asbestos products
- workers involved in the demolition, partial demolition or renovation of structures containing *in situ* asbestos products

An asbestos management program, which identifies, evaluates and controls asbestos hazards, in conformity with this Guide, should be part of an organisation's overall approach to the identification, evaluation and control of all workplace hazards.

<u>NOTE</u>: THIS GUIDE DIFFERENTIATES BETWEEN `HAZARD' (POTENTIAL FOR HARM) AND `RISK' (PROBABILITY OF THE HARM BECOMING ACTUAL). FOR EXAMPLE, ASBESTOS INSULATION IN A BUILDING PRESENTS A <u>HAZARD</u>, BUT <u>RISK</u> IS NIL IF NO ASBESTOS FIBRES ARE RELEASED TO THE AIR.

2. BACKGROUND INFORMATION

For the purposes of this Guide, asbestos is the fibrous form of mineral silicates belonging to the serpentine and amphibole groups of rock-forming minerals. The most significant types include chrysotile, crocidolite and amosite (white, blue and brown or grey asbestos respectively).

As a naturally occurring rock fibre, asbestos is mined, then broken down from mineral clumps into groups of loose fibres.

Asbestos has been used in more than 3000 products, including heat resistant textiles (cloth, padding), asbestos cement products (sheets, pipes), special filters for industrial chemicals, thermal insulation products (pipe and boiler insulation), friction materials (clutch plates, brake linings), gaskets, floor tiles, roofing materials, packing materials, paints and protective paper. It has been used as sprayed insulation for buildings and other structures and in their repair.

Small quantities of asbestos may be found mixed with a wide variety of substances, including magnesite, calcium silicate, diatomaceous earths, talc, clay, chalk, sand, cement, paper, pitch, rubber and a wide range of resins. Because of the use of trade names or other reasons, its presence in compounds may not be obvious.

Exposure to airborne asbestos dust occurs particularly in the course of dust-forming operations, such as handling, sawing, sanding, grinding, drilling, turning or general maintenance, renovations or similar operations upon materials containing asbestos.

2.1 HEALTH ASPECTS

SIGNIFICANT HEALTH RISKS MAY ARISE FROM THE INHALATION <u>OF AIRBORNE ASBESTOS FIBRES</u>, AND THEIR PASSAGE INTO THE LUNGS[(1)]. Small fibrous particles may become airborne and be inhaled. Fibres below 3 micrometres in diameter are referred to as *respirable*, meaning that they may enter the deepest parts of the lung. Most larger fibres are deposited in the nose and major airways, and are cleared by normal physiological processes; however, smaller fibres are generally deposited in the minor airways and airspaces (alveoli).

Inhalation of high concentrations of asbestos may result in **asbestosis**, a progressive scarring of lung tissue. Further development of scar tissue (fibrosis) may occur after the cessation of exposure.

The two main forms of **cancer** associated with the inhalation of asbestos are lung cancer and mesothelioma. Generally, fibres below 3 micrometres in diameter and greater than 8 micrometres in length are potentially carcinogenic, and the risk of cancer increases as fibre diameter decreases. The risk of cancer is also greater with increased exposure to asbestos, and vice versa. Cancer in the gastro-intestinal tract and other sites of the body have been noted in workers exposed to asbestos. Whether links exist between such cancers and asbestos exposure is still uncertain.

There is a long latency period which, in the great majority of cases, ranges from ten to fifty years between exposure and the development of mesothelioma and lung disease, so asbestos-induced cancer will continue to occur in Australia long after asbestos exposure has been brought under control. Application of the recommendations of this Guide has the goal of eliminating the risks of asbestos-related diseases. Nevertheless, there should be a consistent striving towards reducing the levels of asbestos exposure to workers.

All forms of asbestos have been found to cause lung cancer, both in a variety of experimental animals and in exposed humans. Cigarette smoking greatly increases the risk of lung cancer in people heavily exposed to asbestos.[(2)]

Mesothelioma is a cancer of the lining of the chest cavity (the pleura) or, less commonly, the lining of the abdominal cavity (the peritoneum). Crocidolite (blue asbestos) and amosite (brown or grey asbestos) have the most potent documented effects in producing this tumour, which is highly malignant. It has no known association with tobacco smoking. The most common cause of mesothelioma is occupational exposure to asbestos.

Pleural plaques (patches of thickening of the pleural membrane) may be associated with the inhalation of asbestos fibres. The appearance of pleural plaques on X-rays is not in itself an indication of cancer.

It should be noted that medical examinations of persons recently exposed to asbestos cannot reveal the presence or absence of health problems related to the exposure. In particular, X-rays are inappropriate for incidental or brief exposures and may pose an additional risk.

3. GENERAL PRINCIPLES

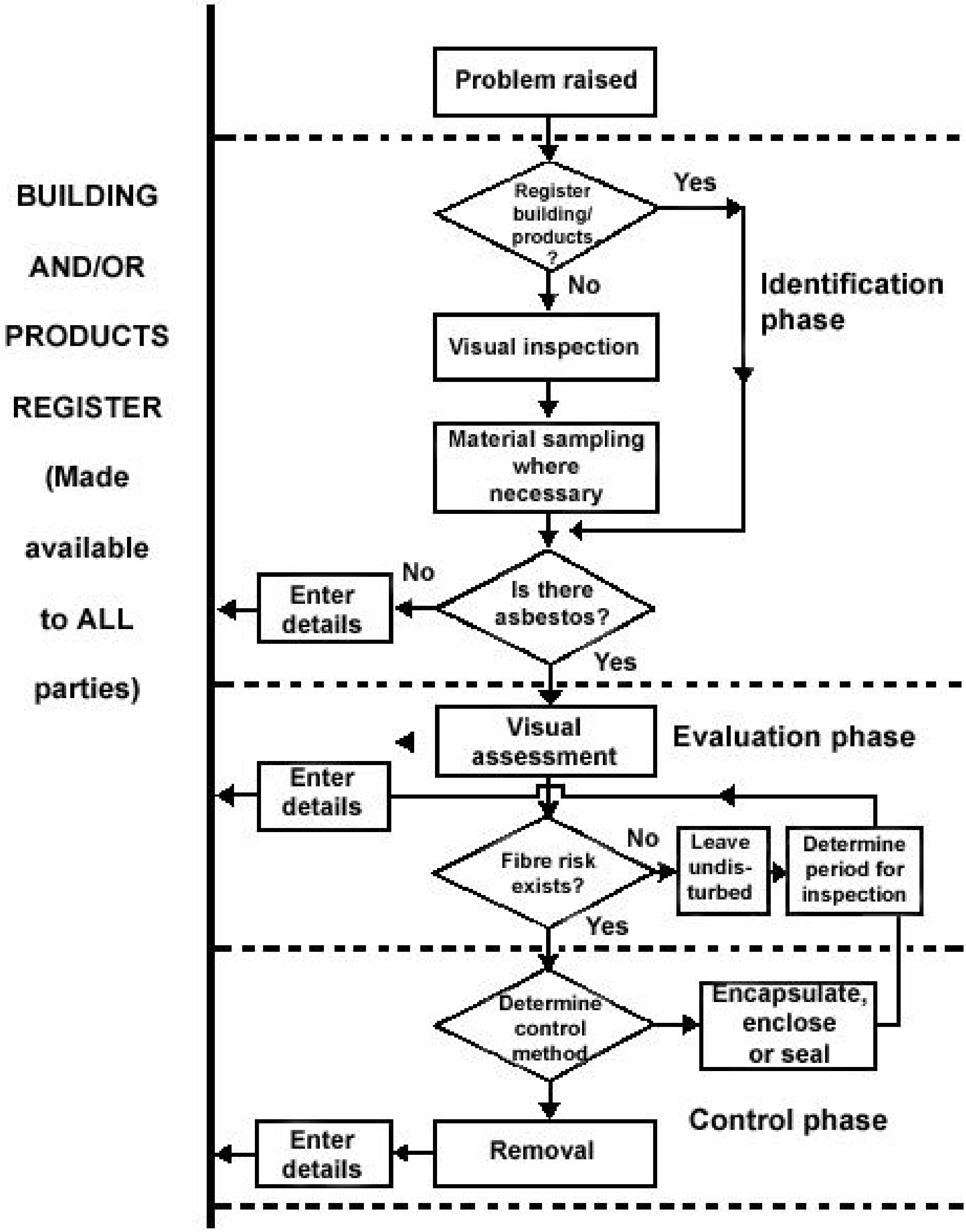
The following principles summarise the position of the National Occupational Health and Safety Commission and should be adhered to by all parties.

3.1 GENERAL

- The ultimate goal is for Australian workplaces to be free of asbestos.
- Asbestos removal may not be immediately necessary, but must be completed before a structure or part of a structure is demolished.
- Removal of such asbestos should be subject to priority setting, determined by the condition and location of the asbestos.
- Asbestos presents a risk only when it is airborne. The risk to health increases as the number of fibres inhaled increases.
- Wherever practicable, substitutes shall be found for asbestos products. Such substitutes for asbestos products should be thoroughly evaluated before use, to ensure that they do not constitute a health hazard. Ultimately, all asbestos products should be eliminated.
- Asbestos which has been incorporated into a stable matrix can be found in many working environments. Provided the matrix remains stable and no airborne dust is produced, it presents no health risk.
- The presence of asbestos should be identified.
- No person shall be exposed to risk of inhalation of asbestos in the course of employment without being provided with full information of the occupational health and safety consequences of exposure and appropriate control strategies.
- At present it is not possible to assess whether there is a level of exposure in humans below which an increased risk of cancer would not occur.(3) Accordingly, exposure should always be limited to the minimum level feasible.
- Asbestos removalists and maintenance workers in an asbestos environment must be suitably protected.
- The recognised occupational exposure standard is that adopted by the National Occupational Health and Safety Commission. The method used to measure exposure is the Membrane Filter Method(4) as endorsed by the National Commission.
- Products containing asbestos shall be labelled accordingly.
- The spraying of asbestos shall be prohibited. All future use of asbestos for insulation shall be prohibited.

FIGURE 1

GENERAL PRINCIPLES OF AN
ASBESTOS MANAGEMENT PLAN



3.2 CONSULTATION

- Where asbestos products are present (or thought to be present) in a building or other structure, full consultation, involvement and information sharing should occur between employers and employees through established consultative processes, at each step of the inspection, identification, evaluation and control process.

3.3 INSPECTION AND IDENTIFICATION

- The aim of inspection is to determine whether a hazard exists.
- The location of asbestos-containing materials shall be determined by persons familiar with construction practices. The materials are then identified by accredited technical persons.

3.4 EVALUATION

- The level of risk shall be determined by competent persons.

3.5 REGISTER

- Owners, or their agents, shall institute an inspection of each structure owned. A register shall be maintained, with regular updating of the results of these inspections. The register will contain details of the site, type and condition of any asbestos products found, and shall be made available for inspection by tenants (employers), employees, union representatives, government representatives, contractors and maintenance personnel. Where no asbestos is found, a record of such a finding shall be kept.

3.6 CONTROL

- Notwithstanding the ultimate goal of an asbestos free workplace, priorities should be set for control in the short term.
- Asbestos products, if stable and inaccessible, should be left *in situ* until demolition, partial demolition or renovation.
- Where *in situ* asbestos is in a stable condition, but accessible, it should be appropriately controlled by a range of options canvassed later in this document.
- Asbestos which is not in a stable condition, or is determined to constitute an unacceptable health risk, shall be removed by a registered removalist.
- Any asbestos left *in situ* shall be clearly labelled and regularly inspected to ensure that it is not deteriorating or contributing to an elevated health risk.
- Property owners in conjunction with agents or employers shall establish procedures to ensure that persons entering an area where asbestos is present shall, unless an assessment of the risk indicates that it is unnecessary, wear appropriate protective equipment and, in all cases, minimise disturbance of the asbestos product.

3.7 REMOVAL AND MAINTENANCE WORK

- Each State and Territory Government should institute a system for the regulation of asbestos removal and/or its necessary maintenance, incorporating a scheme for the registration of asbestos removalists, and for the issuing and review of permits for the removal of asbestos products from particular locations.

- Removal of asbestos shall be carried out only by a removalist registered under the relevant legislation in the appropriate State to perform asbestos removal and maintenance work. Removal shall also be carried out only when a permit under the State legislation has been issued and is in force, for removal work at the particular location. All work shall be undertaken in accordance with the attached *Code of Practice for the Safe Removal of Asbestos*, using a wet removal process, and in accordance with the general procedures listed in this Guide. If dry removal is required for whatever reason, statutory approval would be required.
- A registered asbestos removalist shall give adequate notice to property owners, employers and employees that asbestos removal is to be carried out, and when it is to be carried out. The notification should also include an explanation of the general procedures and equipment involved and the precautions to be taken.
- Asbestos products shall be disposed of in a manner approved by the appropriate authority.

3.8 SUBSTITUTES

The special properties of asbestos cannot always be duplicated in other materials, so its continued use in some highly specialised applications may be unavoidable. Wherever possible, however, asbestos products shall be replaced by materials which either have a lower asbestos content or are, ideally, asbestos-free, and do not themselves constitute a health hazard. When considering alternative materials, account should be taken of all health risks associated with the manufacture, use, transport, storage and disposal of the alternatives proposed.

4. RESPONSIBILITIES

All parties involved with asbestos, such as governments, employers, property owners, employees, health and safety representatives and trade unions, have a positive role in establishing and maintaining safe and healthy work practices.

This role will include ensuring the existence of clear criteria for the evaluation of the hazard and risk associated with the presence of asbestos in the working environment, and determination of the appropriate action to control any assessed risk. Establishment of direct provisions for consultation, communication and co-operation at all levels is essential, and may include the appointment of employee safety representatives, formation of joint health and safety committees and ready access to inspectorial and expert advisory services.

4.1 GOVERNMENTS

Governments have a responsibility, in relation to asbestos, to:

- consider, in consultation with all parties, uniform legislation in general and process guidelines in particular cases, and whether it would bind the Crown
- ensure an adequate system of inspection and effective penalties for breaches by any of the involved parties
- prohibit the spraying of asbestos and use of loose asbestos in insulation
- provide for health monitoring and analysis of collected data; the results of an individual's medical monitoring shall be kept confidential, and released only with the formal authorisation of the individual
- disseminate relevant information
- under Commonwealth legislation, regulate to phase out the import of asbestos and asbestos products
- ensure by legislation the accreditation of asbestos monitoring personnel, the licensing of asbestos removal and maintenance contractors, the advance notification of intended work and the manner in which the work is to be done
- investigate and disseminate information pertaining to the safety of alternative asbestos-free products

4.2 EMPLOYERS

Employers have a responsibility, in relation to asbestos, to:

- provide and maintain, so far as is practicable, safe and healthy work environments and practices generally, and have written policies on the control of asbestos
- comply with legislative provisions
- liaise, where appropriate, with property owners on a continuing basis, so that the existence and condition of asbestos in the working environment is known

- provide instruction and training for employees and supervision of health and safety measures
- consult with employees, their representatives and organisations, and the appropriate regulating authority on control of exposure to airborne asbestos
- anticipate the need for control of asbestos risks to be initiated in any particular case

4.3 PROPERTY OWNERS

Property owners or lessees, or managers or their agents have a responsibility in relation to asbestos, to:

- identify all asbestos products within their properties and to record the location and condition of such asbestos in a register in accordance with Section 3.5
- inform tenants of any asbestos treatment which may become necessary
- ensure that all contractors required to do work are informed of the presence of asbestos
- arrange for regular periodic inspections of properties by a competent person whose advice shall be taken on any treatment indicated

4.4 DESIGNERS, MANUFACTURERS, IMPORTERS, SUPPLIERS AND DEVELOPERS

Designers, manufacturers, importers, suppliers and building developers have a responsibility, in relation to asbestos, to ensure, so far as is practicable, that:

- asbestos is not used in new equipment, products or structures
- equipment used for handling asbestos is efficient in the control of airborne dust
- the presence of asbestos is identified

4.5 EMPLOYEES

Employees have a responsibility, in relation to asbestos, to:

- comply with instructions given for their own safety and health and that of others generally and in work procedures related to asbestos
- co-operate with employers in their fulfilment of legislative obligations
- take care of their own safety and health and that of others, and abide by their duty of care provided for in legislation
- report immediately to their supervisor any perceived safety or health risk

4.6 EMPLOYER AND EMPLOYEE ORGANISATIONS

Employer and employee organisations both have a responsibility, in relation to asbestos, to:

- consult on health and safety matters generally, and on measures that may need to be taken on asbestos in occupied areas or on equipment
- keep themselves informed of advice given by competent persons in relation to inspections of asbestos installations
- co-operate on any reasonable requests for relocation of workstations and variation in work hours during asbestos treatment or removal
- advise members of their obligations and responsibilities under occupational health legislation.

5. HAZARD IDENTIFICATION

Asbestos-containing sprayed insulation materials may be encountered throughout buildings and other structures, especially those built in the 1950s to early 1970s.

Many other asbestos-containing products and materials may still be found. These include vinyl asbestos tiles, laboratory table tops, roofing felts, suspended ceiling tiles, and asbestos cement products. However, these types of materials do not present a significant health risk unless they are tooled, cut, sanded or otherwise abraded or machined (particularly at high speeds) so as to release asbestos dust.

The types of asbestos-containing materials which may be encountered in a building or other structure which are of most concern from a health standpoint include:

- **sprayed-on fireproofing/soundproofing/thermal insulation**. These vary from hard, impervious and well-sealed materials to friable materials applied by spraying or trowelling. The colour will normally vary from white to brown/grey to blue, although in some instances products may have been painted or dyed.

  These materials are found on structural steel members and decks (as fireproofing), ceilings, fire-plugging, fire doors and occasionally on walls (as fireproofing and/or soundproofing). They may be exposed or may be concealed by suspended ceilings or other decorative structures. It should be noted that where the material has been used exclusively for fireproofing, it will probably be found to have been used for the same purpose throughout the building or other structure.

- **acoustic plaster soundproofing**. This is a firm, open-pored, plaster-like material, applied by a trowel. The soundproofing material is usually exposed and not usually painted.

- **insulation.** Asbestos-containing material used in the insulation of air conditioning ducts, hot and cold water pipes, hot-water reservoirs, pressure tanks, and boilers is generally covered with a fabric or metal jacket. Fire doors often contain laminates of asbestos materials covered by wood or metal.

It should be noted that not all spray-on fireproofing/soundproofing, acoustic plaster and insulation contains asbestos. Only laboratory analysis of samples of the particular material can conclusively identify the presence, type and proportion of asbestos.

5.1 MATERIAL SAMPLING

Sampling and analysis of suspect material is the only way to verify the presence of asbestos (air monitoring to determine the presence of asbestos is not acceptable by itself). It is important to sample all suspect material and have it analysed as detailed below. Suspect material should be regarded as containing asbestos, and dealt with accordingly, until the results of the analysis are available.

Samples should be taken of all suspect or friable material. Whatever method is used, it is important that a representative sample be taken. Any variations in the appearance, texture or colour of the material will necessitate additional samples being taken. For multi-storey buildings, at least one sample should be taken per floor.

Samples taken should be adequately labelled, to enable follow-up action. For example, the name and location of the building, the exact location of the sampled material, date of sampling and a batch identification number should all be recorded.

5.2 ANALYSIS OF MATERIAL SAMPLES

Three methods for identifying asbestos are currently used: Polarised Light Microscopy (PLM), X-ray Diffractometry (XRD), and Electron Microscopy (EM).(5) The PLM method generally suffices, but use of one of the other methods for verification of difficult samples may be required.

It is important that the analysis be performed by a competent laboratory to ensure accurate results. False results could lead to expensive abatement actions or allow an existing risk to remain.

The following items should be specified for inclusion in the report received from the testing laboratory:

- the sample identification number
- the analysis method used, that is PLM, XRD, EM
- a description of the sample appearance
- proportion, if known, and type of asbestos present
- comment on other materials detected

This information shall be included in the building register.

5.3 REGISTER

All relevant data from visual inspections or measurements of airborne asbestos shall be systematically recorded in a register which is made available to all parties.

Besides the numerical results of measurements, and the calculated time-weighted averages, the monitoring data shall include information such as:

- the date and exact time of inspection or sampling
- the names of the persons conducting the sampling and analytical determinations
- recommendations made or advice given
- sampling instrument used, its accessories and the method of analysis
- the location, nature, dimensions and other distinctive features of the workplace where static measurements were made, and the workstation or position filled by any person wearing a sampling device
- the source or sources of airborne asbestos emission, their location and the type of work and operations being performed during sampling
- the composition and trade names (if known) of materials containing asbestos
- relevant information on the functioning of the process, engineering controls, ventilation and weather conditions in respect to emission of asbestos dust
- the duration of the workers' exposure, and other comments relating to the exposure evaluation

6. RISK EVALUATION

If analysis of material samples confirms the presence of asbestos, the potential exposure of persons entering the building or other structure should be evaluated. Many factors associated with the condition and composition of the material need to be assessed in this process.

The general condition of all asbestos products contained in the workplace, including those used in the building or other structure for thermal or sound control, shall be visually assessed by a person who is competent to assess the associated risk (that is, the potential of such asbestos products to release airborne dust).

The period between each visual assessment will be determined by the condition and location of the asbestos. In some cases a visual assessment will be required on at least an annual basis. Where the asbestos is in good condition and unlikely to be disturbed, visual assessment at three-yearly intervals may be adequate.

6.1 AIR MONITORING

Air sampling is not an alternative to visual assessment in estimating asbestos contamination and exposure. The Membrane Filter Method [(4)] is the only recognised measurement technique for the determination of airborne asbestos fibre. Results obtained by air sampling are almost invariably below the detection limit of the Membrane Filter Method, especially when samples are taken at times when the asbestos is not being disturbed.

However, air monitoring is required in certain circumstances. For example, when asbestos removal is in progress, the Membrane Filter Method shall be used. Determination of airborne asbestos fibre samples shall be performed only by NATA (National Association of Testing Authorities) registered or government accredited personnel, when such accreditation is available.

If monitoring is required, then personal sampling is considered to be preferable, as this indicates the general distribution of asbestos fibre in the workplace, and the potential for worker exposure. If static air samples are taken, the sample sites should be:

- close to sources of emission in order to evaluate fibre concentrations, or the standard of engineering controls
- at various places in the working area to ascertain the distribution of asbestos dust
- in particular working areas which may be taken to represent typical exposure

NOTE: There are instrumental techniques for the direct determination of airborne asbestos which may have some use as a screening mechanism, but must not be used for determining compliance with the exposure standard. See section 7.1 of the Code.

6.2 EXPOSURE STANDARDS

The National Occupational Health and Safety Commission supports the principle that exposure to airborne asbestos should be kept as low as achievable, and in any case below the specified exposure standards.

The exposure standards listed below are those currently specified by the National Commission for *OCCUPATIONAL EXPOSURES*; that is, for those workers engaged in mining, milling, manufacturing and construction processes related to the use of asbestos, or in the removal of asbestos products.

The exposure standard sets out the time-weighted average (TWA) fibre concentration of the air breathed by the worker throughout a working shift, as calculated from one or more measurements taken over a sampling period of not less than four hours using the Membrane Filter Method [4]. The TWA airborne concentrations shall not exceed:

- chrysotile - 1.0 fibres per millilitre
- crocidolite - 0.1 fibres per millilitre
- amosite - 0.1 fibres per millilitre
- other forms of asbestos - 0.1 fibres per millilitre
- any mixture of these, or where the composition is unknown - 0.1 fibres per millilitre

These values may be reviewed from time to time, therefore the most recent publication of the NOHSC Exposure Standards document [6] should be consulted for any variations.

7. HAZARD CONTROL

An asbestos management program should be seen as part of an organisation's overall approach to risk management. Where the evaluation process has revealed a likelihood of exposure to asbestos fibres, all practicable steps should be taken to ensure that employees are not unnecessarily exposed. A thorough examination of work practices is an essential preliminary action. Procedures designed to ensure that employees are not exposed to asbestos to an extent likely to cause danger to their health should then be adopted. The procedures required may include:

- removal
- substitution
- engineering controls
- safe working procedures
- personal protective equipment
- cleaning, decontamination and waste disposal
- education
- environmental monitoring
- medical surveillance

Consultation should accompany each step.

8. SELECTION OF APPROPRIATE CONTROL METHODS FOR ASBESTOS

The control of asbestos hazards should utilise the most appropriate method applicable to the particular circumstances. Based upon the assessment of the condition of the asbestos, the possibility of further damage or deterioration, and the potential for exposure of personnel to airborne asbestos, the methods of control include: deferment, encapsulation or sealing, enclosure and removal.

The procedures which must be observed during an asbestos encapsulation, sealing, enclosure or removal program are detailed in the attached *Code of Practice for the Safe Removal of Asbestos*.

A SUMMARY OF THE RELATIVE ADVANTAGES AND DISADVANTAGES OF EACH CONTROL METHOD, AS WELL AS SITUATIONS IN WHICH EACH MAY BE CONSIDERED APPROPRIATE, IS PRESENTED IN TABLE 1.

TABLE 1: DETERMINATION OF APPROPRIATE CONTROL METHOD FOR ASBESTOS

DEFER		*ENCAPSULATE OR SEAL*	
APPROPRIATE WHEN:	**NOT APPROPRIATE WHEN:**	**APPROPRIATE WHEN:**	**NOT APPROPRIATE WHEN:**
· Negligible risk of exposure	· Possiblility of deterioration or damage	· Removal difficult or not feasible	· Asbestos deteriorating
AND		· Firm bond to substrate	· Application of sealant may cause damage to material
· Asbestos inaccessible and fully contained	· Airborne asbestos dust exceeds recommended exposure standard	· Damage unlikely	· Water damage likely
OR		· Short life of structure	· Large areas of damaged asbestos
· Asbestos stable and not liable to damage		· Readily visible for regular assessment	
ADVANTAGES	**DISADVANTAGES**	**ADVANTAGES**	**DISADVANTAGES**
· No initial cost	· Hazard remains	· Quick and economical for repairs to damaged areas	· Hazard remains
· Cost of removal deferred	· Need for continuing assessment	· May be an adequate technique to control release of asbestos dust	· Cost for large areas may be near removal cost
	· Asbestos management program required		· Asbestos management system required
			· Eventual removal may be more difficult and costly

ENCLOSURE

APPROPRIATE WHEN:

- Removal extremely difficult
- Fibres can be completely contained within enclosure
- Most of surface already inaccessible
- Disturbance to, or entry into enclosure area not likely

NOT APPROPRIATE WHEN:

- Enclosure itself liable to damage
- Water damage likely
- Asbestos material cannot be fully enclosed

ADVANTAGES

- May minimise disturbance to occupants
- Provides an adequate method of control for some situations

DISADVANTAGES

- Hazard remains
- Continuing maintenance of enclosure
- Asbestos management program required
- Need to remove enclosure before eventual removal of asbestos
- Precautions necessary for entry into enclosure

REMOVAL

APPROPRIATE WHEN:

- Surface friable or asbestos poorly bonded to substrate
- Asbestos is severely water damaged or liable to further damage or deterioration
- Located in A/C duct
- Airborne asbestos exceeds recommended exposure standard
- Other control techniques inappropriate

NOT APPROPRIATE WHEN:

- Located on complex and inaccessible surfaces
- Removal extremely difficult and other techniques offer satisfactory alternative

ADVANTAGES

- Hazard removed
- No further action required

DISADVANTAGES

- Increases immediate risk of exposure especially to removal workers
- Creates major disturbance in building
- Often highest cost, most complex and time consuming method
- Removal may increase fire risk within building; substitute required
- Possible contamination of whole building if removal done poorly

8.1 ENCAPSULATION OR SEALING

Encapsulation involves coating the asbestos material with a sealant, which usually penetrates to the substrate and hardens the material. Sealing is the process of covering the surface of the material with a protective coating impermeable to asbestos. Both are designed to prevent the release of asbestos dust; however, current practice suggests that the use of either method may be of limited application. Encapsulation or sealing is not considered to be an acceptable alternative to repair or removal of severely damaged asbestos materials. Sealing would be inappropriate where the sealed asbestos is likely to suffer mechanical damage, for example, through impact, drilling or sanding.

For large areas the cost of encapsulation or sealing may be near the cost of removal. Any eventual removal may be more difficult and costly. Continuing assessment is required.

The surface to be encapsulated or sealed should be cleaned with an approved vacuum cleaner to remove all debris and dust particles to ensure good adhesion of the coating to be applied. An airless spray must be used in this application, preferably at low pressure and ambient temperature.

Whilst the application of these impermeable coatings may afford a practicable technique to eliminate or minimise the generation of airborne asbestos dust, it should be noted that not all paints and other surface coatings on the market are suitable for these methods. In particular, the sealant should not increase the early fire hazard properties of the material being treated.

8.1.1 **Coatings for encapsulation or sealing**

Both water-based (emulsion) coatings and solvent-based coatings may be used. These may be pigmented or clear. Pigmented coatings, contrasting in colour to the asbestos insulation, will be useful in situations where the asbestos may be subjected to mechanical damage. Damaged areas will be shown by a colour difference, making location of these areas for subsequent repair work relatively simple. Pigmented coatings will also allow easier detection of areas where the coating may inadvertently be absent or is too thinly applied.

Application of coatings shall be by airless spray. Operating pressures should be kept as low as practicable to avoid creating high levels of asbestos dust as the coating material impacts with the surface of the asbestos insulation. Coatings should not be applied by roller because the suction effect arising from this method of application can cause the asbestos insulation to be removed.

To effectively seal asbestos insulation it will generally be necessary to apply several coats of the particular sealing agent. The first, and possibly all of the coats applied, may need to be diluted so that good penetration of the insulation can be achieved. The National Commission intends to review the efficacy and technical specifications for asbestos encapsulants.

Subsequent to sealing any asbestos materials, an efficient clean-up of the surrounding area with an approved vacuum cleaner shall be undertaken to remove any liberated asbestos dust.

8.2 ENCLOSURE

Enclosure is the placing of a barrier between the asbestos material and the surrounding environment. Enclosure of asbestos the material is particularly suitable where the material or its protective coating is

ENCLOSURE

APPROPRIATE WHEN:

?? Removal extremely difficult

?? Fibres can be completely contained within enclosure

?? Most of surface already inaccessible

?? Disturbance to, or entry into enclosure area not likely

NOT APPROPRIATE WHEN:

?? Enclosure itself liable to damage

?? Water damage likely

?? Asbestos material cannot be fully enclosed

ADVANTAGES

?? May minimise disturbance to occupants

?? Provides an adequate method of control for some situations

DISADVANTAGES

?? Hazard remains

?? Continuing maintenance of enclosure

?? Asbestos management program required

?? Need to remove enclosure before eventual removal of asbestos

?? Precautions necessary for entry into enclosure

REMOVAL

APPROPRIATE WHEN:

?? Surface friable or asbestos poorly bonded to substrate

?? Asbestos is severely water damaged or liable to further damage or deterioration

?? Located in A/C duct

?? Airborne asbestos exceeds recommended exposure standard

?? Other control techniques inappropriate

NOT APPROPRIATE WHEN:

?? Located on complex and inaccessible surfaces

?? Removal extremely difficult and other techniques offer satisfactory alternative

ADVANTAGES

?? Hazard removed

?? No further action required

DISADVANTAGES

?? Increases immediate risk of exposure especially to removal workers

?? Creates major disturbance in building

?? Often highest cost, most complex and time consuming method

?? Removal may increase fire risk within building; substitute required

?? Possible contamination of whole building if removal done poorly

8.1 ENCAPSULATION OR SEALING

Encapsulation involves coating the asbestos material with a sealant, which usually penetrates to the substrate and hardens the material. Sealing is the process of covering the surface of the material with a protective coating impermeable to asbestos. Both are designed to prevent the release of asbestos dust; however, current practice suggests that the use of either method may be of limited application. Encapsulation or sealing is not considered to be an acceptable alternative to repair or removal of severely damaged asbestos materials. Sealing would be inappropriate where the sealed asbestos is likely to suffer mechanical damage, for example, through impact, drilling or sanding.

For large areas the cost of encapsulation or sealing may be near the cost of removal. Any eventual removal may be more difficult and costly. Continuing assessment is required.

The surface to be encapsulated or sealed should be cleaned with an approved vacuum cleaner to remove all debris and dust particles to ensure good adhesion of the coating to be applied. An airless spray must be used in this application, preferably at low pressure and ambient temperature.

Whilst the application of these impermeable coatings may afford a practicable technique to eliminate or minimise the generation of airborne asbestos dust, it should be noted that not all paints and other surface coatings on the market are suitable for these methods. In particular, the sealant should not increase the early fire hazard properties of the material being treated.

8.1.1 **Coatings for encapsulation or sealing**

Both water-based (emulsion) coatings and solvent-based coatings may be used. These may be pigmented or clear. Pigmented coatings, contrasting in colour to the asbestos insulation, will be useful in situations where the asbestos may be subjected to mechanical damage. Damaged areas will be shown by a colour difference, making location of these areas for subsequent repair work relatively simple. Pigmented coatings will also allow easier detection of areas where the coating may inadvertently be absent or is too thinly applied.

Application of coatings shall be by airless spray. Operating pressures should be kept as low as practicable to avoid creating high levels of asbestos dust as the coating material impacts with the surface of the asbestos insulation. Coatings should not be applied by roller because the suction effect arising from this method of application can cause the asbestos insulation to be removed.

To effectively seal asbestos insulation it will generally be necessary to apply several coats of the particular sealing agent. The first, and possibly all of the coats applied, may need to be diluted so that good penetration of the insulation can be achieved. The National Commission intends to review the efficacy and technical specifications for asbestos encapsulants.

Subsequent to sealing any asbestos materials, an efficient clean-up of the surrounding area with an approved vacuum cleaner shall be undertaken to remove any liberated asbestos dust.

8.2 ENCLOSURE

Enclosure is the placing of a barrier between the asbestos material and the surrounding environment. Enclosure of asbestos the material is particularly suitable where the material or its protective coating is

8.1 ENCAPSULATION OR SEALING

Encapsulation involves coating the asbestos material with a sealant, which usually penetrates to the substrate and hardens the material. Sealing is the process of covering the surface of the material with a protective coating impermeable to asbestos. Both are designed to prevent the release of asbestos dust; however, current practice suggests that the use of either method may be of limited application. Encapsulation or sealing is not considered to be an acceptable alternative to repair or removal of severely damaged asbestos materials. Sealing would be inappropriate where the sealed asbestos is likely to suffer mechanical damage, for example, through impact, drilling or sanding.

For large areas the cost of encapsulation or sealing may be near the cost of removal. Any eventual removal may be more difficult and costly. Continuing assessment is required.

The surface to be encapsulated or sealed should be cleaned with an approved vacuum cleaner to remove all debris and dust particles to ensure good adhesion of the coating to be applied. An airless spray must be used in this application, preferably at low pressure and ambient temperature.

Whilst the application of these impermeable coatings may afford a practicable technique to eliminate or minimise the generation of airborne asbestos dust, it should be noted that not all paints and other surface coatings on the market are suitable for these methods. In particular, the sealant should not increase the early fire hazard properties of the material being treated.

8.1.1 **Coatings for encapsulation or sealing**

Both water-based (emulsion) coatings and solvent-based coatings may be used. These may be pigmented or clear. Pigmented coatings, contrasting in colour to the asbestos insulation, will be useful in situations where the asbestos may be subjected to mechanical damage. Damaged areas will be shown by a colour difference, making location of these areas for subsequent repair work relatively simple. Pigmented coatings will also allow easier detection of areas where the coating may inadvertently be absent or is too thinly applied.

Application of coatings shall be by airless spray. Operating pressures should be kept as low as practicable to avoid creating high levels of asbestos dust as the coating material impacts with the surface of the asbestos insulation. Coatings should not be applied by roller because the suction effect arising from this method of application can cause the asbestos insulation to be removed.

To effectively seal asbestos insulation it will generally be necessary to apply several coats of the particular sealing agent. The first, and possibly all of the coats applied, may need to be diluted so that good penetration of the insulation can be achieved. The National Commission intends to review the efficacy and technical specifications for asbestos encapsulants.

Subsequent to sealing any asbestos materials, an efficient clean-up of the surrounding area with an approved vacuum cleaner shall be undertaken to remove any liberated asbestos dust.

8.2 ENCLOSURE

Enclosure is the placing of a barrier between the asbestos material and the surrounding environment. Enclosure of asbestos the material is particularly suitable where the material or its protective coating is

liable to mechanical damage. An example of this would be building a box enclosure around exposed asbestos-lagged steam pipes.

A suspended ceiling cannot be considered as an enclosure if any type of work, either routine or otherwise, is performed above the suspended ceiling or if the space between the suspended ceiling and the reinforced concrete slab or ceiling proper above, is an air plenum.

8.3 REMOVAL

Major asbestos removal programs are often complex, expensive and cause substantial disruption to the occupancy of the building. Even then, the removal process poses an increased risk to the personnel engaged in the removal and can result in increased fibre counts in other areas if the removal program is not strictly controlled. In general, asbestos insulation should be removed:

- when it is breaking away from the substrate base; or
- when the insulation is likely to be abraded or otherwise damaged; and
- when the surface is friable and other control techniques are not deemed to be satisfactory

As there is a possibility that non-asbestos insulation may become contaminated from adjacent sprayed asbestos, consideration may need to be given to the treatment of this adjoining non-asbestos insulation.

9. DEMOLITION AND STRUCTURAL ALTERATION

Demolition and structural alteration of buildings or other structures containing asbestos-based insulation shall be under statutory supervision, and any work which may disturb asbestos should be performed by approved removalists holding appropriate licences.

Supervisors of demolition and structural alteration projects involving asbestos must be suitably trained and experienced, and

- report directly to the property owner/construction manager
- have authority to stop work if there is a risk to health and safety
- have full-time involvement in the asbestos work
- work in conjunction with those conducting air monitoring.

Demolition contractors shall be required to assess the presence of asbestos before demolition proceeds. Where asbestos is shown to be present, this should be *reported to the appropriate authority, together with a proposed removal program for approval*. Where asbestos is likely to produce unacceptable levels of asbestos dust in the course of demolition, steps will be required to control exposure.

If possible, all asbestos should be removed before demolition is commenced. In some circumstances, partial removal, followed by partial demolition to allow access to previously obstructed asbestos material, may be necessary. In such cases, the partial demolition operation shall be conducted under conditions appropriate to the removal work. Removal shall be performed in accordance with this Guide by approved asbestos removalists who shall have a legal obligation to remove asbestos, and dispose of the waste, in a safe manner.

Other materials containing asbestos may be encountered during demolition or alteration work, the main example being asbestos cement (fibrocement) building products from which dust can be released into the atmosphere if these products are sawn, drilled or crushed. The techniques for handling and removal of asbestos-cement products are detailed in section 9.1 of the attached Code of Practice.

10. REGISTRATION OF ASBESTOS REMOVALISTS

Contractors or other agencies engaged in asbestos removal and maintenance work, whether incorporated, unincorporated or self-employed, shall be registered as asbestos removalists under State or Territory legislation.

No person should be allowed to remove asbestos, or engage in maintenance work upon asbestos products, unless they or their employer are so registered. Registration should be dependent upon the contractor or other agencies' ability to demonstrate competence in asbestos removal and maintenance work, including the training of operators.

Before the commencement of asbestos removal or maintenance work, a permit for the particular work is required from the relevant authority. A registered removalist who has breached any relevant regulations should have his/her registration cancelled or suspended forthwith. It is appropriate that registered removalists be required to lodge a bond with the registration authority.

11. MEDICAL SURVEILLANCE OF ASBESTOS-EXPOSED WORKERS

Provision for medical surveillance of workers exposed to asbestos exists in State and Territory regulations. It should be noted that medical examination of such workers cannot detect asbestos-related disease at a stage where intervention could lead to recovery. Such monitoring is also ineffective in assessing whether hazardous exposure is occurring. In any case, because exposure to asbestos below the levels which are specified in this Guide, (levels which may be achieved by attention to the precautions also specified herein), will not lead to asbestos-related disease, primary prevention should be directed to reducing or eliminating exposure. Workers who have been heavily exposed to asbestos in the past should be under periodic medical surveillance.

Nevertheless, it is recommended that all workers in all potentially hazardous trades should receive health surveillance through the workplace. Apart from the advantages of general health promotion and protection, such surveillance affords opportunity for assurance as to understanding of specific preventive measures against asbestos exposure; for reassurance on any concerns about exposure; and for checking on suitability for work particularly in confined spaces with respirators. The occupational physician necessarily liaises with the occupational hygenist concerned in environmental management.

The timing and form of any medical examinations vary with individual circumstances. Normally examinations are made at the time of placement, at intervals of two years, and at termination of work, but do not include X-ray, lung function and physical examination unless indications present.

12. LABELLING AND WARNING SIGNS

Material containing asbestos should be labelled as follows:

CAUTION

. CONTAINS ASBESTOS FIBRE

. AVOID CREATING DUST

. SERIOUS INHALATION HEALTH HAZARD

All identified asbestos in a building or other structure should be labelled so that it is clearly visible to persons using the area, until it is finally removed. This requirement applies equally to asbestos in good condition and to treated asbestos.

Labels used for this purpose must identify the material as containing asbestos and should comply with Australian Standard 1216.[7] All warning signs should comply with Australian Standard 1319.[8]

Enclosed areas, and areas which contain encapsulated or sealed asbestos, should be labelled or otherwise signposted with cautionary warning signs in accordance with Australian Standard 1319.[8] The purpose of these cautionary warning signs is to ensure that the asbestos is not worked upon without correct precautions being taken and to ensure that, in the event of damage, the occurrence is reported immediately so that corrective action can be taken.

An example of these signs is shown below.

CAUTION ASBESTOS

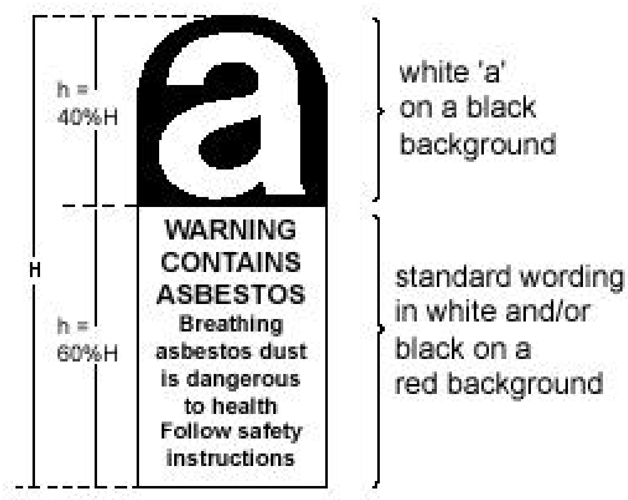
RESPIRATORY PROTECTION MUST BE WORN

NO ADMITTANCE - ASBESTOS

REPORT TO PROPERTY MANAGER

An alternative international[9] symbol may also be used for labelling of asbestos-containing products.

INTERNATIONAL ASBESTOS LABEL



13. DISPOSAL OF ASBESTOS WASTE

Asbestos waste comes in a variety of forms ranging from fine dust, produced by machining operations, to large sheets of asbestos stripped from buildings under demolition. Other forms include lagging materials, loose fibre, swarf, small off-cuts and floor sweepings which may accumulate around or under machines and on floors.

13.1 WASTE CONTAINERS

Solid asbestos waste should be collected in heavy duty polyethylene bags, approximately 0.2mm thick, or other approved containers. It is recommended that a maximum bag size of 1200mm (length) x 900mm (width) be observed. Bags should be filled to no more than 50 per cent capacity.

To reduce bag rupture and to minimise asbestos contamination, asbestos waste should be double-bagged; once at the workface and a second time away from the workface but prior to leaving the removal area enclosure. Where large metal storage bins or kibbles are provided in, or immediately adjacent to the removal area, a single bag may be adequate. In these circumstances, washing down of the bags in the removal area would be a satisfactory method of contamination control.

To prevent bag rupture and for ease of handling, the loaded weight of the bag should not exceed limits consistent with good manual handling practice. Each bag or other container shall be labelled on its outermost surface, with the following warning statement:

CAUTION - ASBESTOS

AVOID CREATING DUST

SERIOUS INHALATION HEALTH HAZARD

Bags or primary containers which have held asbestos material should not be re-used, and containers marked as above should not be used for any other purpose.

13.2 WASTE COLLECTION AND DISPOSAL

Transport and final disposal of asbestos waste material shall be carried out in a manner which will prevent the liberation of asbestos dust to the atmosphere. Care must be taken to ensure that the waste materials are suitably contained, and that the integrity of this containment is not damaged during handling or transportation. In particular, bags of asbestos waste shall not be thrown or dropped from a height which may rupture the bag.

Controlled wetting of waste should be employed, where practicable, to reduce asbestos dust emission during bag sealing and in cases of accidental bag rupture during transportation. Waterlogging should be avoided as this excess contaminated water may leak out of the bags, thereby creating a future source of airborne asbestos dust.

All asbestos waste material shall be buried at a site and in a manner approved by the local and state authorities.

14. OTHER CONSIDERATIONS

A number of matters which are related to the general nature of this Guide have been discussed in detail in the attached Code of Practice. These matters include:

- training and education of personnel involved in removal of asbestos materials
- selection of protective clothing and equipment, including a guide to appropriate respiratory protection
- general hygiene requirements for handling asbestos materials, including personal decontamination

APPENDIX A

REFERENCES

1. Levine, R.J. (ed.), *Asbestos: An Information Resource*, National Institutes of Health, Washington, D.C., (NIH Publ. No. 81-1681), 1981.

2. National Health and Medical Research Council, *Report on the Health Hazards of Asbestos*, NH&MRC, Canberra, 1981.

3. International Agency for Research on Cancer, IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man: ASBESTOS, 14, 81 IARC, Lyon France, 1979.

4. National Occupational Health and Safety Commission, *Guidance Note on the Membrane Filter Method for Estimating Airborne Asbestos Dust*, NOHSC, Sydney, 1988, attached.

5. Rajhans, G.S. & Sullivan J.L., *Asbestos Sampling and Analysis*, Ann Arbor Science Publishers Inc., Michigan, 1981.

6. National Occupational Health and Safety Commission, *Exposure Standards for Atmospheric Contaminants in the Occupational Environment*, NOHSC, Sydney 1988.

7. Standards Association of Australia, AS 1216-1981, *Classification, Hazard Identification and Information Systems for Dangerous Goods. Part 1- (1981): Classification and Class Labels for Dangerous Goods*, SAA, Sydney, 1981.

8. Standards Association of Australia, AS 1319-1979, *Rules for the Design and Use of Safety Signs for the Occupational Environment*, SAA, Sydney, 1979.

9. Council of the European Communities, *Special Provisions on the Labelling of Products Containing Asbestos*, Council Directive 76/769/EEC Annex II, Official Journal of the European Communities No L 263/34, 24.9.83.

BIBLIOGRAPHY

- Ontario Ministry of the Attorney General, *Report of the Royal Commission on Matters of Health and Safety Arising from the Use of Asbestos in Ontario*, Queens Printer for Ontario, Toronto (1984).
- Burdett, G.J. and Jaffrey, S.A.M.T., `Airborne Asbestos Concentrations in Buildings', Ann. Occup. Hyg. 30 No 2, 185-199, (1986).
- Doll, R. and Peto, J., *Effects on Health of Exposure to Asbestos*, (UK) Health and Safety Executive, HMSO, London (1985).
- International Labour Organisation (ILO), Convention 162 `Concerning Safety in the Use of Asbestos', Recommendation 172 `Concerning Safety in the Use of Asbestos', ILO, Geneva, (1986).

ASBESTOS

CODE OF PRACTICE FOR THE SAFE REMOVAL OF ASBESTOS [NOHSC:2002(1988)]

CONTENTS

INTRODUCTION

This Code of Practice outlines the basic principles which should be followed in selecting the most suitable technique for the safe removal of asbestos-based thermal or acoustic insulation including friable asbestos boards, and is aimed at minimising the concentration of airborne asbestos fibre.

This Code is directed at specific removal jobs such as those involving the removal of the sprayed asbestos coatings used for thermal and acoustic insulation in buildings and the extensive asbestos-based lagging on boilers and other industrial plant. It is not intended that procedures outlined in the main body of the Code should cover work involving asbestos-cement (fibro) products and floor tiles containing asbestos.

The work practices and precautions to be adopted in the safe removal of asbestos-based products vary considerably with the type of product, amount of asbestos, its condition and location. The objective of this Code is to provide a guide to good current practice which may be adapted to the particular circumstances of the removal job. Because the work practices for the handling of asbestos-cement (fibro) products differ from those applicable to thermal insulating, the safe working practices for these materials have been presented in a separate section of this Code.

This Code has been compiled with reference to the current NH&MRC(1), OSHA(2) and HSC(3) codes of practice for the removal of asbestos and is designed to be read in conjunction with the attached *Guide to the Control of Asbestos Hazards in Buildings and Structures*, where the more general aspects of asbestos and its potential hazards are outlined.

1. PLANNING AND PROGRAMMING CONSIDERATIONS

As removal of asbestos-containing insulating material by an approved removalist is often done by contract or tender, it is essential that the precise nature of the work to be done is understood by both contractor and client. Any misunderstanding may lead to the contractor utilising removal procedures which endanger the health of his/her employees, neighbouring workers and local residents and may jeopardise his/her removal licence.

1.1 INFORMATION TO BE SUPPLIED BY CLIENT

The client must supply precise details of the removal requirements to the asbestos removalist prior to commencement of any removal work; however, it is recognised that in some cases the full extent of the asbestos material is not always known until after the removal is under way. Some materials may be inaccessible, or concealed in such a way that some removal has to be carried out before the asbestos is detected.

In the preparation of job specifications the following considerations should be addressed:

(a) Location -

- indoors
- outdoors but protected
- outdoors exposed to weather
- enclosed in ducts or trenches below ground level
- difficult or unusual site conditions which will influence the selection or application of removal methods, particularly in regard to transport, scaffolding or weather protection

(b) Technical description of material to be removed, with details of type of asbestos present and any special or unusual materials.

(c) Dimensions of surfaces. Where these are adequately detailed on drawings, preferably coloured to indicate areas for removal, provision of copies of the drawings may be sufficient. Otherwise, information of the following nature will be required:

- surface dimensions of flat or large curved areas, and thickness of insulation
- external diameters of pipes
- length of each size pipe
- number and type of pipe fittings, for example, flanged joints, valves, tees, expansion bends
- particular detail is to be provided if asbestos is to be removed from any part of the building's air conditioning system

(d) Details of any pipework sections that are steam or electrically heated and the arrangement of its insulation.

(e) Details of any section or materials to be left in place.

(f) Confirmation and details of residual heat that will remain in pipework, boilers, turbines or refinery equipment.

(g) Any unusual or specific hazards associated with the removal job.

(h) Temperature considerations [4] -

- normal working temperature for each portion of the plant concerned
- ambient temperature at the removal area

(i) Conditions of substrate surfaces - special requirements, such as the removal or otherwise of protective paint or lacquer from pipework or for the application of paint or other protective coatings to the substrate from which the asbestos-based material has been removed.

(j) Types of fittings and supports and whether or not these may be removed or disposed of with the waste.

(k) Type of finish required.

(l) Special service requirements; for example, where there is any potential hazard from contact with live electrical equipment in use in the removal area, attention should be drawn to this fact.

(m) Where electrical switch gear or panels are to be sealed, consideration should be given to the provision of supplementary ventilation to dispose of potential heat build-up and consequent fire risk.

(n) Site occupancy restrictions and conditions.

(o) Adjacent area cleaning (adjacent areas which are to be cleaned or are to be protected from airborne dust and are to be cleaned on completion).

(p) Safety practices to be followed under relevant legislation.

(q) Location of any relevant electrical cables.

12. INFORMATION TO BE SUPPLIED BY THE APPROVED REMOVALIST

Information pertaining to the relevant sections of 1.1, and how the removalist proposes to undertake the removal program.

If required, the approved removalist should provide specifications or drawings showing details as follows:

(a) Type and extent of isolation required at the asbestos removal area and location of restricted access barriers.

(b) Particular methods to be adopted when removing material, including detail of the contamination control program, for example -

- provision of negative air pressure and the location of the exhaust unit
- location of decontamination unit

(c) Waste disposal program -

- storage on-site

- storage in bin on-site
- removal from building (using an isolated lift)

(d) Waste disposal site and approval from relevant local disposal authority.

(e) Shapes and sizes of temporary buildings required by the removalist, together with particulars of water, light and power requirements.

1.3 GUIDELINES FOR PLANNING AND PROGRAMMING

Frequently, the approved removalist's operations are dependent upon progress of other contractors at the site. It is therefore recommended that the asbestos removalist be provided with details of planning schedules which will control his/her work and allow him/her to effect removal without other personnel being present in the asbestos removal area. Conversely the work of other contractors needs to be scheduled to preclude them working near to, or accidentally breaking into, the asbestos removal area.

The following are the major points to which early consideration should be given:

(a) Safety of personnel.

(b) Identification of types of asbestos involved.

(c) Program of commencement and completion dates. However, it should be recognised that unforeseen problems with removal or the extent of the asbestos cannot always be ascertained prior to removal work commencing.

(d) Responsibility for the supply and application of isolating materials; for example, ropes, barriers, plastic screens, waste containers and warning signs.

(e) Preparation of surfaces (pre-removal) cleaning.

(f) Areas to be left free of insulant on a temporary or permanent basis.

(g) Precise information on extent of work covered by contract.

(h) Limitations of access to removal area.

(i) Conditions of employment on the site, including the labour and supervision required and agreed working hours.

(j) Transport facilities.

(k) Protected storage area pending the removal of asbestos-based materials.

(l) Availability of water, power, heat, light and drainage.

(m) Accommodation, decontamination and canteen facilities.

(n) Provision of access equipment, such as scaffolding or ladders.

(o) Protection of adjacent plant and machinery.

(p) Waste disposal responsibilities and clean-up requirements.

(q) Temporary sealing of asbestos where necessary.

(r) Notification to, and approval from, regulating authorities where necessary.

(s) Responsibility for air monitoring.

(t) Cleanliness standards which must be achieved to fulfil the contract.

1.4 TRAINING

Prior to engagement in the work, all asbestos removal workers shall be instructed in the relevant aspects of asbestos health hazards, safe working procedures, and the wearing and maintenance of protective clothing and equipment. The quality of this training could be assessed as one of the stages in determining whether an asbestos removalist is sufficiently experienced to undertake the removal.

The degree of training should be appropriate to the trade and function of the individual within the organisation and should be sufficiently detailed to ensure that the individual understands not only the procedural and safety requirements, but also the reasons for these requirements.

1.5 SUPERVISORY PERSONNEL

Supervisory personnel shall have a detailed knowledge of the precautions and procedures outlined in this Code and, in the light of this knowledge and personal experience, shall assume the following responsibilities:

- to plan the total removal procedure; the pre-removal setting up, the actual removal and final cleaning operation
- to select the most appropriate technique for removal of asbestos
- to ensure that all necessary measures are taken to reduce the airborne concentration of asbestos dust, and that in any case, workers are not exposed to levels exceeding the recommended exposure standard
- to arrange for, and assess results of, air monitoring where appropriate
- to ensure that all workers under his/her supervision are adequately trained in the safe working practices outlined in this Code
- to ensure that the removal is continually supervised and that the operation is carried out in a safe and proper manner, in accordance with the precautions listed in this Code
- to ensure that personal protective equipment is maintained in good condition
- to ensure that the removal site is maintained in a clean condition, that waste is quickly and properly disposed of, and that the personal hygiene procedures are continually observed

2 PREPARATION OF THE REMOVAL SITE FOR A MAJOR REMOVAL PROGRAM

In preparing the removal site, a number of considerations must be addressed. These include the method of containment of the removal area and whether complete enclosure is possible, the provision and location of decontamination and changing facilities, and the precautions which must be implemented to prevent the spread of asbestos contamination away from the removal area. Each of these aspects is discussed in turn in the following sections.

2.1 DETERMINATION OF ASBESTOS REMOVAL AREA WHERE TOTAL ENCLOSURE IS NOT POSSIBLE

In some instances such as in large power stations or other industrial plant, it may not be possible to provide an enclosure around the asbestos removal area. In these circumstances the boundaries of the asbestos removal area shall be determined by assessment of supervisory staff; however, the boundary would not normally be less than ten metres from the asbestos workface unless an existing barrier is already in place. This distance may be decreased or increased on the basis of air monitoring results for asbestos dust.

The boundary of the removal area shall be defined by barrier, rope or rail and by appropriately placed signs indicating that it is an asbestos removal area. The signs shall be state:

ASBESTOS WORKING AREA - NO UNAUTHORISED ENTRY

RESPIRATORY PROTECTION ESSENTIAL

Static air sampling may be necessary to confirm the suitability of the selected boundaries. Experience will generally enable supervisory staff to quickly determine and set boundaries for most types of removal.

Entry to the removal area shall be restricted to personnel directly engaged in the asbestos removal. Other persons entering the area will be required to observe the appropriate safety precautions for that area. All dirty work clothing, tools, equipment and bagged waste materials should be properly decontaminated before being removed. Those items that cannot be decontaminated through a decontamination unit should be plastic wrapped and sealed and only opened in another removal area.

2.2 SITE PREPARATION FOR ASBESTOS REMOVAL FROM BUILDINGS AND OTHER STRUCTURES

Where total enclosure of the removal area is possible, isolation of the area can be achieved by the installation of plastic sheeting (approximately 0.2mm thick) on the floor and walls of the structure. It may be necessary to erect a temporary timber or metal frame to which the plastic barrier can be attached. All joints shall be overlapped (by approximately 200mm) and double taped to ensure the area is completely sealed off. In some circumstances the use of adhesives may supplement the use of tape.

Existing floor coverings should be removed where practicable. A double layer of plastic sheeting, (suitably fixed by double-sided tape or adhesive to prevent movement between layers), should be used on the floor of the containment area, and a turn-up of 300mm should be used where the floor joins the sidewalls. Extra strength in the containment floor can be achieved by running the double layers of plastic at 90° to each other. `Duct tape' or `plastic wrapping tape' is preferable to `masking tape' when sealing plastic sheeting.

Where asbestos is removed from an entire floor of a multi-storey building, all passenger elevators shall be prevented from stopping at the floor from which asbestos is being removed. Removal workers may gain access to the floor via the fire stairs or from an elevator dedicated for this purpose.

All movable furniture, plant and fittings should be removed from the asbestos removal area. The immovable items should be fully wrapped and sealed in suitable plastic sheeting so that they are effectively isolated from the removal area. In regions of heavy traffic or high wear, additional masking or barricading may be necessary.

Where masking operations may liberate asbestos fibres, all persons in the removal area shall wear respiratory protective equipment approved for asbestos. This precaution is particularly applicable when removing existing barriers or partitions such as false ceiling tiles. Where asbestos materials have fallen on to a false ceiling, the ceiling should only be removed under full removal conditions. Any utility or service line which penetrates into the ceiling space should be sealed up when it is located if it cannot be sealed from outside the removal area.

Aside from specific asbestos extraction units, all ventilation and air-conditioning networks servicing the removal area must be closed down for the duration of the removal job. All vents must be thoroughly masked to prevent the ingress of asbestos dust into the duct network. Upon completion, and after final cleaning of the removal area, all mechanical ventilation filters for recirculated air should be replaced if possible.

Additional care should be taken to ensure that asbestos dust cannot escape at points where pipes and conduits pass out of the removal area. Greater attention to masking and compliance testing is required in these regions, particularly if service riser-shafts pass through the removal area.

To prevent the escape of airborne asbestos dust from the removal area enclosure, an exhaust extraction fan shall be installed in a position so as to create a negative air pressure of approximately 12Pa (water gauge) within the removal area. In this arrangement, the major and usually only route of air into the removal area would be through the decontamination unit.

The air extracted by this system must pass through an appropriate High Efficiency Particulate Air (HEPA) filter to remove any asbestos dust. Ideally, air extraction units should be so situated that access to the filters can be gained from the removal area; however, the unit is kept outside the removal area. This expedites the otherwise difficult decontamination of these units and allows another unit to be brought into service in the event of a breakdown. Where it is not possible to change the filter within the removal area, a temporary enclosure should be constructed around the unit during the filter replacement.

The HEPA filter must comply with the minimum 99.97 per cent efficiency requirement detailed in Australian Standard 1324.[5] A coarse pre-filter should be installed prior to the HEPA filter to prolong the useful life of the high efficiency filter. Where practicable, the discharge point for this extraction unit should be to the outside air, distant from other working areas, air-conditioning inlets or breathing air compressors.

EXTRACTION EQUIPMENT SHALL BE OPERATED CONTINUOUSLY WHILST THE REMOVAL ENCLOSURE IS IN PLACE.

The most satisfactory method for assessing the integrity of the filter and seal fittings is by regular inspection, in conjuction with a static pressure alarm which indicates a failure in the system.

Air monitoring of the exhaust from the extraction unit is a specialised procedure for which the Membrane Filter Method [(6)] is unsuitable because the results obtained may not truly reflect the actual fibre concentration in the exhaust air. Non-isokinetic sampling may give false negative results which may lead to unwarranted confidence in the filter integrity.

WHEN INSTALLING THE ASBESTOS REMOVAL AREA CONTAINMENT, EXTRA CONSIDERATION MUST BE GIVEN TO THE ALTERATION OF THE FIRE RATING OF THE BUILDING AND TO THE PROVISION OF FIRE FIGHTING FACILITIES, EMERGENCY EXITS AND EMERGENCY LIGHTING.

2.2.1 **Compliance testing of removal area containment prior to commencement of work**

Before any asbestos removal begins in an enclosure, a non-toxic smoke generator should be used to test the integrity of the removal area enclosure, prior to the operation of the extraction unit.

A visual inspection of the enclosure shall also be carried out at the beginning of each working period. Any defect revealed during inspection shall be remedied immediately. Where necessary, provision for air monitoring shall be made.

2.3 DECONTAMINATION FACILITIES

In many instances, the only satisfactory method of providing appropriate changing facilities is by the provision of a mobile or specially constructed on-site unit. The decontamination facility should be sited immediately adjacent to, and joined to, the enclosed asbestos removal area. This unit can be divided into three distinct regions, namely:

(a) *DIRTY DECONTAMINATION AREA*

(b) *CLEAN DECONTAMINATION AREA*

(c) *CLEAN CHANGING AREA*

These areas should be separated by means of a suitable airlock or buffer zone. Normally this airlock would consist of spring loaded doors or two or more overlapping sheets of plastic sheet positioned so as to define the boundary between each segment of the decontamination facility, whilst allowing personnel access and airflow towards the removal area. To ensure a good airflow through the unit where doors are used to segment the decontamination unit, large openings with a hinged flap to operate as a one-way valve should be provided.

Generally no more than six persons should use the one decontamination facility. A diagrammatic view showing an example of the arrangement of this facility is presented in Figure 2.

The *DIRTY DECONTAMINATION AREA* should have provision for:

- vacuum cleaning or hosing down of contaminated clothing and footwear
- storage of contaminated clothing and footwear
- airflow towards the removal area
- a shower area with an adequate supply of warm water

The *CLEAN DECONTAMINATION AREA* should have provision for:

- storage of individual respirators in containers or lockers
- airflow towards the dirty decontamination area
- a shower area with an adequate supply of warm water

The *CLEAN CHANGING AREA* should have provision for:

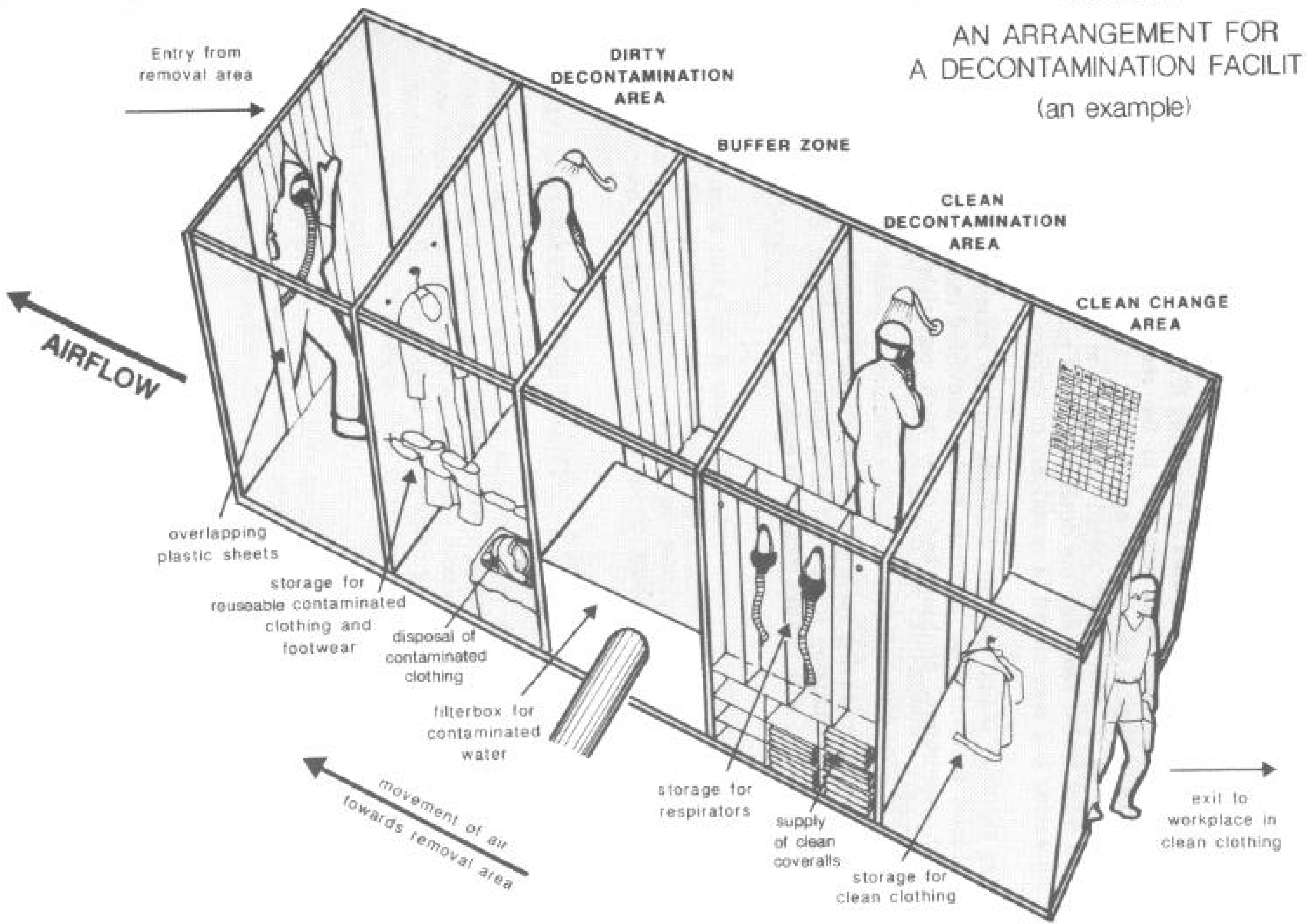
- storage of clean clothing
- separate storage of clean and dirty towels
- airflow towards the clean decontamination area

All water from the decontamination facility should pass through a suitable filter or other trap before it passes into sewer mains.

PROCEDURES FOR THE USE OF DECONTAMINATION FACILITIES ARE DETAILED IN SECTION 5.1.1 OF THIS CODE.

FIGURE 2

AN ARRANGEMENT FOR
A DECONTAMINATION FACILITY
(an example)



2.4 CHANGING FACILITIES WHERE A DECONTAMINATION UNIT IS INAPPROPRIATE

For operations involving the removal of small amounts of asbestos and where the decontamination facilities described earlier are inappropriate, an arrangement shall be adopted to ensure that protective clothing used for asbestos work shall not be worn away from the immediate vicinity of the asbestos removal area.

Normally this would entail the worker removing his/her outer protective garments and overshoes in a designated area attached to the removal area, and then proceeding directly to the changing and showering facilities. The discarded protective clothing should be stored in appropriate sealed containers at the removal area. Respirators should be worn whilst removing the outer protective garments and must be worn until after showering and then stored in containers or lockers.

Changing facilities should be made available for the exclusive use of persons working in an asbestos removal area. Separate storage provision should be made for portable equipment, respirators, clothing and other such materials used in the course of asbestos removal.

Where a permanent changing facility is necessary (for example in larger power stations or dockyards), the changing room shall have separate sections, designated as dirty or clean as appropriate, with clothes lockers in each.

3. EQUIPMENT FOR ASBESTOS REMOVAL

3.1 CUTTING TOOLS

Breaking through the finishing compound and cutting the reinforcing wire in the lagging are operations which can liberate considerable quantities of dust. Care should therefore be taken in the selection of tools and in keeping the insulation wet. Tools should allow cutting of the insulation into small sections while keeping dust levels in the removal area to a minimum.

Power, telephone and fire alarm cables may lie underneath asbestos insulation. These cables must be clearly identified prior to the commencement of any cutting, as severe damage and/or hazard to the worker could result.

Service lines under insulation, particularly on turbines, are vulnerable to damage from cutting tools. Alternate routing, cabling or deactivation of such lines suggested.

The use of any power tool in asbestos removal requires caution since not all types are suitable, particularly in regard to internal dust collection and electrical safety in wet conditions. In general, compressed air driven power tools are preferable. Where doubt exists, reference should be made to the State regulatory authority.

3.2 SPRAY EQUIPMENT

Surface soaking from a spray jet is useful for small areas and where total saturation is not practicable. The spray could be from an adjustable, pistol-grip, garden hose spray, fed from a mains supply or, where no supply is readily available, from a portable pressurised vessel, such as a pump-up garden sprayer. A constant water pressure is desirable.

3.3 TOTAL SATURATION EQUIPMENT

Total saturation equipment is useful for large areas of insulation where time can be allowed for the water to soak in. The equipment consists of an injection harness of light rubber hose with a number of outlets, each terminating in an injection head with its own shut-off control. These heads have numerous side holes through which water is fed into the insulation. The water flow is stopped during transfer of the head from one position to the next.

The heads are moved progressively at 200 to 300mm intervals as the insulation soaks, until the asbestos matrix is wet. A water pressure of approximately 170 kPa (25 psi) is desirable. This can be achieved by tapping a higher pressure source through a reducing valve.

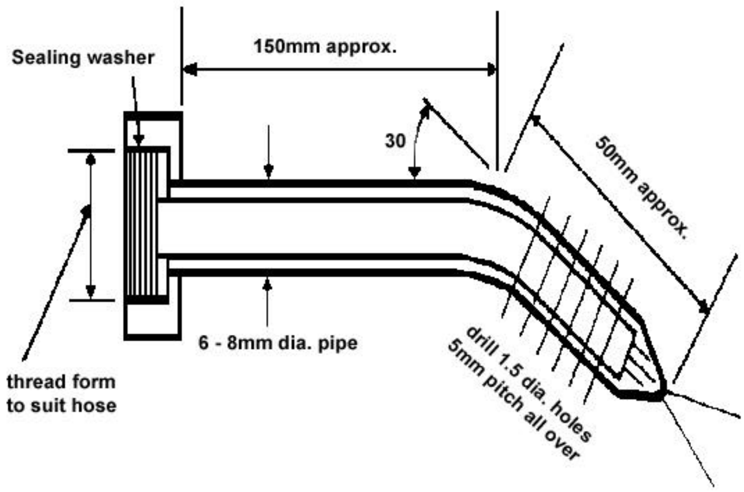


FIGURE 3 TOTAL SATURATION INJECTION HEAD

3.4 VACUUM CLEANING EQUIPMENT

All vacuum cleaning equipment used in association with asbestos removal shall conform with the requirements of the appropriate Australian Standard[(7)] and shall be approved for this purpose by the relevant State authority. In particular, all extracted air must pass through a HEPA filter before discharge into the atmosphere.

3.5 WASTE DISPOSAL EQUIPMENT

The selection of appropriate containers for the removal of asbestos waste, and its subsequent disposal, is detailed in section 13 of the attached Guide.

3.6 INSPECTION OF EQUIPMENT

All equipment used for the removal of asbestos-based material shall be inspected before commencement of the removal job, after repair and at least once in every seven days where continually used.

A register containing details of the examination, state of equipment and repair (if any) is to be maintained by a designated person.

4. REMOVAL TECHNIQUES FOR BUILDINGS AND STRUCTURES

The removal of asbestos-based materials from buildings and other structures shall be carried out by methods which will minimise the release of asbestos dust into the atmosphere, both during and after the removal operation. The choice of method is determined by the nature of the asbestos material, the quantity of insulant and its location.

As the techniques used for the removal of sprayed thermal insulation from buildings are not dissimilar from those used for removal from steampipe and boilers, the following removal methods may equally be adapted to the removal of asbestos from industrial plant and machinery.

4.1 SPRAY METHOD

This method shall be used only where relatively small quantities of asbestos-based materials are to be removed and where the following conditions apply to the material:

- the asbestos-based material is not covered with other materials such as calico or metal cladding which require prior removal
- there is no reinforcing wire or other similar restrictions to removal
- the asbestos-based material is not coated with paint or mastic
- where rapid temperature drop due to excessive water could cause damage to heated metal components
- <u>where no live electrical conductors are present</u> and where no damage to electrical equipment can arise from the ingress of water

The spray shall be applied in such a manner as to ensure that the entire surface of asbestos-based materials is wet, but minimal run-off occurs.

In many instances, it will be helpful if a wetting agent (surfactant) is added to the water to facilitate more rapid wetting of the insulation material.

It is desirable for the asbestos-based material to be wetted through its full depth and maintained in a wet condition. It is recommended that a manually controlled, consistent low pressure, coarse spray such as from an adjustable, pistol-grip garden hose be used for this purpose (see section 3.2). The design of the spraying equipment will be dependent on availability of water supply and access to the area to be sprayed.

It is important that the spray should be copious, but not such that the water droplets generate dust from impact with the surface of the insulation. When using cutting equipment to remove asbestos, the water spray should be directed at the site of the cut and the wetted material removed as the cut progresses.

The wetted asbestos-based material should be removed in sections and immediately placed in suitably labelled containers and properly sealed. Any small sections which may be dislodged should be collected and properly disposed of.

Dust is significantly suppressed, although not entirely eliminated by this technique; therefore appropriate respiratory protection must be used.

4.2 REMOVAL BY SOAKING OR TOTAL SATURATION

The quantity of asbestos-containing insulation to be removed from pipes or ducts is often so extensive, or the material so thick, that the spray method will not suppress the dust sufficiently. An alternative is to soak the insulation by the introduction of water through appropriate applicators. The design and usage of these water injection devices is detailed in section 3.3 of this Code.

The soaking of the asbestos-based materials may start as soon as metal temperatures permit; however, where metal cracking could occur, the metal must be allowed to cool to a suitable temperature.

The following steps are recommended for the soaking procedure:

- where the asbestos-based material is covered by cloth, mastic or other such materials, loose asbestos-based dust or other nuisance dust shall be removed by vacuum cleaning with approved equipment or by wiping with a damp cloth.
- where cladding has to be removed before access is obtained to the asbestos-based material, the cladding shall be removed carefully and surfaces vacuum cleaned continually or, where practicable, sprayed with water.
- holes or cuts must be made in the outer covering to enable water to be injected in such a manner and quantity as to ensure that asbestos-based material is wetted but not washed out by the passage of water. It has been found that slow saturation from the metal interface outwards is quite successful.
- the quantity of water and the time to soak will be dependent on factors such as thickness of insulation, access, location of holes.
- the saturated asbestos-based material shall be removed in sections and immediately placed in properly labelled containers and suitably sealed. During this process, it may be necessary to carefully cut reinforcing wire or similar restraints. The asbestos-based material shall be properly soaked, and small sections which may be dislodged shall be properly disposed of.
- although sufficient water is needed to saturate the asbestos material, excess water may create contamination and waste disposal problems. All waste water must be filtered to remove dust prior to discharge into sewer mains.

4.3 DRY REMOVAL

THIS METHOD IS CONSIDERED TO BE THE LEAST DESIRABLE REMOVAL TECHNIQUE AND SHALL ONLY BE USED WITH PRIOR APPROVAL FROM THE RELEVANT STATUTORY AUTHORITY AND WHERE THE SPRAY AND SOAKING METHODS CANNOT BE USED. Such may be the case where there are live electrical conductors or where major electrical equipment could be permanently damaged or made dangerous by contact with water.

Notwithstanding the general guidance given earlier in this Code, the greater potential for the generation of airborne asbestos dust in dry removal techniques demands that particular attention be given to the following points:

- the work area shall be fully isolated with impermeable sheeting and the interior maintained at a slight negative pressure, using approved exhaust equipment.
- all personnel involved in the removal operation must wear full-face, positive pressure, supplied air respirators.

- asbestos-based material shall be removed in small pre-cut sections with minimum disturbance in order to reduce the generation of dust. Waste material shall be immediately placed in appropriate wetted containers.
- in some cases it may be possible to use local exhaust extraction to minimise airborne dust concentrations. In order to achieve the required efficiency, a minimum air velocity at the extraction point of 1 m/s is recommended and the area of the nozzle should be large enough and placed close enough (not greater than diameter of nozzle) to ensure efficient dust collection.(8) Filtration must be sufficiently complete to permit the return of air to the workplace (see section 3.4).

4.4 REMOVAL FROM HOT METAL

Removal of asbestos from hot metal presents one of the worst conditions of removal due to the spread of dust on convection currents of air. Wherever possible, sufficient time should be given to allow the machinery to cool to below 100°C before removal is attempted. However, if this is not possible owing to system requirements, then extreme care is essential.

In using the dry removal method on hot surfaces, particular care shall be taken in the selection of dust extraction equipment to cope with the convection currents involved. The selection of appropriate personal protective clothing also becomes more important.

4.5 TECHNIQUES FOR SMALL REMOVAL JOBS

4.5.1 **Use of glovebags**

Glovebags are single use bags constructed from transparent, heavy duty polyethylene, with built-in arms and access ports. Generally these glovebags are approximately 1 metre wide by 1.5 metres deep and are designed to completely isolate small removal jobs from the general working environment. As such, glovebags provide a flexible, easily installed and quickly dismantled, temporary enclosure for small asbestos removal jobs.

THIS TECHNIQUE IS THEREFORE PARTICULARLY SUITED TO THE REMOVAL OF ASBESTOS LAGGING FROM INDIVIDUAL VALVES OR JOINTS IN STEAMPIPE OR OTHER SIMILAR LOCATIONS. THERE ARE A VARIETY OF COMMERCIAL BAGS WHICH ARE SUITABLE FOR THIS PURPOSE.

The major advantage of these glovebags is that they contain all waste and contamination within the bag, thereby eliminating the need for extensive personal protective equipment and decontamination. The only significant limitation to the use of glovebags is the volume of waste material that they may contain. As such, care needs to be exercised to prevent overfilling with water or waste.

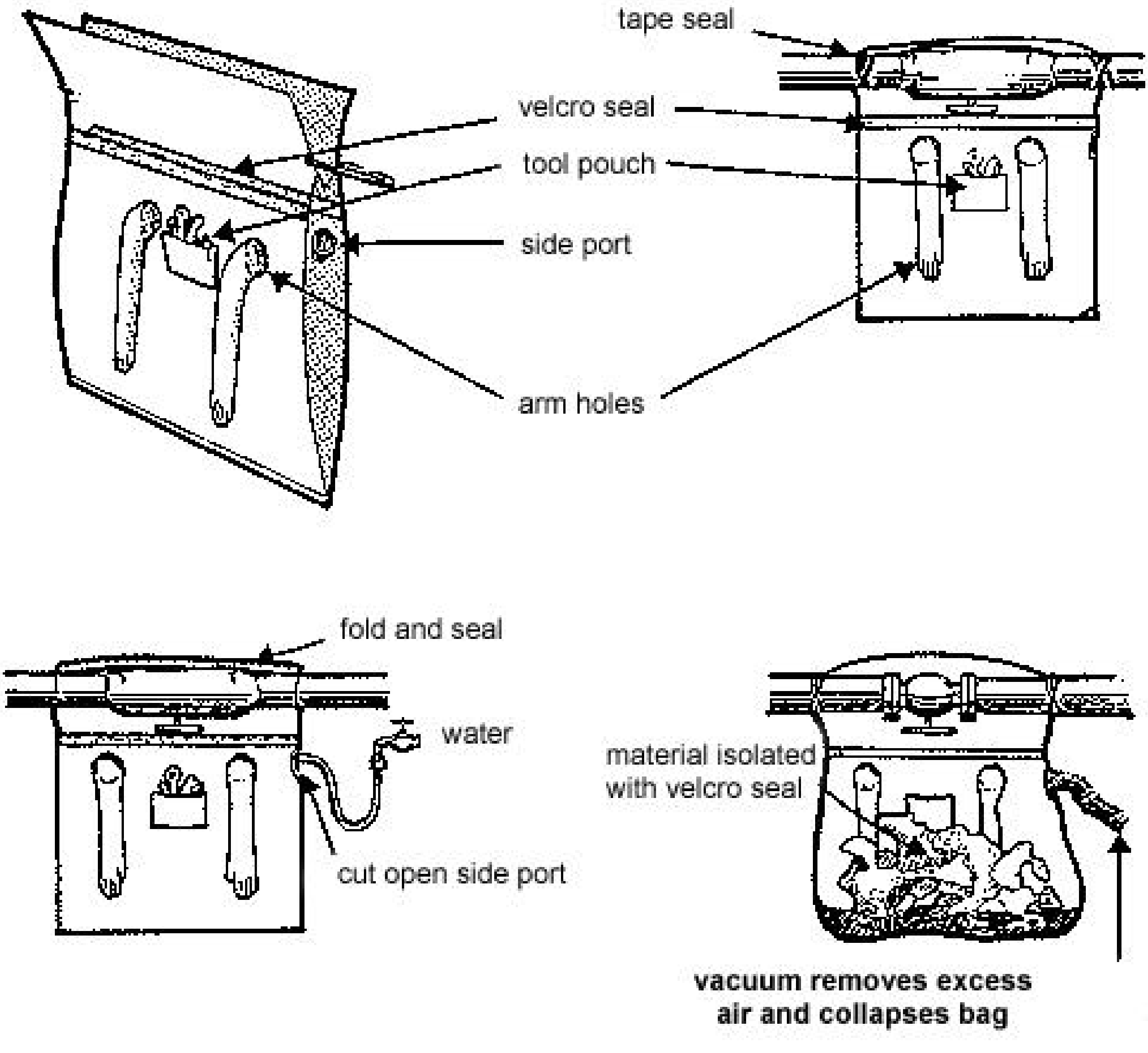
The correct technique for the use of glovebags is as follows:

- the glovebag shall be installed so that it completely covers the pipe or other structure where asbestos work is to be done. The pipe lagging on either side of the bag must be sufficiently sound to support the weight of the bag and its wet contents. Glovebags are installed by cutting the sides of the glovebag to fit the size of the pipe from which asbestos is to be removed. The glovebag is attached to the pipe by folding the open edges together and securely sealing them with tape. All openings in the glovebag must be sealed with duct tape or equivalent material. The bottom seam of the glovebag must also be sealed with duct tape or equivalent to prevent any leakage from the bag that may result from a defect in the bottom seam.

- employees using glovebags must as a minimum, wear a half-face respirator fitted with particulate cartridges approved for asbestos. This precaution is taken in case the bag is punctured or a leak develops from a poor seal.
- the asbestos material from the pipe or other surface that has fallen into the enclosed bag must be thoroughly wetted with a wetting agent (applied with an airless sprayer through the pre-cut port provided in most glovebags, or applied through a small hole cut in the bag).
- once the asbestos material has been thoroughly wetted, it can be removed from the pipe, beam or other surface. The choice of tool used to remove the asbestos material depends on the nature of the material to be removed. Asbestos-containing materials are generally covered with painted canvas and/or wire mesh. Canvas may be cut and peeled away from the asbestos-containing material underneath. Where the asbestos-containing material is dry, it should be re-sprayed with a wetting agent to ensure that it generates as little dust as possible when removed.
- after removal of the asbestos-containing material, the pipe or surface from which asbestos has been removed must be thoroughly cleaned with a wire brush and wet-wiped until no traces of the asbestos-containing material can be seen. In addition, the upper section of the bag should be washed down to remove any adhering asbestos materials.
- any edges of asbestos-containing insulation that have been exposed as a result of the removal or maintenance activity must be encapsulated with a sealing compound to ensure that these edges do not release asbestos dust to the atmosphere after the glovebag has been removed.
- once the asbestos removal and encapsulation have been completed, a vacuum hose from an approved vacuum cleaner should be inserted into the glovebag through the access port to remove any air in the bag that may contain asbestos dust. Once the bag has been evacuated, it should be squeezed tightly (as close to the top as possible), twisted, and sealed with tape, keeping the asbestos materials safely in the bottom of the bag.
- the vacuum line can then be removed from the bag and the glovebag itself removed from the workplace to be disposed of properly.

FIGURE 4

USE OF GLOVE BAGS



4.5.2 **Mini-enclosures**

In some instances, such as removal of asbestos from a small ventilation system or from a short length of duct, a glovebag may not be either large enough or of proper shape to enclose the item. In such cases, a mini-enclosure can be built around the area where small-scale, short-duration asbestos maintenance or removal work is to be performed.

The mini-enclosure should be constructed from polyethylene sheeting (approximately 0.2mm thick) and can be small enough to restrict entry to the asbestos removal area to one worker. The plastic sheeting shall be affixed to the walls of the room or other existing or temporary supports, and a double layer of plastic shall be laid on the floor. As with the larger structures discussed earlier, adequate overlap should be given where the walls and floor are joined. The two layers on the floor should be secured to minimise movement between layers. Care must also be taken to ensure that any penetrations such as pipes or conduits are properly sealed.

Constructed as part of the mini-enclosure are two small, approximately 1 metre square changing rooms. The changing area should be separated from the removal area by double, overlapping layers of plastic. A similar arrangement should also separate the dirty changing area from the clean changing area outside the enclosure. This arrangement is presented diagrammatically in Figure 5 on the following page.

While inside the mini-enclosure, the worker should wear disposable coveralls, overshoes and appropriate respiratory protection. Upon leaving the removal area part of the enclosure, the worker should vacuum down his/her coveralls, removing them in the dirty changing area section of the enclosure. After leaving the enclosure, the worker should shower and then remove respiratory equipment before changing into fresh clothing.

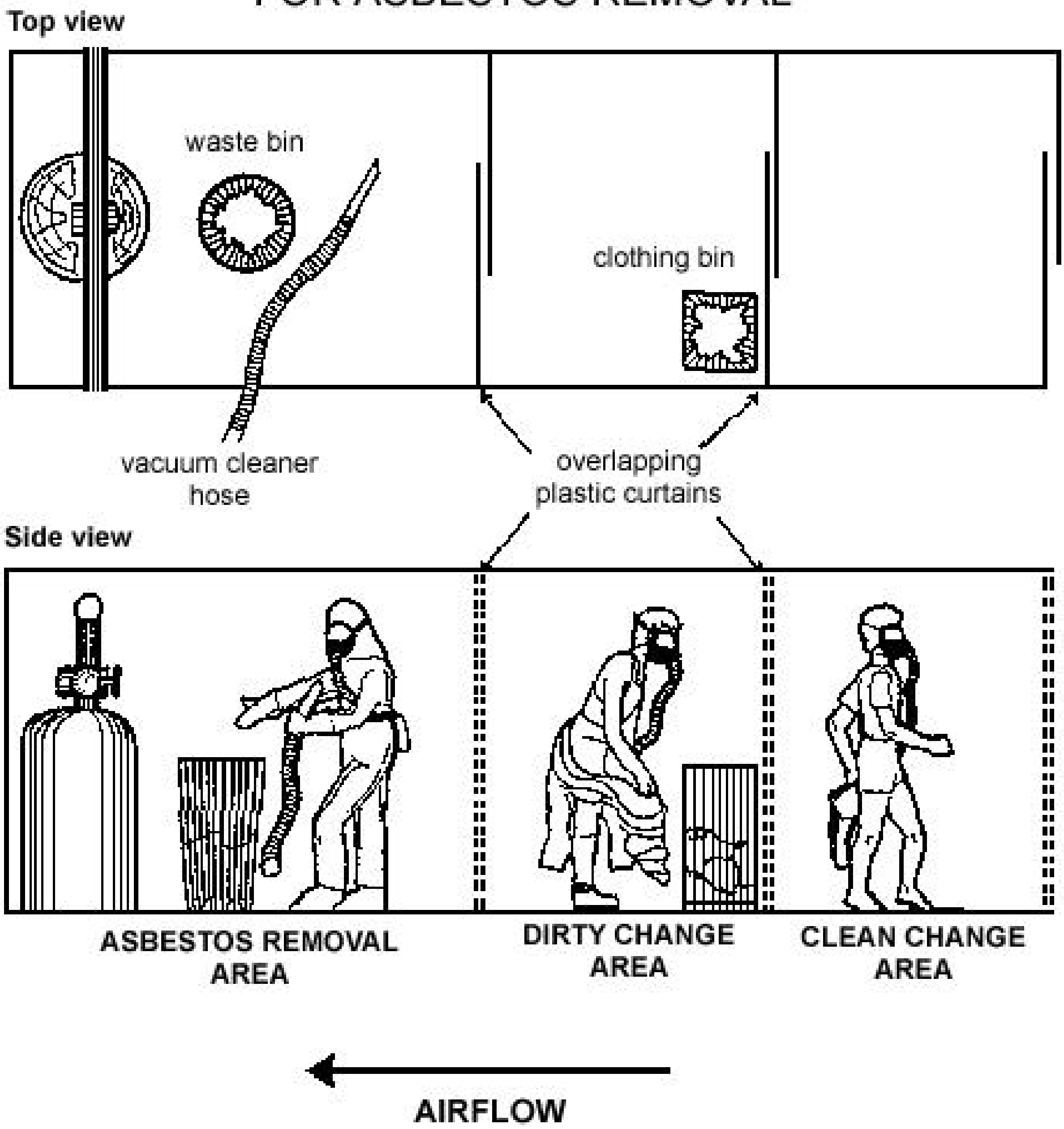
In this application, an airline respirator would be inappropriate, as the worker must wear his/her respirator on the journey from the removal area to the shower.

The advantages of mini-enclosures are that they limit the spread of asbestos contamination, reduce the potential exposure of bystanders and other workers who may be working in adjacent areas, and are quick and easy to install. The disadvantage of mini-enclosures is that they may be too small to contain the equipment necessary to create a negative pressure within the enclosure; however, the double layer of plastic sheeting separating the removal and changing areas will serve to restrict the release of asbestos dust from the enclosure.

The procedures to be followed in dismantling the mini-enclosure are the same as those outlined for larger enclosures in section 8 of this Code.

FIGURE 5

LAYOUT OF A MINI-ENCLOSURE FOR ASBESTOS REMOVAL



5. GENERAL HYGIENE REQUIREMENTS

Persons working with asbestos materials shall observe a high standard of hygiene and good housekeeping to ensure that asbestos dust is not taken from the asbestos removal area to other environments.

Persons leaving a removal area shall first go through the decontamination procedures appropriate for that site. The more detailed procedures for decontamination are detailed in the following sub-section of this Code.

In general, persons involved in asbestos removal shall be provided with changing facilities separate from those used by other groups of workers. Clean overalls, outer clothing and dirty overalls shall be segregated.

WORK CLOTHING SHALL NOT BE TAKEN HOME AND UNDER NO CIRCUMSTANCES SHOULD OUTER CLOTHING WORN IN THE REMOVAL AREA BE WORN AWAY FROM THE REMOVAL AREA.

PERSONS SHALL NOT EAT, DRINK OR SMOKE IN THE ASBESTOS REMOVAL AREA as this would require the removal of respirators, potentially exposing workers to high concentrations of asbestos dust.

5.1 DECONTAMINATION PROCEDURES

In circumstances where the decontamination unit cannot be located adjacent to, and joined to, the removal area enclosure, procedures to minimise asbestos contamination shall be implemented. Usually this would require workers to discard their coveralls and overshoes or other outer garments in an isolated changing area attached to the removal area enclosure, and thereafter change into fresh outer clothing for the journey to the decontamination facility.

Where use is made of these temporary changing facilities at the removal area, de-dusting must be carried out before the protective equipment is placed in the dust-proof accommodation provided.

5.1.1 **Personnel**

Persons leaving an asbestos removal area shall first ensure that protective clothing and footwear are thoroughly cleaned of adhering gross contamination by vacuuming with an approved vacuum cleaner, or by hosing down with water, prior to entering the decontamination unit. *REMOVING DUST FROM CLOTHING BY SHAKING OR BLOWING OFF WITH COMPRESSED AIR IS FORBIDDEN.*

Following this initial cleaning, the worker must shower fully clothed in the *DIRTY DECONTAMINATION AREA*, with respirator worn and operating. After showering, the wet clothing is removed and placed in the storage provided.

The worker then passes through the buffer zone or airlock and removes his/her respirator whilst showering in the *CLEAN DECONTAMINATION AREA*. The discarded respiratory equipment is then stored in a locker or other appropriate enclosure. Where airlines are brought through the decontamination facility, provision should be made to wash the airline and enclose the end in plastic once it is disconnected from the respirator mask.

During the final shower, the worker must pay particular attention to washing of hair, face and fingernails.

Following this final shower, the worker passes through the second airlock or buffer zone into the *CLEAN CHANGING AREA*. Here the worker changes back into his/her conventional work clothing stored in the lockers provided.

Personnel must not smoke, eat or drink in any part of the decontamination facility.

Part of the responsibility of the removal supervisor is to ensure that provision is made for routine cleaning of the decontamination facility, disposal of discarded coveralls and overshoes, and the laundering of wet garments and towels.

5.1.2 **Equipment**

All tools and electrical equipment such as vacuum cleaners and power tools should be left in the removal area until the completion of the removal job. When the equipment is removed it should be vacuumed thoroughly and all accessible surfaces wiped over with a damp cloth. Where decontamination is not possible, the item should be plastic wrapped and sealed, and only opened in another removal area.

6. PROTECTIVE CLOTHING AND EQUIPMENT

When the use of respiratory equipment and protective clothing is required, adequate rest breaks should be provided for, taking into account the physical strain caused by the use of such equipment.

Accordingly, consultation between employers and employees should establish a normal work/rest regime to be followed in the particular circumstances depending on factors such as the type of protective equipment and method of work.

6.1 RESPIRATORY PROTECTION

The degree of respiratory protection required is determined by the nature of the removal job, the type of asbestos and the potential for exposure to dust.

A DETAILED GUIDE TO THE SELECTION OF APPROPRIATE RESPIRATORY PROTECTION FOR VARIOUS OPERATIONS INVOLVING ASBESTOS IS PRESENTED IN APPENDIX B OF THIS CODE.

For minor removal jobs, especially when removing asbestos-cement (fibro) sheets or using glovebags, an *approved* disposable respirator or half-face respirator fitted with particulate cartridges should be worn. Alternatively, *approved* air-purifying ventilated helmet or visor respirators can be used.

During masking of a removal area or during final cleaning where there is potential for exposure to airborne asbestos, the use of an *approved* disposable particulate respirator would suffice. These conditions would NOT apply inside the removal area during other asbestos removal operations.

In general, positive pressure, hood or full-facepiece powered air-purifying respirators with Class M filters or positive pressure demand compressed airline respirators shall be worn by all personnel directly engaged in asbestos removal operations inside a removal area enclosure. Inspection and supervisory personnel, not physically engaged in the removal operation, may use powered air-purifying respirators fitted with appropriate particulate filters when working in the removal area.

The air supply equipment for airline respirators shall be located outside and distant from the work area and must be maintained in good order to avoid interruption in the air supply or deterioration in the quality of the breathing air.

Audible and visual warning of compressor failure shall be provided to warn operators of any system malfunction. The air supply equipment shall be of sufficient capacity to allow time for personnel to clear the removal area if a supply failure occurs.

Powered, air-purifying respirators must be designed, or shielded, so that their operation is not degraded by water from showering.

ALL RESPIRATORY PROTECTIVE EQUIPMENT USED IN ASBESTOS REMOVAL WORK MUST CONFORM TO THE REQUIREMENTS OF AUSTRALIAN STANDARDS[9,10] AND BE APPROVED BY THE RELEVANT STATE OR TERRITORY AUTHORITY FOR THIS PURPOSE.

The asbestos removalists and/or supervisor must be familiar with the aforementioned Australian Standards and shall ensure the provisions contained therein are adhered to at all times. Arrangements shall be made for regular inspections and servicing of non-disposable respirators.

Respirators shall be issued on a personal basis. Users shall receive instructions on the correct method of using respirators and the importance of good facial fit. The user's name shall be clearly marked on all non-disposable respirators.

It is the employer's responsibility to ensure that all protective equipment is maintained in a clean and safe working condition. Where a number of different respirator types are suitable and available, individual operators may express a preference for a particular type.

6.1.1 **Faceseal**

Persons wearing spectacles or persons with beards, sideburns or even a visible growth of stubble, may not be afforded adequate protection from asbestos dust where the respirator worn relies on a good faceseal, that is, a close contact between face and seal.

A complete solution to the problem of facial hair, or the wearing of spectacles involves the use of equipment which does not require a faceseal, for example, ventilated helmet respirators, or positive pressure powered respirators with blouses.

If there is any doubt as to the adequacy of protection, individuals concerned should not be permitted to work in asbestos removal areas.

6.2 PROTECTIVE CLOTHING

Asbestos does not enter the body through the skin, and has no harmful effect on the skin. Thus removal of asbestos itself does not call for the wearing of any special skin covering, although any asbestos deposited on the skin and in the hair must be scrubbed off before leaving the decontamination area.

The selection of protective clothing is therefore determined not by asbestos exposure but by climate, degree of physical exertion required, the other hazards involved in the work, and ease of decontamination.

Closely woven, disposable or washable coveralls without pockets or cuffs, but including an integral head covering, in combination with disposable overshoes, greatly assist in personal decontamination; however, these synthetic garments may make a substantial contribution to the heat stress of the individual in some environments. Trousers and coverall cuffs should be worn outside of boots and gloves. Where specific decontamination facilities are not available, the use of disposable coveralls is recommended.

As several variables influence the type and amount of clothing worn in asbestos removal, decisions on what is appropriate in the particular circumstances should always be based on consultation between employers and employees.

6.2.1 **Laundering of protective clothing**

All clothing worn in an asbestos removal area shall be regarded as potentially contaminated with asbestos. As such, it is important that care is taken to ensure that the contractor, or other persons handling the clothing, fully understand the precautions necessary for handling asbestos-contaminated clothing. It is generally considered preferable that, where possible, all laundering be done on-site or in a facility provided and operated by the asbestos removalist.

Contaminated clothing may be safely laundered in a conventional washing machine separate from other laundry, provided the clothing is thoroughly wetted when discarded by the worker and not allowed to dry out until it is washed. Contaminated clothing to be laundered by a commercial laundry shall be despatched in a thoroughly wetted state in an impermeable container clearly marked *ASBESTOS CONTAMINATED CLOTHING*.

Where clothes dryers are used to dry work clothes and/or overalls, the exhaust air from the unit should either pass through a filter or be discharged to the outside atmosphere. Random air monitoring may be carried out in the laundering facility to ensure laundry workers are not being exposed to asbestos dust.

THE LAUNDERING OF PROTECTIVE OR WORK'S CLOTHING IN WORKERS' HOMES SHALL BE STRICTLY PROHIBITED.

7. ENVIRONMENTAL MONITORING OF REMOVAL SITE

An airborne asbestos monitoring program is necessary in order to determine whether the precautions and work procedures described in this Code are being applied in a satisfactory manner, and that permitted asbestos exposure levels are not exceeded.

Air monitoring is not intended to be used as a preventive or control measure, but as a check at intervals, which may be random, in order to ensure that control procedures are operating satisfactorily and that workers are not being exposed to harmful environments.

The location and frequency of air monitoring is very much dependent upon the method of removal, the quality of the removal area containment, the monitoring history at the particular site and the possible consequences of fugitive releases. For larger removal areas or on dry removal jobs, a fairly extensive monitoring program should be implemented at the start of the removal program to check the integrity of the containment and decontamination facilities.

The need for further monitoring and its frequency should be determined on the basis of the results obtained. Problem areas, or neighbouring regions with a high occupancy of unprotected persons, should be monitored routinely every shift, while consistently clear areas may only require a random sample.

The recommended exposure standard for asbestos and its basis is outlined in section 6.2 of the attached Guide.

During asbestos removal operations, where complete containment of the removal area is not possible (section 2.1), asbestos fibre concentrations in the air shall be measured at a number of positions outside the barriers which contain the removal area. Such data are important in determining the positions of barriers and the effectiveness of the control procedures. Air monitoring shall also be done in decontamination areas. Generally, it will not be necessary to monitor each individual job where asbestos material is being removed by the same procedure and where the monitoring history has indicated that there has been no problem with asbestos contamination.

7.1 AIR MONITORING TECHNIQUE

The determination of airborne asbestos concentrations shall be made in accordance with the detailed method set out in the NOHSC *Guidance Note on the Membrane Filter Method for Estimating Airborne Asbestos Dust*.[6]

Briefly, this determination is achieved by drawing an accurately measured volume of air through a specially prepared membrane filter, and thereafter counting the number of asbestos fibres collected on this filter, using an optical microscope. This data can then be used to calculate a result which may be compared to the recommended exposure standard detailed in section 6.2 of the attached Guide. *COMPARISON WITH THIS EXPOSURE STANDARD IS ONLY VALID IF THE DETAIL OF THIS METHOD IS OBSERVED.*

\`Static' air samples taken over a short period at a fixed location can only serve as an indicator of the effectiveness of contamination control. Comparisons between samples taken for engineering control and the recommended exposure standard are not valid. True worker exposure can only be estimated from personal samples attached to, and taken within, the breathing zone of the individual. These personal samples should preferably extend over an entire shift.

Since the measurement of airborne asbestos concentration is an important and highly skilled process, the monitoring shall only be carried out by suitably trained personnel who have been instructed in the sampling techniques and analytical procedures.

It should be noted that the Membrane Filter Method is the only technique which can be used to determine compliance with the asbestos exposure standard, and where monitoring is undertaken to this end, it must be done by that method and should be performed by National Association of Testing Authorities, Australia (NATA) registered or government accredited personnel, when available. However, because of the four-hour sampling period required, and the subsequent time needed for sample preparation and counting, it may not be of sufficiently informative value during the course of, for example, short-term asbestos disturbance, control, or removal operations. In such circumstances more reliance should be placed upon frequent visual inspection of the containment area.

The results of air monitoring shall be made available to workers in the area, and the site supervisor notified immediately if the fibre count exceeds the recommended level.

8. DISMANTLING OF ASBESTOS REMOVAL AREA

On completion of the asbestos removal job, all tools and equipment not used for cleaning should be removed from the removal area so that efficient vacuuming of the inside of the removal area enclosure can be undertaken. In taking these tools and equipment from the removal area, appropriate decontamination procedures must be observed (section 5.1.2).

By spraying the internal surfaces of the plastic containment around the removal area with polyvinyl acetate (PVA) or similar water based paint, any asbestos dust adhering by electrostatic attraction is effectively encapsulated. Personnel involved in this spraying operation should wear an airline respirator or a half-face respirator fitted with combined organic vapour/dust cartridges. Plastic surfaces may become very slippery while the paint is wet, so unnecessary movement within the enclosure should be avoided until the paint has dried.

The plastic enclosure surrounding the removal area may only be dismantled if a thorough inspection reveals no visible traces of asbestos contamination and air samples taken within the enclosure indicate a result below the level specified by the relevant statutory authority. The visual assessment may, in some circumstances, include analysis of settled dust within the enclosure by optical microscopy. Air monitoring should only be undertaken once the PVA has dried, as the airborne mist will adversely affect the ability to detect fibres in the sample.

It should be stressed that visual inspection and air monitoring are complementary techniques and dismantling may only proceed after both techniques give clearances.

The sealing plastic may then be dismantled, folded and placed in appropriate disposal bags and sealed. The sealing plastic should not be re-used, but treated as asbestos waste, [see section 12 of the attached Guide]. Safety barricades and warning signs should not be removed until the complete area has been thoroughly cleaned.

Prior to resumption of normal work in the area by unprotected personnel, a comprehensive visual inspection shall be undertaken to ensure removal has been satisfactorily completed and that no source of asbestos dust remains in the area. Particular attention should be paid to examination of ledges, tops of air conditioning ducts, cracks in the floor, folds in plastic sheeting and crevices or areas which may have been overlooked during the initial clean-up.

The asbestos removal job shall only be considered to have been completed when a visual inspection reveals no further evidence of asbestos contamination and static air samples give a clear result.

9. HANDLING OF ASBESTOS-CEMENT (FIBRO) PRODUCTS[11]

A large number of building products used in the building and construction industry in Australia have been compounded from asbestos-cement. These products include, but are not limited to:

- flat or corrugated, compressed asbestos-cement sheeting (fibro)
- fibro pipes - water, drainage and flue
- roofing shingles
- flexible building boards (for example, Villaboard, Hardiflex, Wundaboard, Flexiboard)

While new fibrous-cement products no longer contain asbestos, prior to 1970 crocidolite was used in many products. Provided these products are maintained in good order, they present no health risk; however, precautions must be observed during structural alteration or demolition involving asbestos-cement materials.

9.1 PRECAUTIONS TO BE OBSERVED WHEN WORKING WITH ASBESTOS-CEMENT PRODUCTS

In general, work procedures should be designed to minimise the generation of dust and, where possible, action should be taken to avoid the spread of any asbestos dust contamination. In particular, the following practices should be adopted:

- use non-powered hand tools such as hand-saws, as these generate a smaller quantity of predominantly coarser dust or waste chips.
- wetting down the material further reduces the release of dust when cutting. High pressure water jets shall not be used.
- *POWER TOOLS UNLESS APPROVED BY THE RELEVANT STATUTORY AUTHORITY FOR ASBESTOS WORK, AND ABRASIVE CUTTING OR SANDING DISCS, IN PARTICULAR, SHALL NOT BE USED ON ASBESTOS-CEMENT PRODUCTS.*
- work with asbestos-cement products in well-ventilated areas, and where possible, in the open air.
- good work hygiene principles should be observed. This may entail the use of plastic drop sheets to collect off-cuts and coarse dust or the use of approved vacuum cleaning equipment. Where it is necessary to sweep floors, the area involved should be wetted to suppress dust.
- all off-cuts and collected dust should be disposed of as asbestos waste.
- approved respiratory protection should be used when appropriate, particularly in confined spaces.

9.2 REMOVAL OF ASBESTOS-CEMENT (FIBRO) SHEETING

The following precautions should be observed when removing asbestos-cement roofing, wall sheeting or other fibro products from buildings or other structures:

- all windows and doors on the building should be closed, or in factory-type buildings where there is no ceiling, the area below or adjacent to the work should be roped off.
- the asbestos-cement sheets should be sealed or wetted with water, but not with high pressure water jets. The sheets should not be wetted if this creates a high risk of a worker slipping from a roof.
- workers should wear disposable coveralls and either an approved disposable respirator or an approved half-face respirator mask fitted with dust cartridges approved for asbestos.
- only power tools approved by the appropriate statutory authority for asbestos work may be used for removal.
- asbestos-cement sheets should be removed with minimal breakage and should be lowered to the ground, **not dropped**.
- the removed sheets should be stacked on a ground sheet and not allowed to lie about the site where they may be further broken or crushed by machinery or site traffic.
- all asbestos-containing waste should be kept wet, wrapped in plastic or otherwise sealed and removed from the site as soon as practicable, using covered bins or on a covered truck.
- the asbestos-containing waste should be disposed of in a manner, and at a site, approved by the appropriate disposal authority. Asbestos-cement sheets should not be re-used.
- any asbestos-cement residues remaining in the roof space or around the removal area should be cleaned up, using an approved vacuum cleaner if necessary.

APPENDIX A

RELATED DOCUMENTATION

REFERENCES

1. National Health and Medical Research Council (NH&MRC): *Code for the Safe Removal of Asbestos-based Thermal/Acoustic Insulating Materials*, NH&MRC, Canberra, 1979, (amended 1981).

2. US Department of Labour, Occupational Safety and Health Administration (OSHA*): Work Practices and Engineering Controls for Major Asbestos Removal, Renovation and Demolition Operations* - *Non Mandatory,* Appendix F, Section 1926.58, 1986

3. Health and Safety Commission (UK): *Work with Asbestos Insulation and Asbestos Coating - Approved Code and Guidance Note*, HMSO, London, 1985.

4. National Health and Medical Research Council (NH&MRC): *Effects of Heat on Health, Comfort and Performance,* NH&MRC, Canberra, 1979. (available from NOHSC)

5. Standards Association of Australia, AS 1324-1973, *Air Filters for Use in Air Conditioning and General Ventilation*, section 4.3.1., Sydney.

6. National Occupational Health and Safety Commission: *Guidance Note on the Membrane Filter Method for Estimating Airborne Asbestos Dust* Part 2 - Air sampling for paraoccupational situations, NOHSC, Sydney, 1988 (attached).

7. Standards Association of Australia, AS 3544-1988 *Industrial Vacuum Cleaners for Particulates Hazardous to Health*, Sydney.

8. American Conference of Governmental *Industrial Hygienists, Industrial Ventilation - a Manual of Recommended Practice*, 18th Edition, Michigan, ACGIH, 1984.

9. Standards Association of Australia, AS 1715-1982 Selection, *Use and Maintenance of Respiratory Protective Devices*, Sydney.

10. Standards Association of Australia, AS 1716-1984 *Respiratory Protective Devices*, Sydney.

11. National Health and Medical Research Council (NH&MRC): *Code of Practice - Working with Asbestos Cement (Fibrocement) Building Materials*, NH&MRC, Canberra, 1981.

12. Health and Safety Executive (UK): *Respiratory Protective Equipment for Use Against Asbestos*, Guidance Note EH 41, HMSO, London, 1985.

13. Health and Safety Executive (UK*): Probable Asbestos Dust Concentrations at Construction Processes*, Guidance Note EH 35, HMSO, London, 1984.

LEGISLATION

Legislation relevant to asbestos has been introduced, or is being introduced, in all States and Territories. Other legislation relates to clean air, waste disposal and so on.

At the time of publications the relevant Acts and regulations are:

NEW SOUTH WALES

Factories, Shops and Industries Act 1962

Factories (Health and Safety - Asbestos Processes) Regulations (1984)

Occupational Health and Safety Act 1983

Occupational Health and Safety (Asbestos Dust) Regulation 1984

Occupational Health and Safety (Asbestos Removal Contractors) Regulation 1988.

Construction Safety Act 1912

Regulation 84 a-j, Construction Work Involving Asbestos or Asbestos Cement 1983, (Amended March 1984 and August 1986).

Environmentally Hazardous Chemicals Act 1985

Chemical Control Order - Asbestos Waste Chemical Control Order 1987 (Packaging, Disposal as Landfill).

Mines Inspection Act 1975

General Rules 65b. Section 56, July 1984 (Reprinted March 1985).

Poisons Act 1966 (Amended July 1985).

Clean Air Act 1961

Dangerous Goods Act 1975

Waste Disposal Act 1970

VICTORIA

Labour and Industry Act 1958

Labour and Industry (Asbestos) Regulations 1978

Labour and Industry (Asbestos)(Amendment) Regulations 1979

Occupational Health and Safety Act 1985

Environment Protection Act 1970

Health Act 1958

QUEENSLAND

Factories and Shops Act of 1960

Asbestos Rule (Rule 9), 1977, as amended on 20 December 1980, 30 January 1982, and 11 June 1983.

Construction Safety Act 1971

Regulation: Division V.A. Subsection 57.E. Licences for demolition, involving asbestos.

Building Act 1975

Clean Air Act of 1963

Health Act of 1937

WESTERN AUSTRALIA

Factories and Shops Act 1963#

Asbestos Regulations 1978

Factories and Shops (Asbestos) Regulations, 1985.

Construction Safety Act 1972#

Construction Safety Regulations 1973 Part VII (A)

Asbestos Removal Regulation, 1984.

Health Act 1911

Health (Disposal of Asbestos Waste) Regulations, 1984.

Occupational Health, Safety and Welfare Act 1984

*Occupational Health, Safety and Welfare Amendment Act 1987**

Occupational Health, Safety and Welfare (Workplace) Regulations 1988

*Acts Amendment (Occupational Health, Safety and Welfare) Act 1987**

* awaiting proclamation 1988, repealing those indicated thus#

SOUTH AUSTRALIA

Occupational Health Safety and Welfare Act, 1986

(Industrial Safety) Regulations, 1987.

Regulation 39 - Asbestos Work.

(Construction Safety) Regulations, 1987.

Regulation 161.1	-	Control of Spraying of Asbestos
Regulation 161.2	-	Construction Work in the Vicinity of Asbestos
Regulation 161.3	-	Sealing, Encapsualting or Enclosing Asbestos
Regulation 222	-	Licence for Asbestos Removal Work

Dangerous Substances Act 1979

Health Act 1935

Waste Management Commission Act 1979

TASMANIA

Industrial Safety, Health and Welfare Act 1977

Administrative and General Regulations, Part VI.,

Division 2 - Asbestos.

Health and Welfare Provisions, Regulations 228-246.

Dangerous Goods Act 1976

NORTHERN TERRITORY

Construction Safety Act 1975

AUSTRALIAN CAPITAL TERRITORY

ACT Building Ordinance 1972, as amended 1984

ACT Asbestos Removal Manual

ACT Dangerous Goods Ordinance 1984

ACT Building Regulations

COMMONWEALTH

Quarantine Act 1956

Custom (Prohibited Imports) Regulation No. 90

AUSTRALIAN STANDARDS

Issued by Standards Association of Australia, Sydney

AS 1216	*Classification, Hazard Identification and Information Systems for Dangerous Goods.*
Part 1 - 1984	*Classification and Class Labels for Dangerous Goods.*
AS 1318 - 1985	*Rules for Use of Colour for the Marking of Physical Hazards and the Identification of Certain Equipment in Industry (SAA Industrial Safety Colour Code).*
AS 1319 - 1983	*Safety Signs for the Occupational Environment.*
AS 1530	*Methods for Fire Tests on Building Materials, Components and Structures.*
Part 3 - 1982	*Test for Early Fire Hazard Properties of Materials.*
AS 1715 - 1982	*Selection, Use and Maintenance of Respiratory Protective Devices.*
AS 1716 - 1984	*Respiratory Protective Devices.*
AS 2342	*The Design and Use of Graphic Symbols and Public Information Symbol Signs.*
Part 6 - 1985	*Guidelines for the Implementation of Symbol Sign Systems.*
AS 2601 - 1983	*The Demolition of Structures (known as the SAA Demolition Code.)*

APPENDIX B

GUIDE TO THE SELECTION OF APPROPRIATE RESPIRATORY PROTECTION

APPROPRIATE RESPIRATORS

There is a wide range of respiratory protection available for protection from airborne asbestos dust. In general, the selection of a particular respirator is determined by the nature of the asbestos work and the probable maximum concentrations of dust that would be encountered in this work. Another consideration would be the personal characteristics of the wearer that may affect the facial fit of the respirator; for example, amount of facial hair, or whether glasses are worn.

Table 2 below provides, in approximate order of increasing efficency, an indication of some respirators which may be used for protection against asbestos dust. The protection afforded by each device depends not only upon the design and fit of the respirator, but also upon the efficency of the filters (L,M,or H) where applicable.

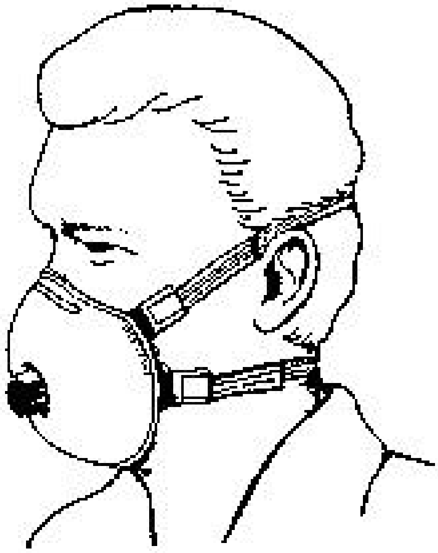
Australian Standards AS-1715[9] and AS-1716[10] provide detailed advice on the selection, use and maintenance of respiratory protective equipment and should be consulted for more detailed advice on *Nominal Protection Factors* and other relevant matters.

TABLE 2

FIGURE	TYPE OF RESPIRATOR
6	· disposable, half-face particulate respirators
7	· half-face, particulate filter (cartridge) respirator
8	· powered, air-purifying, ventilated helmet or hood respirator
9	· full-face, particulate, filter (cartridge) respirator
10	· full-face, powered air-purifying particulate respirator
11	· full-face, positive pressure demand respirator
12	· full suit or hood, continuous flow, airline respirator

FIGURE 6

DISPOSABLE, HALF-FACE PARTICULATE RESPIRATORS



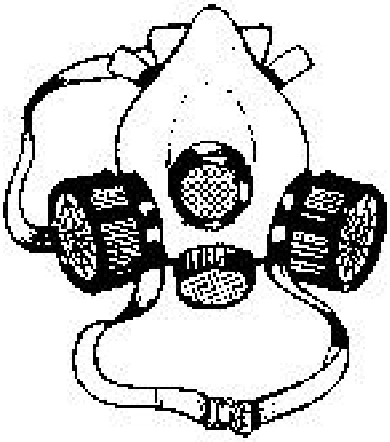
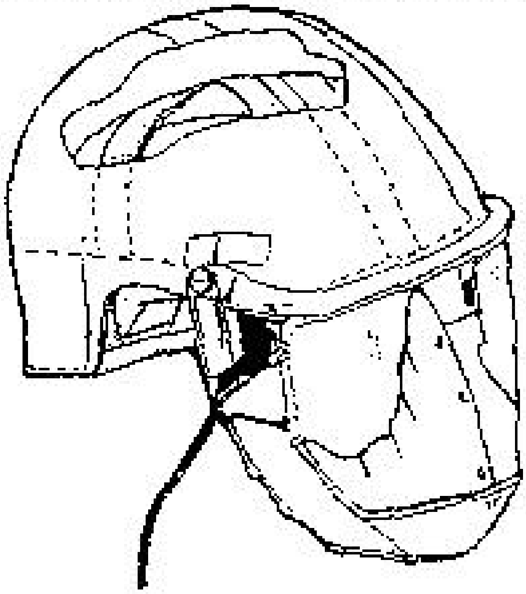


FIGURE 7

HALF-FACE PARTICULATE FILTER (CARTRIDGE) RESPIRATOR

FIGURE 8

POWERED, AIR-PURIFYING,
VENTILATED HELMET RESPIRATOR



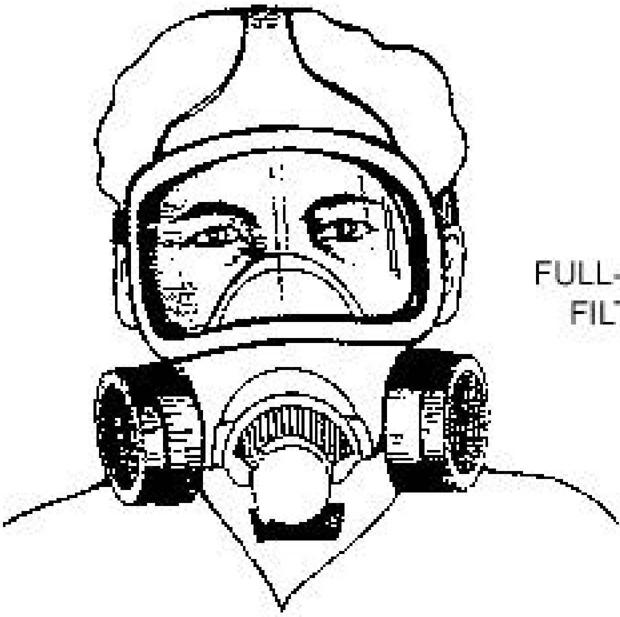
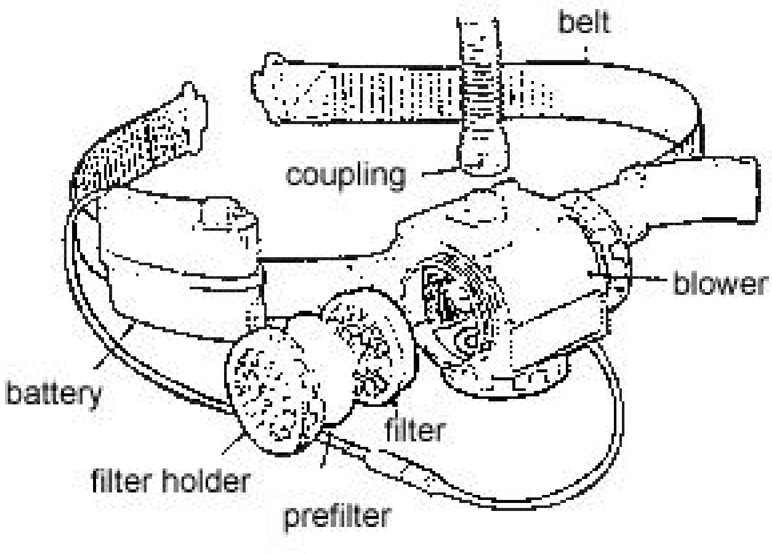


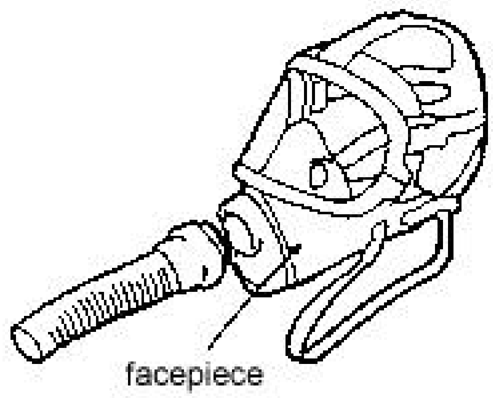
FIGURE 9

FULL-FACE PARTICULATE
FILTER (CARTRIDGE)
RESPIRATOR

FIGURE 10

FULL-FACE, POWERED
AIR-PURIFYING
PARTICULATE RESPIRATOR





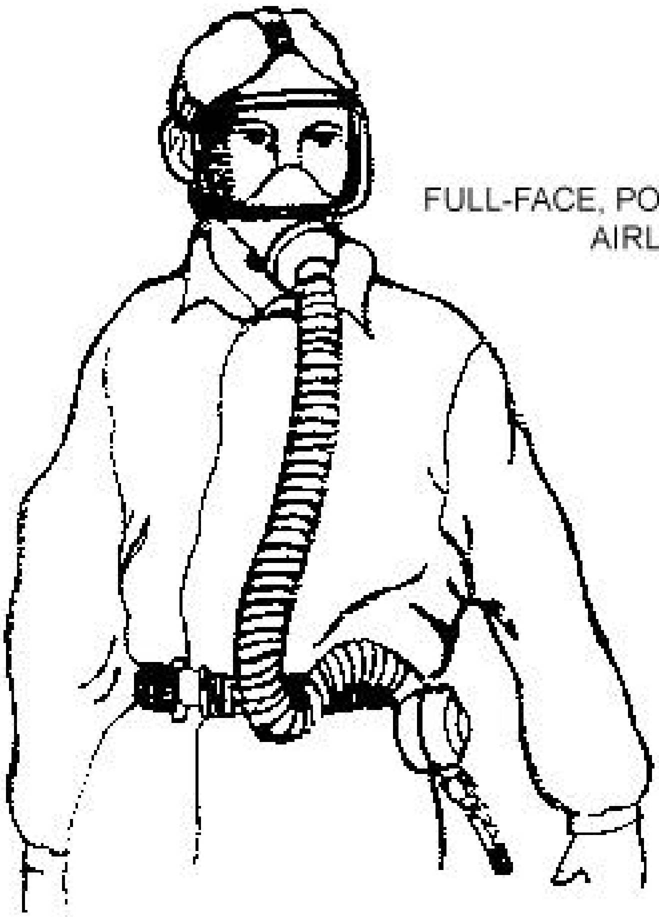


FIGURE 11

FULL-FACE, POSITIVE PRESSURE DEMAND AIRLINE RESPIRATOR

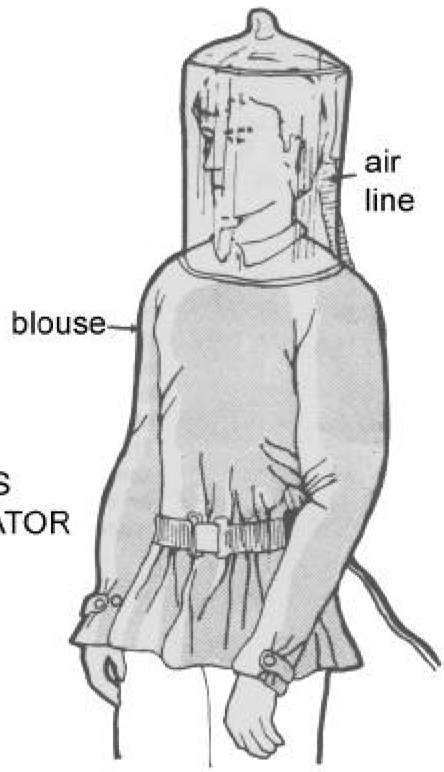


FIGURE 12

FULL SUIT OR HOOD, CONTINUOUS FLOW, AIRLINE RESPIRATOR

TABLE 3

GUIDE TO PROBABLE EXPOSURE LEVELS AND APPROPRIATE RESPIRATORY PROTECTION FOR PARTICULAR ASBESTOS REMOVAL JOBS

Adapted from the Health and Safety Executive (UK) publication: *Respiratory Protective Equipment for Use Against Asbestos*[12,13] with changes in nomenclature to suit Australian practice. (Reproduced with permission of the HSE and the Controller of Her Majesty's Stationery Office).

CONCENTRATION (fibres/mL)	JOB	EQUIPMENT
0 to 2	simple short sampling; simple enclosure erection; clearance sampling; but not for use for removal of insulation or use inside enclosures when removal is in progress.	any *approved* respirator, including disposable or half-face cartridge respirators (Class L or M)
2 to 4	some sampling operations; perhaps enclosure erection under adverse conditions; but not for use for removal of insulation or use inside enclosures when removal is in progress.	any *approved* respirator with Class M filters except those fitted with or consisting of half-face masks; or any positive pressure airline respirator.
4 to 20	extensive sampling operations perhaps on friable lagging; some sealing operations; enclosure erection under adverse conditions and on friable lagging, but not for use for removal of insulation or use inside enclosures when removal is in progress.	any *approved* full-face respirator fitted with Class H filters, or any positive pressure demand or continuous flow airline respirator.

TABLE 3 (Continued)

CONCENTRATION (fibres/mL)	JOB	EQUIPMENT
0 to 180	certain forms of wet stripping in which wetting is prolonged and effective, certain small-scale dry stripping operations.	any approved, full-face, (Class H) powered air purifying or airline respirator. Ventilated helmet or visor respirators are not appropriate
180 to 500	certain forms of dry stripping; ineffective wet stripping (light wetting - no time given to saturate).	any approved positive-pressure full-face, airline or powered air purifying (Class H) respirator. NO LESSER RESPIRATOR WILL SUFFICE
500 +	dry stripping in confined areas.	positive pressure, airline supplied suits or hoods only. NO LESSER RESPIRATOR WILL SUFFICE

NOTE: This guide does not take account of personal features such as facial hair or the need to wear spectacles. Full protection will not be achieved if either of these is present and interferes with the face seal. Nor does the guide take any account of misuse of the protective equipment.

TABLE 4

GUIDE TO PROBABLE EXPOSURE LEVELS AND APPROPRIATE RESPIRATORY PROTECTION FOR PARTICULAR JOBS INVOLVING ASBESTOS-CEMENT (FIBRO) PRODUCTS

Adapted from the Health and Safety Executive (UK) publication: *Respiratory Protective Equipment for Use Against Asbestos*,[12,13] with changes in nomenclature to suit Australian practice.
(Reproduced with permission of the HSE and the Controller of Her Majesty's Stationery Office).

CONCENTRATION (fibres/mL)	JOB	EQUIPMENT
0.5 to 5	construction - machine drilling, hand sawing and water jetting* of asbestos-cement; perhaps other processes also.	disposable or half-face particulate cartridge respirators (Class L or M)
10 to 50	cutting asbestos-cement board with circular saws, angle grinders or abrasive wheel cutters which do not have efficient local extraction*.	any approved full-face particulate Class H respirator including high efficiency powered air purifying respirators.

*NOTE: The high pressure water jetting or dry machining of asbestos-cement products with power tools is not recommended.

ASBESTOS

GUIDANCE NOTE ON THE MEMBRANE FILTER METHOD FOR ESTIMATING AIRBORNE ASBESTOS DUST [NOHSC: 3003 (1988)]

CONTENTS

PREFACE

The National Occupational Health and Safety Commission is a tripartite body established by the Commonwealth Government to develop, facilitate and implement a national health and safety strategy.

This strategy includes standards development, research, training, information collection and dissemination, and the development of common approaches to occupational health and safety legislation.

The National Commission comprises representatives of the peak employee and employer bodies - Australian Council of Trade Unions and Confederation of Australian Industry - as well as the Commonwealth, State and Territory Governments.

In line with the Commission's philosophy of participation, standing committees and working parties are basically tripartite in nature, but also include persons with specialist knowledge and representatives of groups with special needs.

With the establishment of the National Occupational Health and Safety Commission, some functions which were previously the responsibility of the National Health and Medical Research Council (NH&MRC) were transferred to the National Commission. One such function was the continuing development of the Membrane Filter Method for Estimating Airborne Asbestos Dust.

Whereas other Commission Working Parties are of a tripartite nature, the Working Party on the Membrane Filter Method has retained its existing NH&MRC membership of experienced occupational hygienists. Under the direction of the tripartite Standards Development Standing Committee, the Working Party was charged with reviewing the existing NH&MRC Membrane Filter Method and other alternative methods of monitoring asbestos and developing a standard methodology for the determination of airborne asbestos.

Although the Membrane Filter Method for Estimating Airborne Asbestos Dust only addresses the scientific or technical considerations of this technique, this document should be read in conjunction with the National Commission's *Guide to the Control of Asbestos Hazards in Buildings and Structures*,[1] and *Code of Practice for the Safe Removal of Asbestos*.[2] These publications outline the appropriate exposure standards for asbestos and the principles of result reporting and employer-employee consultation which are endorsed by the National Commission.

GLOSSARY OF TERMS

Occupational and Regulatory Sampling	Occupational and regulatory samples are those samples taken within the *Worker Breathing Zone* and give results that are indicative of the worker's exposure under representative working conditions. As they represent actual personal exposure, the results of such sampling can be compared with occupational exposure standards.
Paraoccupational Sampling	Paraoccupational samples are those *static samples* taken as an indicator of the effectiveness of process control techniques, and are not representative of actual occupational exposures. As the results obtained from paraoccupational sampling do not reflect actual worker exposure, they cannot be compared with occupational exposure standards.
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 section 8.7).
Static Samples	For the purposes of this document static samples are samples taken at fixed locations, usually between one and two metres above floor level.
Total Sample Duration	Total Sample Duration is the sum of the Single Sample Durations taken over the sampling period (see section 8.8.2).
Worker Breathing Zone	The Worker Breathing Zone is described by a hemisphere of 300mm radius, extending in front of the face and measured from a line bisecting the ears. Breathing Zone samples are usually obtained if the filter holder is fastened to the jacket lapel of the worker. **The cowl must always point downwards**. The worker carries the pump on a belt or in a pocket. These samples are known as `Personal Samples'.

INTRODUCTION

While airborne asbestos fibre concentrations from all types of asbestos[3] in the occupational environment are generally determined by the Membrane Filter Method, 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 influencing factors. Inter-laboratory comparisons of dust measurements are feasible only if agreement can be reached concerning all details of the method.

This updated version of the original 1976 NH&MRC Membrane Filter Method[4] retains the basic analytical method of phase contrast light microscopy. Any changes should not markedly affect the estimates of airborne fibre concentration but should improve the reliability of the method and produce more reliable results when used by different laboratories. The original NH&MRC method (amongst others) was used extensively in developing the Asbestos International Association (AIA) RTM-1[5] and the present drafts of the International Standard Organisation[6] and the European Reference Method.[7] The National Commission wishes to acknowledge assistance provided by, amongst others, the UK Health and Safety Executive.[8]

This updated version is based largely on the AIA Reference Method, with minor modifications and various additions to adapt it to sampling in paraoccupational situations where the airborne fibre concentration is low relative to that found in the occupational environment where persons are working directly with asbestos-containing materials. Moreover, in these paraoccupational situations (which include sampling positions outside the temporary enclosures erected during the removal of asbestos-based thermal/acoustic insulating materials) asbestos fibres often comprise only a small percentage of the total number of fibres which might be found in a sample of the ambient air. **It must therefore be strongly emphasised that the results obtained by following the paraoccupational method should not be related to exposure standards which apply to occupational situations where the fibres are principally asbestos**.

Most informed authorities consider much of this paraoccupational sampling to be wasteful of resources and money, as the results obtained are often meaningless unless used to confirm the effectiveness of the control measures in use during asbestos removal or asbestos disturbance operations. As these situations now produce the bulk of airborne asbestos sampling, it is necessary to provide a formal method so that results can be more comparable. However, it must be strongly emphasised that the results obtained by following the abovementioned method should not be related to occupational exposure standards because of the different types of fibres found in occupational situations (predominantly asbestos) to those found in paraoccupational sampling (sometimes no asbestos at all).

Persons new to asbestos dust sampling and analysis should not undertake work in this field without making personal contact with an experienced occupational hygienist or scientist to obtain the essential training in the techniques involved.

SCOPE OF THIS METHOD

Part I of this document describes the procedures required to estimate personal exposure and to assist in the control of occupational environments where asbestos processes are in operation and the airborne fibres which are present are known to be predominantly asbestos.

Part II describes the sampling techniques that can be used in the paraoccupational environment where fixed station sampling is used and where airborne fibre levels may be low, or fibres may not necessarily be asbestos.

Part III details laboratory analytical procedures which are common to both the occupational and paraoccupational components of this method.

It should be emphasised that in mixed dust situations the presence of other fibres and fibre-like particles may interfere with the interpretation of any results.

It must also be recognised that the use of this method has limitations when applied to samples containing plate-like or acicular particles (e.g. talc, gypsum and certain other minerals and fibres), and consequently should not be implementated without a full qualitative understanding of the sample. There are analytical methods which can be used to develop a more complete understanding of complex samples. These techniques include polarising light microscopy, electron microscopy, X-ray diffractometry, gravimetric methods etc.

For occupational sampling, in the absence of other technically convincing information, all particles complying with the defined geometric conditions (see section 8.5), are to be considered as asbestos fibres and counted as such, thereby ensuring that under-estimates of asbestos exposure are minimised. This rule should also be applied to paraoccupational sampling but with the knowledge that it frequently over-estimates the asbestos concentration. It is also intended that the procedures described in this document can be used for epidemiology. However, for epidemiological purposes, more complex analysis may be required to achieve a complete understanding of occupational exposure.

Part IV describes the main sources of errors that arise when using the method, and gives several quantitative estimates of the overall `accuracy'.

GENERAL METHOD DESCRIPTION

A sample is collected by drawing a measured quantity of air through a membrane filter by means of a 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 and eyepiece graticule. 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.

PART I

AIR SAMPLING FOR OCCUPATIONAL SITUATIONS (ASBESTOS PROCESSES)

The first part of this method is intended to be used for the sampling of airborne asbestos dust in occupational environments where the airborne fibres are known to be predominantly asbestos. This method shall be used to determine compliance with Exposure Standards[9] or the various regulatory limits throughout Australia which apply to asbestos processes. These include asbestos manufacturing industries, as well as maintenance and construction work directly concerned with *in situ* asbestos-containing products.

Terms such as *Occupational and Regulatory Sampling, Worker Breathing Zone, Single Sample Duration* and *Total Sample Duration* have particular significance to this method and are defined in the Glossary at the beginning of this document.

1. STRATEGY FOR OCCUPATIONAL SAMPLING

1.1 GENERAL PRINCIPLES

Occupational exposure measurements are carried out to achieve one or both of two major objectives:

- to assess exposure relative to an occupational exposure standard and to enable appropriate dust control measures to be implemented
- to provide estimates of exposure for epidemiological investigations of morbidity and mortality

Sampling procedures should be arranged so as to cause minimal interference with the activities of the worker. All sampling must be conducted in the breathing zone of a worker so that the results are indicative of the worker's exposure to asbestos fibres under representative working conditions.

1.2 TOTAL SAMPLE 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 four hours, and preferably over an entire shift**.

Section 8.7 details acceptable minimum and maximum loadings of fibres on the filter, and it is this loading which dictates the range of possible sampling time for different airborne fibre concentrations.

1.3 FLOWRATE

If a 25mm filter is used, the flowrate should be selected in the range 0.4 to 2 litres/min such that a volume of 100 litres $\pm$ 20 per cent (that is 80-120L) is collected over the desired Single Sample Duration. For a 13mm filter the above flowrates and volumes should be divided by five.

As a minimum, the flowrate through the filter holder must be checked both before and after sampling. If the difference is greater than 10 per cent of the initial flowrate, 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 must be able to measure flowrate to an accuracy of $\pm$5 per cent of the true flow at the 90 per cent confidence level. (See Appendix B for flowrate calibration.)

1.4 SINGLE SAMPLE DURATION

To assist in the selection of flowrate, the following table gives Single Sample Durations for various flowrates at volumes of 80, 100 and 120 litres.

TABLE 1

SINGLE SAMPLE DURATION FOR VARIOUS FLOWRATES

	Sample Volume (litres)		
Flowrate	80	100	120
L/min		minutes	
0.4	200	250	300
0.5	160	200	240
1.0	80	100	120
2.0	40	50	60

The following Table is based on a 25mm diameter filter, and shows the lowest calculated concentrations that would result from the loadings as detailed in section 8.7. See also section 4 for presentation of results.

TABLE 2

LOWEST CALCULATED CONCENTRATION BASED UPON FILTER LOADINGS

	Sample	Volume	(litres)
	80	100	120
		fibres/mL	
Minimum Filter Loading			
40 fibres/100 graticules	0.24	0.19	0.16
15 fibres/100 graticules	0.09	0.07	0.06
10 fibres/100 graticules	0.06	0.05	0.04
Maximum Filter Loading			
1 fibre/graticule	0.6	0.48	0.4
2 fibres/graticule	1.2	0.97	0.8
10 fibres/graticule	6.1	4.8	4.0

NOTE: that by using these procedures, the concept of `optimum' filter loading[4] (usually lying in the range 80 to 300 fibres/100 graticule areas) as required by various other methods is not used. However, unlike these methods, fixing of the sample volume per cm^2 of effective filter area overcomes the now well-known problem where the observed fibre concentration appears to be over-estimated when using the low sample volumes, and under-estimated with high volumes.[10 - 13]

The penalty in this approach is that the practical detection limit (approximately 10 fibres/100 graticule areas) resides around 0.05 fibres/mL. Sample volumes and minimum practical detection limits have been designed to allow determination of airborne asbestos dust below the current technical limit for amphibole asbestos. However the reliability of the method decreases below 0.1 fibres/mL for occupational samples. **No attempt should be made to reduce the detection limit in occupational environments by increasing sampling volume**.

A second penalty is that precision suffers at high fibre concentrations (> 5 to 10 fibres/mL), which means that results can only be expressed in broad terms (see section 4). However, this is acceptable because the results are then clearly in excess of the exposure standard, and the reported results reflect the lack of precision by using an appropriate number of significant digits.

1.5 BLANKS

For each batch of filters used in a specific field sampling exercise or for every twenty-five filters in the batch, select one unused filter and subject it to the same treatment of handling and transport as for normal samples, but do not draw any air through it, or attach it to the worker. See section 8.6 for details of blank analysis.

1.6 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 available should be recorded for control design and epidemiological studies. Appendix D gives an example of a dust sampling record.

2 LIMITATIONS OF THE METHOD, AND PRESENTATION OF RESULTS

With the parameters specified in this method, that is, a 100 litre ($\pm$ 20 per cent) sample volume and a minimum apparent filter loading of 10 fibres per 100 graticule areas, the practical lower detection limit is approximately 0.05 to 0.1 fibres/mL. This limit arises because it is generally accepted that blank, unused filters can give a reading of several countable fibres per 100 graticule areas. These `fibres' may be unidentified contaminants on the filter, or artifacts from the clearing process which have the appearance of fibres.

It follows that the above detection limit may not be achieved when any of the above factors interfere with the counting process.

It must be recognised that neither counting more fields nor increasing sampling duration overcomes the problem of background dust which has been collected on the filter, especially when asbestos is a minor constituent in the overall dust cloud.

Insufficient information is available to determine at what level the reliability of the method becomes so poor that results have little meaning. It is clear that this level will not be a single value, but will be a range depending at least upon 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 0.05 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 should be expressed in the manner detailed in Table 3 on the following page.

TABLE 3

REPORTING OF OCCUPATIONAL SAMPLING RESULTS

	Calculated Concentration* (fibres/mL)	Reported Concentration (fibres/mL)
(I)	less than 0.05	< 0.05
(II)	0.05 to less than 0.10	2 decimal places and 1 significant figure
(III)	0.10 to less than 5.00	to 1 decimal place and 2 significant figures
(IV)	5.00 to 10.0	0 decimal place and 1 significant figure
(V)	greater than 10	> 10

Example:

	Calculated Concentration* (fibres/mL)	Reported Concentration (fibres/mL)
(I)	0.049	< 0.05
(II)	0.055	0.06
"	0.084	0.08
(III)	0.65	0.7
"	4.74	4.7
(IV)	6.34	6
(V)	13.42	>10

***NOTE:** If the actual count is less than 10 fibres/100 graticule areas, then the count is not significantly above that of background. The results should be calculated using the minimum practical detection limit of 10 fibres/100 graticule areas and reported as `less than' the calculated value expressed to 1 significant figure and no more than the first decimal place.

Example:

A 100 litre sample with a 25mm diameter filter count of 4 fibres for 100 graticule fields yielded a calculated concentration of 0.0194 fibres/mL. However, because the actual fibre count is below the detection limit of 10 fibres per 100 graticule areas, the concentration when recalculated using this limit is < 0.0484 fibres/mL. When rounded off as required by the above Table, the result shall be quoted as < 0.05 fibres/mL.

PART II

AIR SAMPLING FOR PARAOCCUPATIONAL SITUATIONS

Part II of this method is intended to be used for the field sampling of airborne asbestos dust in paraoccupational situations. These include sampling in the following situations:

- outside asbestos stripping and encapsulating areas
- inside decontamination rooms
- for clearance monitoring after asbestos stripping and encapsulating
- inside buildings or ships which contain asbestos

This type of sampling is often conducted in areas that contain high proportions of non-asbestos fibres or particles which conform with the geometric requirements of a `fibre' as defined by this method. Many experienced occupational hygienists would strongly recommend against this form of sampling as these interferences cause severe problems in interpretation. This is particularly true in situations where the results of the sampling are intended for use in estimating risks to health from suspected environmental contamination by airborne asbestos. **In such situations it is <u>inappropriate</u> to consider that the results from such monitoring have the same significance in terms of health consequences as does occupational monitoring outlined in Part I.** This advice is supported by a number of Australian[14] and international documents.[15,16]

Terms such as *Paraoccupational Sampling, Static Samples, Single Sample Duration* and *Total Sample Duration* have particular significance to this method and are defined in the Glossary at the beginning of this document.

3. STRATEGY FOR PARAOCCUPATIONAL SAMPLING

3.1 GENERAL PRINCIPLES

All sampling must be conducted so that the results are representative of the particular and specified situation being tested. Only static samples are allowed, and these should be taken over a single sample duration of not less than one hour (see section 3.3).

In situations where asbestos is actively being removed or disturbed, dust concentrations may vary widely both within a single day and from day to day, or from place to place. Additionally, variations in work procedures produce concentrations which can vary over one or more orders of magnitude. These factors may influence airborne levels obtained outside the removal area.

Air sampling outside asbestos removal operations is often carried out to ensure that negligible airborne asbestos is present. However, some results so obtained can be misleading due to the non-asbestos fibres which the sampling will detect but not identify. On occasions, air sampling should be used for testing the reliability of enclosures when they are initially installed. Once it has been established that such enclosures are controlling dust emissions, the emphasis should be placed on more efficient methods of testing, such as daily checking of the integrity of the barrier and the work practices that are carried out inside the enclosure. The choice of sampling conditions and interpretation of results should be determined by an experienced occupational hygienist.

Air monitoring in an environment which is representative of normal work activities is acceptable, however the artificial generation of an unrealistic environment is not acceptable.

The use of air monitoring which is associated with the deliberate creation of artificial contamination by sweeping, beating, or the blowing of air on to asbestos-containing or contaminated areas (that is, `aggressive' air monitoring) must not be employed. Data obtained under such conditions do not reflect current or future activities and therefore are of no value in the assessment of risk. Furthermore the practice may result in the transference of contamination from one part of a building to another without significantly affecting the measured airborne asbestos fibre concentration and/or can lead to misleading results due to the disturbance of non-asbestos fibres in the environment.

It is important to understand that air sampling should not be used as a substitute for frequent and thorough inspections by an occupational hygienist experienced in asbestos matters. Careful visual examination will reveal situations that are likely to create future contamination problems. Meticulous cleaning, resulting in the absence of any visible dust, will generally lead to acceptably low level contamination which reduces to less than detectable levels due to the process of normal cleaning.

3.2 TOTAL SAMPLE 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 preferably not be less than four hours. In some situations where urgency may dictate, the Total Sample Duration may be reduced to a minimum of one hour. However, it is necessary to ensure that the higher flowrate can be accurately measured and must comply with the total volume range specified in section 3.3 below.

Section 8.7 details acceptable maximum and minimum loadings of fibres on the filter, which therefore dictate the range of possible sampling times for different airborne fibre concentrations.

Single samples of short duration (still within the volume limit of section 3.3) may be necessary if high background levels of particulate matter or fibres are present which would prevent accurate analysis.

3.3 FLOWRATE

The flowrate should be selected in the range 1 to 8 litres/min such that a volume of 500 litres ± 20 per cent (i.e. 400-600L) is collected over the desired Single Sample Duration. In some situations, ambient levels of airborne dust from other parts of the site may lead to very dense samples which cannot be counted, or the excess dust may obscure some asbestos fibres in the sample.

Where past experience has shown that this is likely to occur, a lower sample volume of 240 litres may be used. Sample volumes of less than 240 litres are not recommended because of the increased loss of precision in the results obtained. Under conditions of very low airborne fibre concentrations or when Single Sample Durations much greater than four hours are desired, it is permissible to increase the sample volume to a maximum of 1000 litres.

The flowrate through the filter holder should be checked at least before and after sampling. If the difference is greater than 10 per cent from the initial flowrate, 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 must be able to measure flowrate to an accuracy of ±5 per cent of the true flow at the 90 per cent confidence level. See Appendix B for flowrate calibration.

3.4 SINGLE SAMPLE DURATION

To assist in the selection of flowrates, the following table gives Single Sample Durations for various flowrates at volumes of 400, 500 and 600 litres.

TABLE 4

SINGLE SAMPLE DURATIONS FOR VARIOUS FLOWRATES

	Sample	Volume	(litres)
Flowrate	400	500	600
L/min		minutes	
1.0	400	500	600
2.0	200	250	300
8.0	50	63	75

The following table is based on a 25mm diameter filter, and shows the lowest calculated concentrations that would result from loadings detailed in section 8.7. See section 4 for presentation of results.

TABLE 5

LOWEST CALCULATED CONCENTRATIONS FOR VARIOUS FILTER LOADINGS

	Sample	Volume	(litres)
	400	500	600
		fibres/mL	
<u>Minimum Filter Loading</u>			
40 fibres/100 graticules	0.048	0.039	0.032
15 fibres/100 graticules	0.018	0.015	0.012
10 fibres/100 graticules	0.012	0.010	0.008
<u>Maximum Filter Loading</u>			
1 fibres/graticule	0.12	0.10	0.08
2 fibres/graticule	0.24	0.19	0.16
10 fibres/graticule	1.21	0.97	0.81

Because Part II is concerned with situations generally giving rise to very low airborne asbestos concentrations, the concept of a fixed sample volume/cm^2 of effective filter area as required by Part I is not possible. Note that the use of larger sample volumes than specified in Part I leads to a different estimate of observed fibre concentrations, and should <u>not</u> be compared to present occupational Exposure Standards. At best, these measurements can only assist people in ensuring dust levels are less than certain arbitrary limits.

3.5 BLANKS

For each batch of filters used for sampling, or for every twenty-five filters in the batch, select one unused filter and subject it to the same treatment of handling and transport as for normal samples, but do not draw any air through it, nor attach it to the worker. See section 8.6 for details of blank analysis.

3.6 SAMPLING RECORD

All sampling details and data necessary for the determination of the fibre concentration must be recorded. Furthermore, as much data as available should be recorded for control design and epidemiological studies. Appendix D gives an example of a sampling record.

4. LIMITATIONS OF THE METHOD AND PRESENTATION OF RESULTS

With the parameters specified in section 3, that is, a 500 litres ($\pm$ 20 per cent) sample volume and a minimum fibre loading of 10 fibres/100 graticule areas, the practical lower detection limit is approximately 0.01 fibres/mL.

It is generally accepted that blank, unused filters can frequently give a reading of 1 or 2 countable fibres per 100 graticule areas. The `fibres' may be unidentified contaminants on the filter, or artifacts from the clearing process which have the appearance of fibres. Thus the above detection limit may not be achieved when any of these factors interferes with the counting process.

Because of the inherent variability of the method, especially at the very low concentration levels treated by Part II of this method, all calculated values should be expressed in the manner detailed in Table 6 on the following page. For each sample it is essential to describe conditions existing prior to, and during sampling, as well as the exact position of the static sampler, the area of the location being sampled and any other relevant details.

TABLE 6

REPORTING OF PARAOCCUPATIONAL SAMPLING RESULTS

	Calculated Concentration* (fibres/mL)	Reported Concentration (fibres/mL)
(I)	less than 0.005	< 0.01
(II)	0.005 to less than 0.100	to 2 decimal places and 1 significant figure
(III)	0.10 to 1.00	to 1 decimal place and 1 significant figure
(IV)	greater than 1.00	> 1

Examples:

	Calculated Concentration* (fibres/mL)	Reported Concentration (fibres/mL)
(I)	0.0049	< 0.01
(II)	0.0054	0.01
"	0.063	0.06
(III)	0.356	0.4
(IV)	2.34	> 1

***NOTE:** If the actual count is less than 10 fibres/100 graticule areas, then the count is not significantly above that of background. The results should be calculated using the minimum practical detection limit of 10 fibres/100 graticule areas and reported as `less than' the calculated value expressed to one significant figure and no more than the second decimal place.

Example:

A 400 litre sample with a 25mm diameter filter count of 3 fibres for 100 graticule fields yielded a calculated concentration of 0.0036 fibres/mL. However, because the actual fibre count is below the detection limit of 10 fibres/100 graticule areas, the concentration when recalculated using this limit is < 0.0121 fibres/mL. When rounded off as required in the above Table, the result shall be quoted as < 0.01 fibres/mL.

PART III

LABORATORY TECHNIQUES AND ANALYSIS

The third part of this method details the analytical procedures to be used for both types of sampling as described in Parts I and II. For clarity, aspects common to Parts I and II (such as sampling equipment) will be included in Part III.

5. EQUIPMENT

(See Appendix J for Specifications)

5.1 SAMPLING PUMP

A portable battery powered pump must be used for personal sampling. The capacity of the battery must be sufficient to operate continuously over the chosen sampling time. The pump should be capable of maintaining the required flowrate with a variation within $\pm$10 per cent for the entire sampling duration, allowing for increasing filter loads. Pumps with automatic flow control facilities are recommended. The performance characteristics of field sampling pumps vary considerably and reference should be made to experienced laboratories for selection of pumps for specific sampling applications.

The flow must be sufficiently free from pulsation. As a minimum and tentative criterion there must be no visible vibration of a rotameter float if such a flowmeter is connected to the filter holder with the filter inserted. It may be necessary to install a pulsation damper between the pump and the filter if an internal pulsation damper has not been included or if the pump shows significant pulsation.

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

Caution: When sampling in explosive gas or dust atmospheres as defined in AS 2430(17), ensure that the sampling pump meets the equirements of AS 2380(18).

5.2 FILTERS

Membrane filters (mixed esters of cellulose or cellulose nitrate) of 0.8 micrometre pore size with printed grids must be used, and a diameter of 25mm is preferred. Airborne dust should be collected on the upper (grid) surface of the filter.

It is acceptable to use 13mm filters and filter holders provided that flowrates and sample volumes are adjusted to give identical sampling volumes per square centimetre of effective filter area.

5.3 FILTER HOLDER

It is necessary to use an open faced filter holder fitted with a protective cowl. The cowl helps to protect the filter from accidental contamination. A metallic or conductive coated cowl is preferred because of the possible risk of fibre loss due to electrostatic charge when using plastic cowls. This is especially true when operated under conditions of low relative humidity.

Filter holders and cowls must be meticulously washed with detergent and water and thereafter rinsed thoroughly. After exposure to high asbestos concentrations it may be necessary to dispose of the holders and cowls, or only re-use in environments with high dust concentrations where any potential contamination would not have a significant effect upon results. **Filter holders which have previously been used with fibreglass filters should never be used for asbestos work because of the risk of cross-contamination**.

The design of the filter support utilised in some filter holders requires that a secondary support pad should be used. The purpose of this support pad is to ensure an even distribution of air passing through the primary membrane. These support pads are usually made of pure cellulose and have a much larger pore size than the primary filter upon which the fibres are collected.

5.4 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 be avoided.

Filters should be transported in the closed holders in which the samples were collected.

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 exposed filter from its holder, taking care to grasp only the unexposed filter 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 transportation, the filter can easily be removed from the dish with a surgical scalpel.

The filter holders or petri dishes should be packed into a rigid container with some soft packing material to prevent both crushing and vibration of the filter. Samples should be clearly and unambiguously labelled, taking care to ensure that filters cannot be accidentally re-used. The filters should not be marked for this purpose because of the risk of damaging the filter.

6. SAMPLE PREPARATION

6.1 CLEANING SLIDES AND EQUIPMENT

Clean conditions should be maintained at all times. A dirty preparation area may result in sample contamination and erroneous results. Particular care should be taken to ensure that the presence of bulk asbestos samples in the laboratory does not cause contamination.

The slides should be cleaned with lens tissue or industrial paper tissue and laid out on a clean surface such as a sheet of lens tissue. Each coverslip should be cleaned with lens tissue immediately before use to ensure that the surfaces are free from contamination.

The scalpel and forceps should be wiped with lens tissue and placed on a clean surface (for example, lens tissue). When mounting a series of filters, the mounting tools must be wiped clean before dealing with each sample.

6.2 FILTER SAMPLE CUTTING

If a 13mm diameter filter is used, the total filter must be mounted. It is preferable to mount only one half of a 25mm diameter filter. All cutting should be done to give a single clean cut, with no disturbance to the filter face. Either a curved bladed scalpel used with a rolling action or a very sharp razor has been found satisfactory.

6.3 MOUNTING THE SAMPLE

For mounting, use the acetone-Triacetin* method only, as described in Appendix A.

* glycerol triacetate

WARNING

ACETONE VAPOUR IS HIGHLY FLAMMABLE, AND MOUNTING SHOULD BE CARRIED OUT WITH ADEQUATE VENTILATION. ON NO OCCASION SHOULD IT BE USED IN THE VICINITY OF AN OPEN FLAME OR OTHER IGNITION SOURCES.

7. OPTICAL REQUIREMENTS

7.1 MICROSCOPE EQUIPMENT

Microscopes with identical `specifications' can give quite different performances; therefore it is necessary that the performance of proposed and existing microscopes be assessed by means of a `Detection Limit Test Slide' (see Appendix F). It is important that experienced practitioners be consulted before selecting microscopes for asbestos dust determination. It is recommended that the following specification be used to select a microscope suitable for asbestos dust counting.

- **Light Source** - Koehler or pseudo-Koehler illumination is preferred. It is preferable for the illuminator to be built-in, but an external lamp with a plane mirror can be satisfactory. A variable light intensity control is necessary for both methods of illumination.
- **Substage Assembly** - An Abbe or achromatic phase-contrast condenser incorporated into a substage unit is required. There must be a means of centering each condenser annulus with respect to the phase plate in the corresponding objective and a means of focusing 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 10X and 40X parfocal phase-contrast achromatic objectives is required. The 40X objective must have a numerical aperture (NA) of 0.65 to 0.75. 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 400X and 650X. At least one eyepiece must permit insertion of a graticule and should be of the focusing type. The use of body magnification changers and wide-field 10X eyepieces is not recommended.
- **Graticule** - The graticule for this method is the Walton-Beckett circular eyepiece graticule (Graticules Limited Type G22). When using the 40X phase objective and an appropriate eyepiece, the image plane diameter of the graticule circle must be 100 micrometres $\pm$ 2 micrometres. See Appendix E for graticule specification, source of supply and ordering information.

7.2 MICROSCOPE ACCESSORIES

Considerations in the selection of microscope accessories:

- A Centering 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 or blue filter may reduce eye fatigue.
- The stage micrometer should be from a reputable source, preferably one millimetre in length and must be subdivided into at least 10 micrometre intervals.
- High quality microscope slides should be used.

- The coverslip thickness should be that for which the microscope is designed, usually 0.17mm thickness (that is, No. 1 1/2). Incorrect coverslip thickness will detract from the quality of the final image.

7.3 MICROSCOPE ADJUSTMENT PRINCIPLES

Microscope adjustments and testing with the Detection Limit Test Slide must be part of the daily counting routine. Follow the manufacturer's instruction while observing the following guidelines:

- 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 image of the light source must be in focus and centred on the condenser iris or annular diaphragm for true Koehler illumination
- 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.

7.4 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 interoccular distances. (See Appendix E for eyepiece graticule calibration procedures).

7.5 MICROSCOPE/OBSERVER PERFORMANCE ASSESSMENT

Past experience has shown that differences in counts arise from differences in microscope quality, setting up and cleanliness. It is therefore necessary that laboratories following this method should maintain contact with experienced laboratories.

As mentioned in section 7.1, a Detection Limit Test Slide is available which will assist in the regular assessment of microscope and observer performance. If Block 5 on the Detection Limit Test Slide (Mark 2) cannot be distinguished, the microscope (or observer) is not suitable for work with this method and should not be used until this deficiency has been investigated and corrected. Block 7 should not be resolved.

8. COUNTING AND SIZING FIBRES

8.1 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 may experience difficulty in defining and counting the fibre content in a dust sample. The following notes (and drawings in Appendix H) have been prepared to assist and guide the observer in assessment and interpretation of asbestos dusts collected on membrane filters. It must be recognised that the use of this method has limitations when applied to samples containing plate-like or acicular particles (for example, talc, gypsum and certain other minerals and fibres), and consequently should not be implemented without a full qualitative understanding of the sample.

8.2 LOW POWER SCANNING

With a total magnification of 100X to 150X (that is, 10X objective), scan the entire filter area.

The margin normally covered by the filter holder 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, or gross aggregation of fibres or dust, the filter must be rejected.

At least half of the mounted filter area must be countable, otherwise it must be rejected.

8.3 GRATICULE FIELD SELECTION

After a satisfactory low power scan, change the microscope objective to 40X phase contrast 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 filter, it will be necessary to focus below (up to 10 micrometres) and slightly above the surface.

When counting and sizing, constant use of the fine focus is necessary because of the small depth of field of a 40X objective (that is, 2 to 3 micrometres).

Counting fields should be examined throughout the entire area of the filter or filter segments ensuring that the choice is not biased by the lack or presence of fibres. If the grid of a filter obstructs the view, move the stage to another field. Do not count fields that lie within 3mm of the filter edge and within 2mm of the cutting line.

8.4 LABORATORY WORKING CONDITIONS

The working environment in a laboratory may systematically influence the accuracy of the actual counting. Subjective factors such as lighting, seating and noise should be suitable for the task.

8.5 COUNTING CRITERIA

8.5.1 Accuracy for determining fibre length and diameter is critical, and full use must be made of the eyepiece graticule. Estimate the length of curved fibres along the curve of the fibre (that is, true length).

8.5.2 A *countable fibre* is defined as any object having a maximum width less than 3 micrometres and a length greater than 5 micrometres and a length/width ratio greater than 3:1, and which does not appear to touch any particle with a maximum dimension greater than 3 micrometres. A countable fibre with both ends within the graticule area shall count as one fibre; a countable fibre with only one end within the area shall count as half a fibre; a fibre with both ends outside the area must not be counted.

8.5.3 Graticule areas for counting shall be examined as in section 8.3 above.

8.5.4 An agglomerate of fibres, which at one or more points on its length appears to be solid and undivided but which at other points appears to divide into separate strands, is known as a split fibre. Any other agglomerate in which fibres touch or cross one another is known as a bundle.

8.5.5 A split fibre is regarded as a single countable fibre if it meets the definition in 8.5.2, the width being measured across the undivided part, not the split part.

8.5.6 Fibres in a bundle are counted individually if they can be distinguished sufficiently to determine that they meet the definition in 8.5.2. If no individual fibres meeting the definition can be distinguished, the bundle is a countable fibre if the bundle as a whole meets the definition in 8.5.2.

8.5.7 If more than one-eighth of a graticule area is covered by an agglomerate of fibres and/or particles, the graticule area must be rejected and another counted.

8.5.8 Count as many fields as is necessary to yield a total fibre count of 100 but count a minimum of 20 fields even if more than 100 fibres are counted. Do not count any more than 100 fields if a total of 100 fibres is not reached.

8.5.9 All relevant information must be recorded. It is good practice to record each field and fibre as it is observed. (See Appendix I for an example of a fibre counting form.)

8.6 BLANKS

Parts I and II require that blank filters be used. If any `blank' yields fibre counts greater than 3 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 3 fibres/100 graticule areas, and also exceeds 10 per cent of the actual sample fibre count/100 graticule areas, the samples to which the particular blank is appropriate should be rejected.

It is prudent to check each batch of filters to ensure that blank levels of new filters are not excessive.

For example, if the fibre count of a blank filter was 4 fibres/100 graticule areas (that is, 0.04 fibres/area) while the sample yielded 15 fibres in 100 graticule areas (that is, 0.15 fibres/graticule area).

$$\frac{\text{Blank Count}}{\text{Sample Count}} = \frac{4}{15} \times 100 = 27\%$$

As this ratio exceeds 10 per cent, the sample is rejected. Furthermore, because the blank count exceeded 3 fibres/graticule area the cause of contamination must be found and corrected.

8.7 ACCEPTABLE FIBRE LOADINGS ON FILTERS

8.7.1 **Minimum loading**

For reliable counting, a fibre loading of a filter should exceed 40 fibres/100 Walton-Beckett graticule areas. In special circumstances (for example, when an indication of concentration with low precision is acceptable) it is permissible to lower the acceptable fibre loading to 10 fibres/100 Walton-Beckett graticule areas.

If less than 10 fibres/100 graticule areas is observed, then the figure of 10 fibres/100 graticule areas is the minimum that can be used to calculate airborne fibre concentration.

The lowering of the acceptable fibre loading to 10 fibres/100 graticule areas gives, at best, barely acceptable coefficients of variation. The limitations as described in Part IV should also be considered when measuring very low fibre concentrations.

Note that a sample count of 10 fibres/100 Walton-Beckett graticule areas can just be distinguished from the background `blank' count of 2 fibres/100 graticule areas for typical sampling/analytical coefficients of variation of 0.6 to 0.8. For this reason, it is mandatory to ensure that blank counts are not greater than 2 fibres/100 graticule areas before accepting 10 fibres/100 graticule areas as a minimum loading.

8.7.2 **Maximum loading**

Experience shows that the filter loading should not exceed a maximum of 5 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 1 fibre per graticule area when mixed dusts or agglomerates are present, and can sometimes be doubled when only fibres are present. Average filter loadings between 5 and 10 fibres/graticule area tend to result in an under-estimation, and should be treated with caution. Average filter loadings exceeding 10 fibres/graticule area should be rejected.

8.8 CALCULATION OF DUST CONCENTRATION

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.

8.8.1 Single values

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

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

where:

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

Results should be presented in the manner detailed in either sections 2 or 4.

8.8.2 Time-weighted average values

When several consecutive samples of different sampling duration are taken, calculate the time-weighted average values from the single values as follows:

$$C_{TW} = \frac{\sum c_i . t_i}{\sum t_i} \qquad \frac{c_i t_i + c_2 t_2 + ... + c_n t_n}{t_i \ + t_2 \ + ... + t_n} \qquad \text{....... (2)}$$

where:

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

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

$$C_{TW} = \frac{\sum C_1}{n} = \frac{C_1 + C_2 + ... + C_n}{n} \qquad \text{...... (3)}$$

Results should be presented in the manner detailed in either sections 2 or 4.

9. QUALITY CONTROL[8]

A good quality control procedure is essential because of the large differences in results obtained both within and between laboratories using all manual fibre-counting methods. Laboratories using the method must participate in systematic checks to assess inter-laboratory variation. It is important to provide a measure of the reproducibility and stability of a laboratory's performance in relation to other laboratories and to an automatic method. These exchanges should be supplemented by checks of internal consistency, which should aim to measure the mean and reproducibility of each counter's difference from the average of the laboratory. It is unsatisfactory for a counter to have an average result equal to the laboratory mean if that counter's average performance conceals considerable variation from sample to sample.

In a large laboratory, a satisfactory procedure is to have all the counters recount a specified fraction of the routine slides. The fraction should be chosen to provide a quality control sample about once a week, and to ensure that these slides are fully representative of the laboratory's routine samples. For example, a laboratory counting 5000 samples a year could select every hundredth filter (whatever its type) for recounting by all of its counters, and could keep a running check of the mean and standard deviation of each individual's difference from the laboratory mean.

A laboratory with only one or two counters would have to maintain a stock of permanently mounted and well-characterised slides for periodic check counting, and could again calculate the mean and standard deviation of the counts in relation to those accepted for the stock slides.

Systematic records of quality control results should be kept and regularly examined to assess individual counter and overall laboratory performance. It should be remembered that, in common with monitoring for other particulates, errors will be introduced in sampling.

PART IV

SAMPLING AND ANALYTICAL ERRORS

The estimation of airborne asbestos dust comprises sampling and analytical errors, each of which has a systematic and random component. These can be minimised by strict adherence to the method and by participating in intra and inter-laboratory Quality Assurance schemes. The following list describes some of the common sources of error.

10. SOURCES OF ERROR

Some common sources of error are listed below:

10.1 SYSTEMATIC ERRORS

10.1.1 **Sampling**

- flowrate
- sampling time
- non-representative or biased sampling
- contamination - deliberate or accidental

10.1.2 **Analytical**

- effective filter area
- counting area
- filter mounting
- microscope
- observer
- contamination

10.2 RANDOM ERRORS

10.2.1 **Sampling**

- flowrate variability
- random fluctuations of the airborne dust cloud

10.2.2 **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 error

As only a small proportion of the fibres deposited on the filter are counted, errors arise in the estimation of the total number of fibres on the entire filter surface. Theoretically, the Poisson Distribution defines the variation in fibre counts resulting from the viewing ofrandomly 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 coefficient of variation of the fibre counts would not exceed 10 per cent.

The Poisson error is the minimum inherent error of the Membrane Filter Method and in many other practical situations such as particle `counting', electron microscope methods and blood counts.

11. 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 within and between laboratories. 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 the future to provide estimates of empirical precision (that is the closest approach possible to a statement of accuracy for a method with known *`true'* values).

Much work has been done in an attempt to arrive at these estimates, and to date only a partial conclusion has been reached. Examples of confidence intervals calculated from the Poisson Distribution are presented in Table 7 below:

TABLE 7

THEORETICAL CONFIDENCE INTERVAL FOR RESULTS USING POISSON DISTRIBUTION

NUMBER OF FIBRES COUNTED PER 100 GRATICULE AREAS	95% CONFIDENCE INTERVAL FOR RESULT
100	±20% of the calculated result
40	-26% to +36% of the calculated result
10	-50% to +84% of the calculated result (that is, the true result may be in the range of 50-184% of the calculated result)

Confidence limits apply to the measured result and not the final reported result, which is a rounded-off representation of the measured result. Other sources of random and systematic errors add significantly to the uncertainty in estimating the airborne asbestos dust concentration, and these have been known to increase the above confidence intervals by up to a factor of 2 or 3. Tables 8 and 9 present the findings of empirical studies[(19)] in the United States into the precision of the Membrane Filter Method in estimating airborne asbestos concentrations. There is no reason to assume that this variability would not be reflected in Australia.

TABLE 8

COEFFICIENTS OF VARIATIONS FOR EXPERIENCED LABORATORIES

Total No. of Fibres Counted	Coefficients of Variations* Analytical Only	Sampling & Analytical
10	0.60	0.90
15	0.55	0.80
40	0.45	0.70
100	0.40	0.65

***** The Coefficient of Variation (CV) is calculated by dividing the standard deviation by the arithmetical average of a set of fibre concentrations determined with a number of observers estimating the dust concentration of a specific dust cloud or of a single filter.

TABLE 9

90% CONFIDENCE LIMITS DERIVED FROM EMPIRICAL STUDIES (19)

Total No. of	Analytical		Sampling & Analytical	
Fibres Counted	LCL	UCL	LCL	UCL
10	3	21	2	26
15	6	31	4	37
40	18	74	12	93
100	49	175	31	222

LCL = Lower Confidence Limit

UCL = Upper Confidence Limit

At the lowest count allowed by this method of 10 fibres/100 graticule areas, experience indicates that the inherent variability of the combined sampling/analytical process can yield `real' values as low as 2 and as high as 26 fibres/100 graticule areas. Precision increases as the count becomes higher. However, observing significantly more than 100 graticule areas in an attempt to improve precision often results in no real gain due to operator fatigue and other subjective errors.

APPENDIX A

ACETONE-TRIACETIN MOUNTING PROCEDURE

There are various methods available for generating acetone vapour to `clear' membrane filters. The original NH&MRC Membrane Filter Method[4] employed a flask of acetone heated on a hot plate, water bath or infra-red lamp. An increasing number of Australian laboratories have now adopted the `hot-block' method.[20] This method uses a heated metal block in which a small amount of acetone is rapidly vapourised and directed on to the filter. This has certain advantages in terms of filter preparation and safety. The NH&MRC paper[4] should be referred to for constructional details, bearing in mind that for added safety it is wise to use a low voltage source of power (for example, 12V) and not 240V mains electricity.

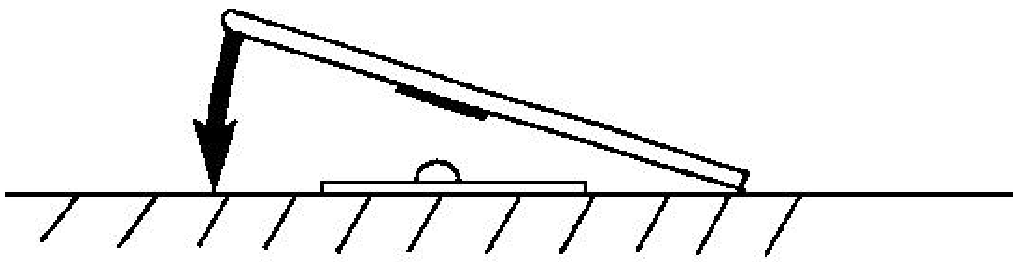
An alternative method recommended by the (UK) Health and Safety Executive[8] consists of a boiling acetone reservoir with a condensing coil to prevent acetone escape. In this method, temperature control is reasonably critical and the larger quantity of acetone poses a potential fire hazard. Other methods are described in Appendix A of the AIA RTM 1 document.[5] However, these are not recommended because they are not as inherently safe as the `hot block' method and generally do not clear filters as effectively.

After acetone clearing, the cleared filter should be left to stabilise for at least five minutes. Thereafter, the slide and its adhering filter is treated, using the following technique:

Lay a freshly cleaned coverslip on a clean horizontal surface and using a variable dispenser capable of consistently delivering a quantity between 5-10uL (for half of a 25mm dia. filter) of glycerol triacetate (Triacetin) on the coverslip. Lower the already (acetone) cleared filter on to the coverslip and allow the weight of the slide to spread the Triacetin evenly. See Figure 1.

Too much Triacetin (as indicated by excess liquid emerging from the edges of the coverslip) can cause the outside edge of the filter to eventually 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.

FIGURE 1



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 twenty-four hours until the entire filter has dissolved under the action of the Triacetin. Provided the above procedures are followed, the finished product will be stable, will not disintegrate, nor be subject to significant 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

FLOWRATE CALIBRATION AND CORRECTIONS

(I) FOR FLOWRATES 0.4 - 2.0 L/min

Internal and external flowmeters must be calibrated with a primary calibration device. One suitable calibration procedure makes use of a soap film flowmeter. The flowmeters described in this section are of the variable area type (that is, `rotameters').

1. Choose an accurate burette (or similar measuring device) of 300-500 mL capacity. Attach a tube to the bottom of the burette, and then clamp it in an inverted vertical position in a stand.

2. Set up the sampling pump, allow flow to stabilise, complete with connecting tube, filter holder and filter as used in the field.

3. Connect the soap film flowmeter. 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, allow the flow to stabilise and adjust the flowrate to the nominal desired figure according to the internal flowmeter (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 flowmeter, 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 the appropriate graduated marks.

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:

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

$$Q_c = \frac{V}{T}$$

where

Q_c = true volumetric flowrate (mL/min) at calibration conditions

V = volume of burette (mL)

T = 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 (that is flowrate measured and expressed at the prevailing temperature and pressure) and not mass flowrate (that is 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 500m or 15^{o}C respectively compared to the calibration conditions.

EXAMPLE:

During the calibration of a pump with an internal flowmeter a soap film flowmeter of 500mL volume gave an average of 31.7 seconds for the bubble to traverse its length.

What is the flowrate under these conditions?

Using the equation in this Appendix:

$$Q_c = \frac{V}{T} = \frac{500}{31.7/60} = 946 \text{ mL/min}$$

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

(II) FOR FLOWRATES EXCEEDING 2.0 L/min

If an accurate burette of 1,000mL capacity is chosen, then flowrates up to approximately 4 L/min can be calibrated. However, it is not acceptable to manually time the passage of the bubble if the time interval over the measured volume is less than 15 seconds. It is not acceptable to use a soap film flowmeter of capacity exceeding 1 litre. Photocell activated electronic timers can be used if it is proven that no added artifacts are introduced which can cause inaccuracy. At high flowrates, pressure drops across restrictions in the calibration train may cause further inaccuracies, and must be taken into account.

If secondary standard flowmeters (for example, rotameters) are used, it is imperative that they be regularly calibrated against a suitable primary standard, giving due consideration for pressure drop and pulsation problems.[21]

APPENDIX C

MEASUREMENT OF EFFECTIVE FILTER AREA

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

1. Place a small quantity of dark coloured dust (for example, 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 visible deposit on the filter.
3. Remove the filter from the holder, and mount on to a microscope slide in the normal manner as described in Appendix A.
4. Measure at least two and preferably four different diameters of the resultant dust spot to within $\pm$ 0.2mm. Among other methods, microprojection measurement, or the use of microscope object stage verniers have been found satisfactory.
5. Provided that the measured diameters of the filter differ by no more than 1mm, a simple arithmetical 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 final calculated area is sufficiently accurate.
7. Provided that the three individual filter diameters differ by no more than 1mm, an arithmetical 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 1mm, 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 twelve months to ensure that the correct effective filter area is known.

APPENDIX D

DUST SAMPLING RECORD
(Example Only)

All data necessary for the determination of the fibre concentration must be recorded in a sampling record. Furthermore, as much data as available should be recorded for control design and epidemiological studies.

SAMPLING DETAILS

- instrument type and number
- flowrate: (initial, intermediate and final)
- duration
- sampling strategy used
- date, hour
- sampled by

SAMPLING ENVIRONMENT DETAILS

- designation: (job title and work location)
- harmful substances: (for example, types of asbestos.)
- brief description of working process
- variable parameters which can exercise an influence on dust formation
- work practices: (if applicable)
  - working conditions: (normal, abnormal)
  - material: (for example, type, size, condition)
  - airflow: (worker in dust airflow - yes/no
    obvious influence on adjoining working places)
- methods of dust control: (if applicable)
  - 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

SPECIFICATIONS FOR EYEPIECE GRATICULE AND CALIBRATION

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.

A technical description of this graticule can be found in a paper in the Annals of Occupational Hygiene.(22)

The desired diameter (d) of the circle to appear as 100 $\pm$ 2 micrometres in the image plane (D) 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.

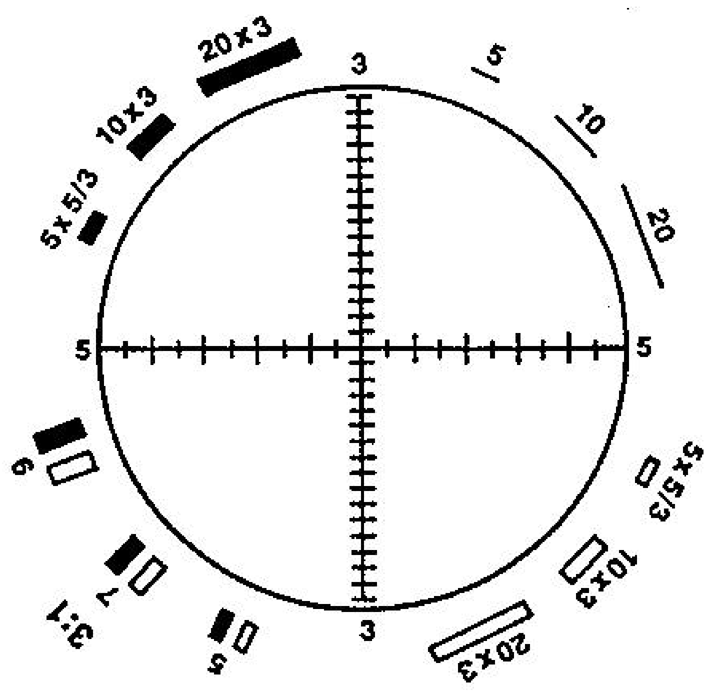


FIGURE 2
Walton-Beckett graticule for evaluating fibrous dusts

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 on to 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:

   diameter to be specified (d) = $(1_a/1_o)$. D

   It is also necessary to specify the overall diameter of the glass disc as detailed by each microscope manufacturer.

   <u>EXAMPLE:</u>

   Step 5 produced an object length of a Porton graticule of 108 micrometres

   Step 6 produced an actual length of 4.50mm

   Step 7: $\frac{4.50}{0.108} \times 0.1 = 4.17$ mm

   For this example, the graticule diameter was found to be 17mm. Thus a 17mm diameter, Type G22 Walton-Beckett graticule of circle diameter 4.17mm, 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. In most cases individual invoices and deliveries can be arranged on a single bulk order if requested.

PART 2: CALIBRATION OF EYEPIECE GRATICULES

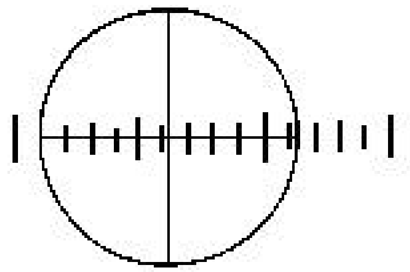
1. Obtain a stage micrometer, preferably with a scale having two or ten micrometre divisions, and place on the object stage of the microscope.
2. Make sure interpupillary distance of eyepieces is set correctly.
3. Note the objective magnification and any intermediate magnification used.
4. Focus the microscope on to the graduated marks of the stage micrometer.
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 micrometre and add to the number of whole divisions of the stage micrometer after converting to micrometres.

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

<u>EXAMPLE</u>:

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

FIGURE 3



   Note that 10 whole divisions span across the graticule (that is 10 x 10 micrometres).

3. The remainder of the 11th division is estimated as being one-third of a whole division (that is, three micrometres).

   Adding these together yields 103 micrometres, 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

DETECTION LIMIT TEST SLIDE

The recommended HSE/NPL Detection Limit Test Slide (Mark II) for use in Phase Contrast Microscopy is available from:

PTR OPTICS
UNIT D9
CROSS GREEN APPROACH
CROSS GREEN INDUSTRIAL ESTATE
LEEDS
YORKSHIRE
UNITED KINGDOM

DESCRIPTION

The standard test slides consist of epoxy replicas of a Master Slide produced and certified by the National Physical Laboratory (UK). The replicas are mounted on a 75 x 25mm glass slide which is either 1.2 or 0.8mm thick. The slide is covered by a coverslip 0.17mm thick with a layer of another resin with a different refractive index in betweem.

The test objects consist of a series of seven blocks of grooves of length 8.5mm filled with a resin of refractive index 1.58 in a medium of refractive index 1.485. The grooves have a V-shape profile and have a depth-to-width ratio of about 0.1. The blocks are separated by gaps 20 micrometres wide. A set of four deep marker grooves is placed on either side of the array and a further two sets of two marker grooves spaced at an interval of 120 micrometres intersect the array at right angles. The zone of the test objects to be used is delineated by the rectangle bounded by these marker grooves. This zone can easily be located, as the field of view in which it is found is engraved on the coverslip. This is illustrated in Figure 4.

The widths of the grooves within each block and the calculated phase change (in degrees) associated with the maximum path difference in the light rays passing through the test objects are in Table 10.

METHOD OF USE

Set up the microscope for phase contrast microscopy as recommended for the membrane filter method.

Locate Block 1 (the coarsest set) of the test objects and move the slide to observe adjacent blocks. Determine the block of the finest grooves that can be seen. It is unlikely that all seven blocks of grooves will be detected using optical phase contrast techniques, even on the best research microscope. On the basis of present information, a satisfactory system will detect Block 5.

Full details are supplied with the slide.

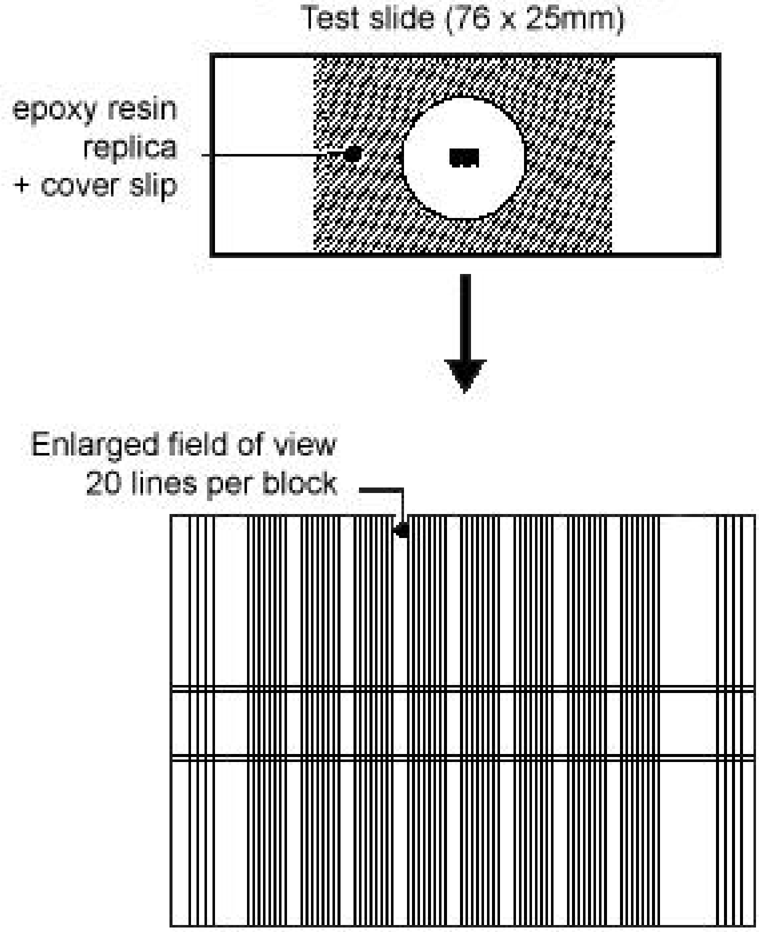
TABLE 10

WIDTHS OF TEST OBJECTS AND CALCULATED MAXIMUM PHASE CHANGE INDUCED IN LIGHT RAYS PASSING THROUGH TEST OBJECTS OF HSE/NPL TEST SLIDE

Block Number	Groove Width (micrometres)	Maximum Calculated Phase Change (in degrees) for light rays*
1	1.08	6.6
2	0.77	4.7
3	0.64	3.9
4	0.53	3.2
5	0.44	2.7
6	0.36	2.2
7	0.25	1.5

*wavelength = 530 nanometres passing through test objects.

FIGURE 4
HSE/NPL Test slide for phase contrast microscopy



APPENDIX G

MICROSCOPE ADJUSTMENT PROCEDURE

Good quality phase contrast microscope equipment should be used as detailed in section 7.2. The equipment should be maintained in first-class condition. 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. 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 1mm of lower face of specimen slide.
4. Using a convenient level of illumination and 10x 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 the image of the bulb (removing the diffusing disc if one is fitted) and centre the bulb filament, focusing 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 focused, 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. *Slightly* adjust the condenser focusing 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 40x objective with no phase annuli in the condenser system. Close down the field diaphragm and re-focus 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 40x objective.
11. Revert to normal viewing.

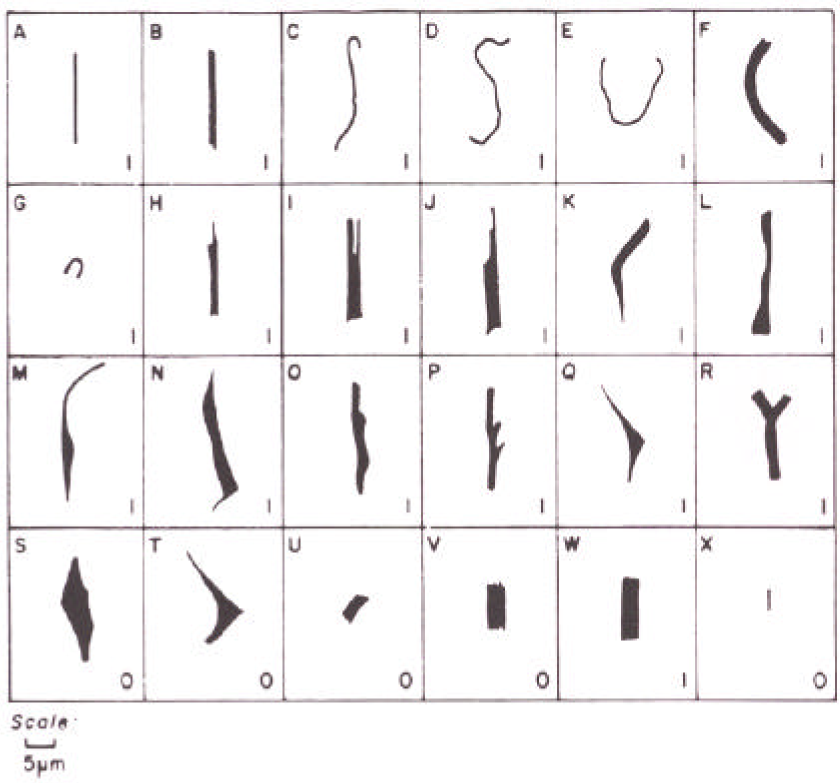
APPENDIX H

DRAWINGS OF VARIOUS ASBESTOS FIBRES

<u>**NOTE**</u>: **All drawings are the same scale (1mm represents one micrometre). The number in the right bottom corner of each drawing indicates the number of fibres (as defined) counted.**

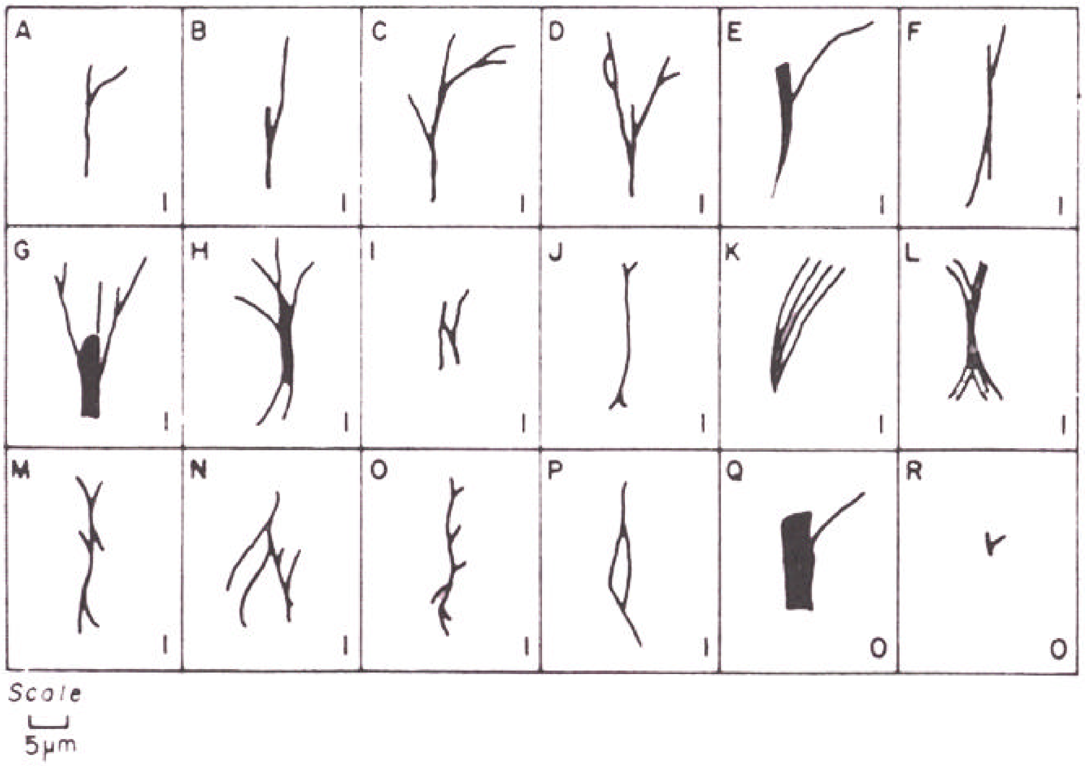
SINGLE FIBRES: These are the simplest of the fibres to identify and count. They are also the most common measurable fibres seen on the membrane filter. Amosite and crocidolite fibres generally assume a straight needle-like form. Chrysotile fibres, while sometimes straight, often assume a curved or curly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

FIGURE 5



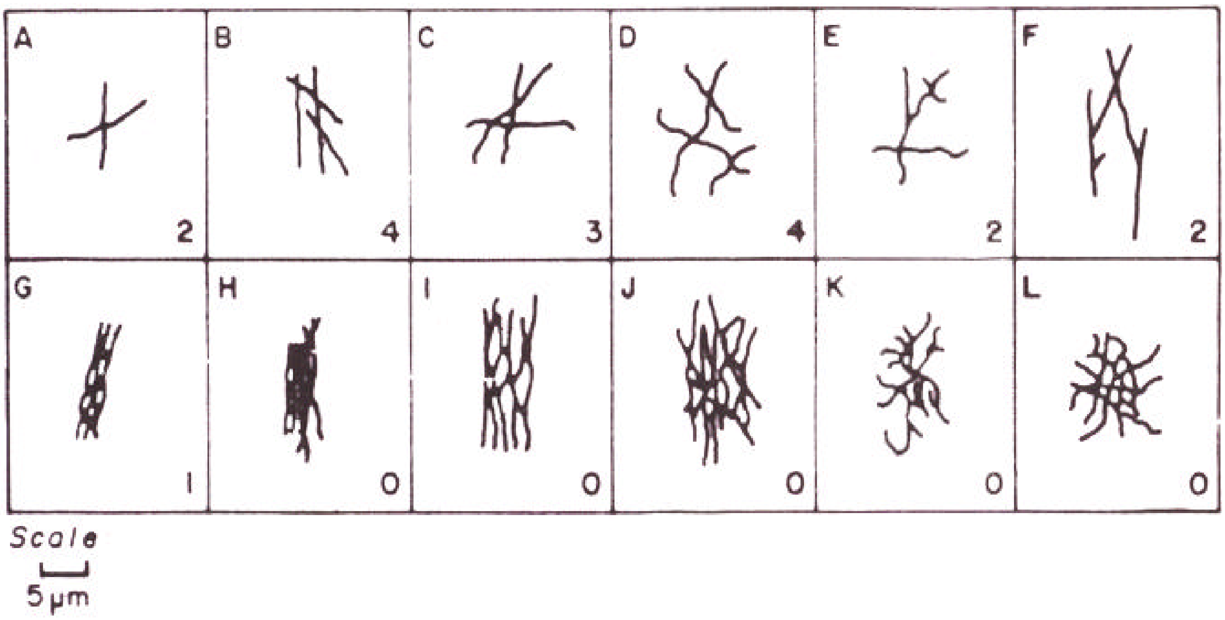
SPLIT FIBRES: These appear generally as a fibre or fibres splitting away from a single stem.

FIGURE 6



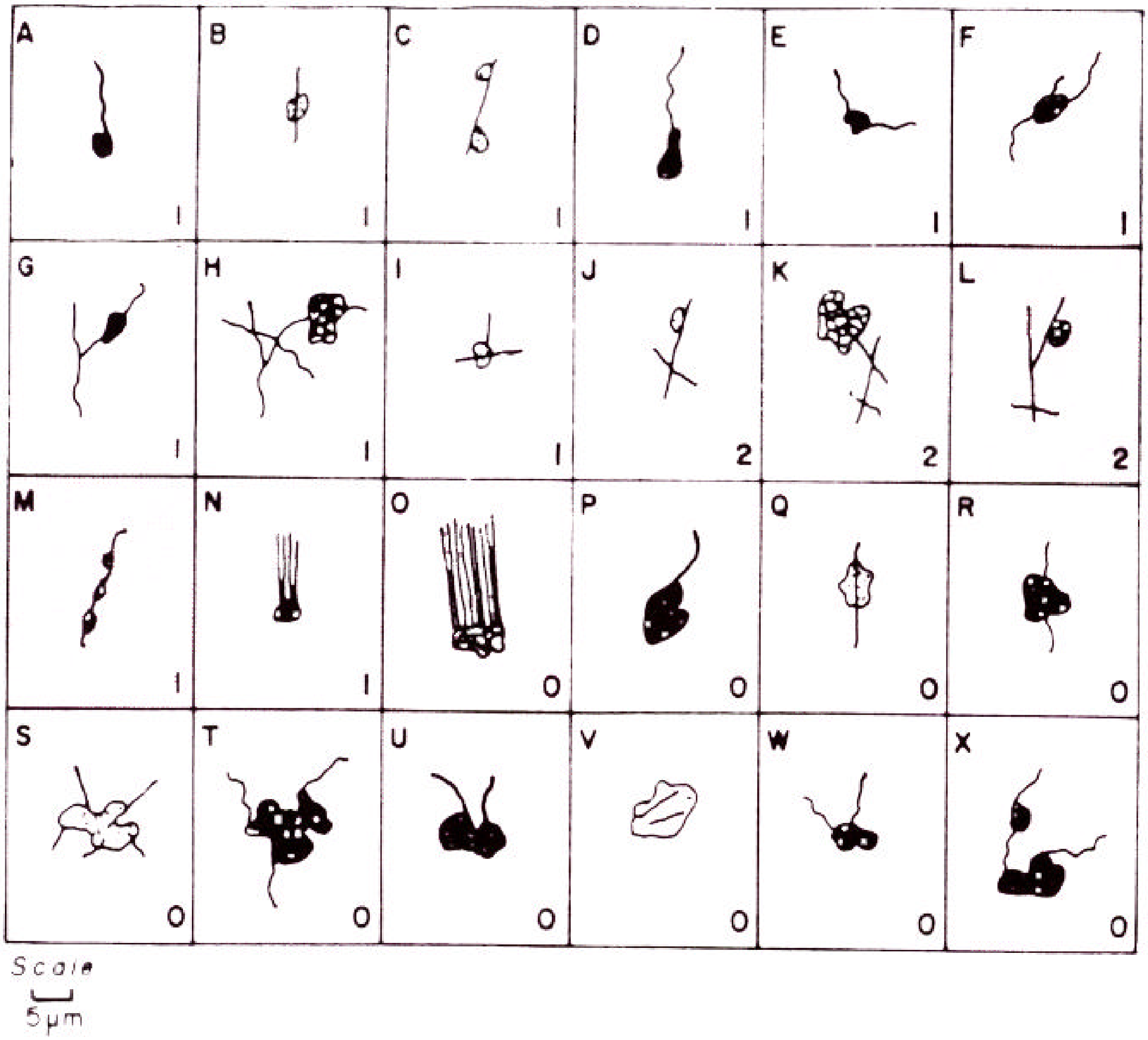
GROUPED FIBRES: These are formed when fibres overlap, intertwine or pack together. The simplest form is when two fibres overlap and cross each other. In this case, each fibre in the group appears as a discrete entity. In more complex form, fibres lie nearly parallel and appear to originate from the same bundle.

FIGURE 7



FIBRES WITH OTHER PARTICLES: This group consists of fibres attached to, or embedded in, particulate matter. For example, this latter material could be parent asbestos rock, or resins, cement, silicates used in manufactured products. Under the microscope some fibres, especially chrysotile, appear 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.

FIGURE 8



APPENDIX I

EXAMPLE OF FIBRE COUNTING RECORD

Name of job ________________________________	Date
	Pump No.
Location of Sample ________________________________	Filter No.
	Flow
Additional Remarks ________________________________	Time off
	Time on
	Total time
	Sample taken by

LAB USE ONLY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Fibres Per Field																					
Accum Total																					

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	
Fibres Per Field																					
Accum. Total																					

	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	
Fibres Per Field																					
Accum. Total																					

	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	
Fibres Per Field																					
Accum. Total																					

	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	
Fibres Per Field																					
Accum. Total																					

Scanner's remarks ________________________________

A simplified formula for calculating dust concentration is:

$$\text{Dust concentration } C = 1000 \times \frac{\text{No. of fibres}}{\text{No. of fields}} \times \frac{\text{effective filter diameter(mm) squared}}{\text{graticule diameter}(\mu\text{m}) \text{ squared}} \times \frac{1}{\text{volume(L)}}$$

$$C = 1000 \times \frac{\boxed{}}{\boxed{}} \times \frac{\boxed{}}{\boxed{}} \times \frac{1}{\boxed{}}$$

$C = \boxed{}$ fibres/mL

Sample analysed by	Date / /	Checked

APPENDIX J

SPECIFICATIONS FOR FILTERS, FILTER HOLDERS AND PUMPS

(1) FILTERS

Membrane filter (mixed ester cellulose or cellulose nitrate), 13 or 25mm diameter, pore size 0.8um, with grid. Some manufacturers include:

Gelman Sciences Inc., Type GN4 (gridded)
Nuclepore cellulosic white gridded
Millipore Corp., Type MF (gridded)
Sartorius, mixed cellulose esters

(2) SUPPORT PADS

Millipore Corp
Nuclepore Corp

(3) FILTER HOLDER AND COWL

Some cowls are supplied with an end piece which has a small opening of approximately 3-4mm in diameter. These end pieces must be removed during sampling such that a large opening approximately the size of the effective filter area is used.

(i) **Filter Holder, 25mm diameter**.

Supplier:
Gelman Sciences Inc., Product No. 1107

A cowl must be used with the Gelman Filter Holder. If cowls are not available directly from Gelman, figures 9 and 10 give details of alternative cowls that can be made to order.

FIGURE 9

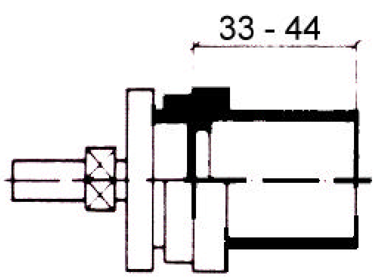
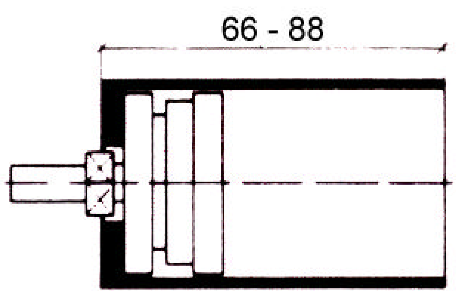


FIGURE 10



(ii) **Filter Holder (monitor), 25mm diameter**.

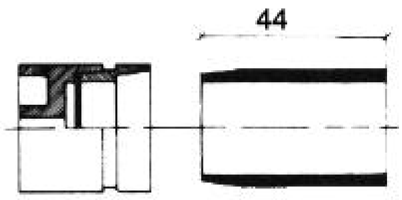
Supplier: Nuclepore, Stock No. 300015 (3-piece cassette including 50 mm cowl) Refer figure 11.

Nuclepone, Stock No. 300075 (3-piece cassette including 50 mm cowl - manufactured with electrically conducting [anti-static] material).

Supplier: Millipore Corp, Order No. M000025AO (3-piece cassette). An anti-static cowl (order no. M000025RO) should be used with the cassette. Refer to figure 12.

FIGURE 11

FIGURE 12



(4) PUMPS

Sampling pumps used for estimating airborne asbestos dust should be capable of maintaining the appropriately chosen flow rate within ± 10% for the entire sampling duration. Pumps with automatic flow control facilities are recommended. Because performance characteristics of field sampling pumps can vary considerably, reference should be made to experienced laboratories for selection of pumps for specific sampling applications.

When sampling in explosive gas or dust atmospheres as defined in AS 2430[17], ensure that the sampling pump meets the requirements of AS 2380[18].

APPENDIX K

REFERENCES

1. National Occupational Health and Safety Commission (NOHSC*), Guide to the Control of Asbestos Hazards in Buildings and Structures*, NOHSC, Sydney, 1988, attached.
2. National Occupational Health and Safety Commission (NOHSC), *Code of Practice for the Safe Removal of Asbestos*, NOHSC, Sydney, 1988, attached.
3. United States Department of the Interior, *Selected Silicate Minerals and their Asbestiform Varieties - Mineralogical Definitions and Identification Characterisations*, Bureau of Mines Information Circular 1977, IC 8751.
4. National Health and Medical Research Council, *Membrane Filter Method for Estimating Airborne Asbestos Dust*, NH&MRC, Canberra, 1976.
5. Asbestos International Association, *Reference Method for the Determination of Airborne Asbestos Fibre Concentrations at Work Places by Light Microscopy (Membrane Filter Method*), Recommended Technical Method No.1 (RTM 1), London, 1982.
6. International Standard Organisation, *Determination of the Number Concentration of Airborne Inorganic Fibres by Phase Contrast Optical Microscopy - Membrane Filter Method*, 3rd Revision, ISO/TC, 146/SC2 WG5, 1986.
7. Official Journal of the European Communities, *Council Directive*, 19 September 1983, (83/477/EEC), Annex 1.
8. Health and Safety Executive, *Asbestos Fibres in Air*, MDHS 39, HSE Occupational Medicine and Hygiene Laboratory, HMSO, London, 1984.
9. National Occupational Health and Safety Commission, *Exposure Standards for Atmospheric Contaminants in the Occupational Environment*, NOHSC Sydney, (in press).
10. Beckett, S.T., `The Effects of Sampling Practice on the Measured Concentration of Airborne Asbestos,' Ann. Occup. Hyg., 23, pp.259-272 (1980).
11. Peck, A.S. et al, `Airborne Asbestos Measurement: Preliminary Findings Identify a New Source of Variability in Membrane Filter Method,' Am. Ind. Hyg. Assoc. J., 46, B14-16, (March 1985).
12. Peck, A.S. et al, `Sample Density and the Quantitative Capabilities of PCM Analysis for the Measurement of Airborne Asbestos.' Am. Ind. Hyg. Assoc. J., 47, A230-234, (April 1986).
13. Cherrie, J. et al, `The Influence of Fibre Density on the Assessment of Fibre Density Concentration Using the Membrane Filter Method,' Am. Ind. Hyg. Assoc. J., 47(8), 465-474, (1986).
14. National Health and Medical Research Council, *Report on the Health Hazards of Asbestos*, NH&MRC, Canberra, 1982.
15. Her Majesty's Stationery Office, Asbestos, *Final Report of the (UK) Advisory Committee on Asbestos*, Volumes 1 & 2, HMSO, 1979.

16. Pinchin, D.J., in Royal Commission on Matters of Health and Safety Arising from the Use of Asbestos in Ontario, *Asbestos in Buildings*, Study No.8, Ministry of the Attorney-General, Toronto, 1984.

17. Standards Association of Australia, AS 2430-Part 1 (1987) Explosive Gas Atmospheres, and AS 2430-Part 2 (1986) Combustible Dusts, SAA Sydney.

18. Standards Association of Australia, AS 2380 - Part 7 (1987), *Electrical Equipment for Explosive Atmospheres - Explosion Protection Techniques: Intrinsic Safety i*, SAA Sydney.

19. Asbestos Information Association (North America), *A Study of the Empirical Precision of Airborne Asbestos Concentration Measurements in the Workplace by the Membrane Filter Method*, AIA, Virginia, USA, 1983.

20. Baron, P.A. and Pickford, G.C., `An Asbestos Sample Filter Clearing Procedure', Appl. Ind. Hyg., 1(4), 169-171, 1986.

21. Nelson, G.O., *Controlled Test Atmospheres*, Ann Arbor Science Publishers, Michigan, 1971.

22. Walton W.H. and Beckett S.T., `A Microscope Eyepiece Graticule for the Evaluation of Fibrous Dusts,' Ann. Occ. Hyg., 20, 19-23, 1977.