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CHAPTER 6

Dust control development 1970–1980

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(1) INTRODUCTION

With the introduction of the 1970 Asbestos Regulations came the requirement for the dust control industry in the United Kingdom to provide for the first time on a large scale, efficient extraction equipment capable of meeting specific pollution values at economic cost. Although the industry had been used to dealing with toxic or noxious materials prior to this date, it had usually been on a 'one off' basis and the solutions arrived at were invariably an expensive combination of overdesigned glove box hoods with massive air volumes applied.

For many years development work within the dust control industry had tended to concentrate on the actual filtering device and although high levels of efficiency and sophistication had been attained in this direction, to some degree it was at the expense of improvements in capture hood design. The requirements of the United Kingdom Asbestos Regulations in minimizing to a specific level the dust concentration at the machine end of the system therefore made necessary the development of more efficient hooding systems.

The following notes are presented therefore for the interested student, based on the experiences in the asbestos extraction field of the author during the last few years. It is hoped that the information conveyed will be used by the practical engineer for the design and improvement of the work place environment.

(2) TERMINOLOGY

Emission velocity

The speed at which dust particles are released by the machine, process, or operation. Often considered to be the most difficult element to calculate or measure. However, careful investigation by the design engineer can often give a lead as to its value, particularly if there is some mechanical component involved.

Capture velocity

The velocity that needs to be exerted at the dust release point to entrain the dust particles into the collector hood. The capture velocity should always be at least equal to and preferably greater than the velocity of the particles at the point of entrainment.

For manual operations this is usually in the order of 75 m per min, for mechanical reciprocating operations around 150 m per min, and for revolving operations 500 m per min or more.

Face velocity

The average velocity exerted over the open mouth of the capture hood.

Volume (of air)

The quantity of air pulled through a capture hood and equal to the face velocity multiplied by the open area of the hood mouth.

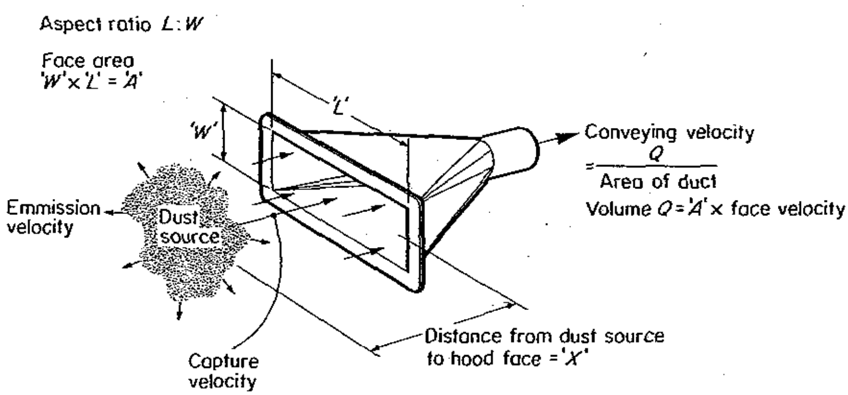

Figure 6.1 Terminology

Conveying velocity

The velocity at which the collected material is conveyed along the ducting system. For asbestos 18 to 20 m per s is found to give adequate conveying without unduly increasing the pressure requirement of the fan or the risk of abrasion.

Filtration velocity

The average velocity at which the dust laden air passes through the filtration medium. For asbestos this is usually 1.5 m per min with woven fabrics and 1.8 m per min with heavier felted materials.

Aspect ratio

The relationship between the length and width of the capture hood open mouth.

(3) EXHAUST HOOD LOCATION

The cost of a dust control installation is, within certain parameters, proportional to the quantity of air entrained and filtered. Consequently, the quantity of air required to achieve a set collection efficiency is of considerable economic importance and every effort should be made to minimize this volume. The most obvious way of influencing the effectiveness of the hood is by adjustment of its position relative to the dust source. Whereas a certain amount of data is available regarding the siting of exhaust hoods mainly from work carried out by Dallavalla in the 1930s and from which most basic formulas have been derived, all too often the economic and engineering importance of this information is either ignored or misunderstood by the dust control designer.

By measuring the velocity contours in front of a freely suspended circular hood Dallavalla derived the formula for the centre line air flow relationship:

$$Q = V(10x^2 + A)$$

where

Q = Quantity of air
V = The capture velocity at the dust source.
X = The distance from hood mouth to dust source.

and

A = The open face area of the hood

From this formula the centre line velocities in front of the hood may be expressed either as percentages of the face velocity as Figure 6.2, or shown graphically as Figure 6.3. It is worth noting that this formula is basically correct for round,

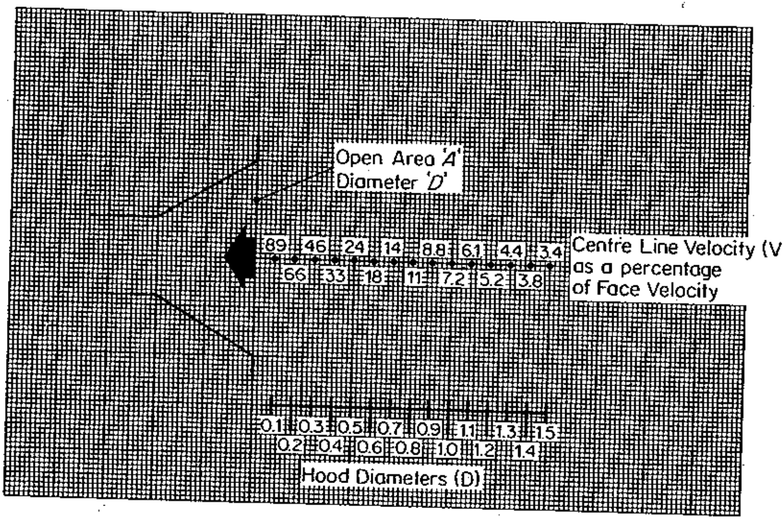

Figure 6.2 Centre line velocities of an exhaust hood

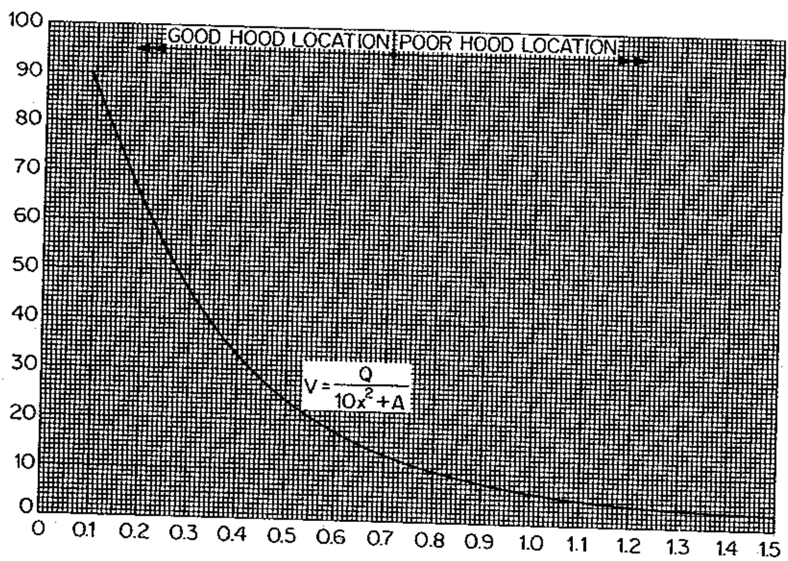

Figure 6.3 Distance x, dust source to hood mouth, expressed in terms of hood diameters

square, or rectangular hoods with an aspect ratio of less than 4 : 1. In the case of a square or rectangular section, the hood 'diameter' can be defined as

$$'D' = 2.\sqrt{\frac{WXL}{\pi}}$$

This information can therefore provide the practical engineer with an instant indication as to the resultant capture velocity of a hood in a certain position relative to the dust source, as well as being used to gauge the likely efficiency of a system. Perusal of Figure 6.3 will show that the closer the hood is to the dust generation point the more economic is the system and generally any hood that is located more than 0.7 'D' away from the source can be regarded as poorly positioned, inefficient, and uneconomic.

The savings that may be achieved by relocating a hood closer to the dust source may be seen from the following example: The necessary air volume when a hood of 400 mm diameter is placed 320 mm from a dust source where a capture velocity of 150 m per min is required is:

$$\begin{aligned} Q &= V(10X^2 + A) \\ &= 150\,(10 \times 0.32^2 + 0.2^2\pi) \\ &= 172.5 \text{ m}^3 \text{ per min.} \end{aligned}$$

If the same hood is now repositioned 200 mm from the dust source and the capture velocity kept constant, the air volume becomes:

$$\begin{aligned} Q &= 150\,(10 \times 0.2^2 + 0.2^2\pi) \\ &= 79 \text{ m}^3 \text{ per min} \end{aligned}$$

By comparing the two results it will be seen that by moving the hood 120 mm nearer to the dust source, the air volume and therefore the cost of the whole installation could be reduced by more than half, thus considerably enhancing the economic viability of the system. The practical engineer may speculate as to how many existing installations would benefit by applying the above technique.

(4) TESTING TECHNIQUES

Testing a capture hood either during development or once finally installed can be a time consuming affair. The only absolute method is to sample the airborne particles in the vicinity of the machine, usually for asbestos by drawing air through a 20-mm membrane filter. The membrane filter upon completion of the test period is then mounted and examined microscopically at 500× magnification using phase-contrast lighting. This method although capable of producing highly accurate results is time consuming, expensive, and requires a skilled microscope operator to make the particle count. It should also be remembered that investigation has shown that even with trained microscope operators counting errors of up to 15% are not unusual. Although no suitable alternative exists when a quantitative assessment is required, the practical engineer may find the following equipment extremely useful in determining the order of magnitude of an emitted dust cloud, either from an existing installation or when testing new capture hood designs. The majority of asbestos particles in the size range in which we are interested are not visible to the naked eye under normal lighting conditions. However, a high intensity back lighting technique has been developed which will, if correctly used, illuminate dust particles within the respirable size range. Figure 6.4 shows a diagrammatic arrangement of the equipment used and Figure 6.5 a practical illustration. A simple asbestos dust generating operation when viewed under normal workshop lighting shows virtually no visible dust cloud. The same operation with the specialist back lighting indicates the full extent of the dust cloud produced and the contrast between the two is quite marked. It is emphasized that both of these photographs show exactly the same operation and the same amount of material was being removed (and converted to dust) in both cases.

The value of special lighting techniques coupled with photography and airborne sampling is demonstrated in the following case history. In the late 1960s, the author coming to grips for the first time with specific asbestos dust hood design chose a standard circular saw bench as the prototype on which to design satisfactory hoods as well as develop techniques which would be helpful when faced with more complex machinery. When cutting 15-mm thick asbestos cement board the dust concentration in the operator's breathing zone without exhaust equipment was found to be an alarming 3,000 fibres per cm^3. During the investigation work that followed it was found that the below table hood supplied with the machine was for the most part quite satisfactory in design. However, use of the Tyndall beam showed that most of the wayward particles were being

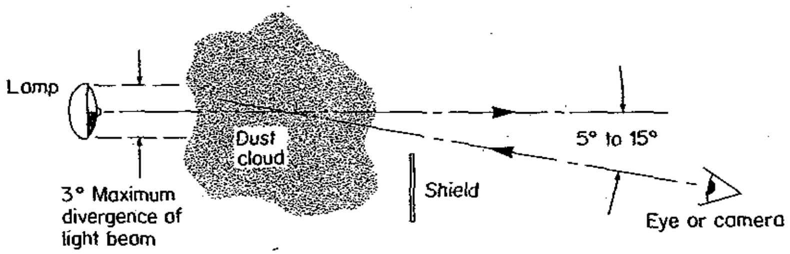

Figure 6.4 Technique for illuminating a dust cloud with a Tyndall beam. Reproduced by permission of the Health and Safety Executive

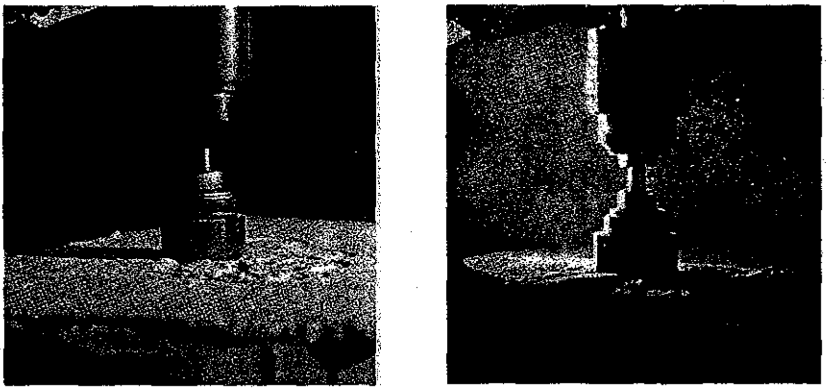

Figure 6.5 *High density back lighting technique: practical result*

Figure 6.6 Design and support of top hood showing dust cloud when extract air is switched off

Figure 6.7 Design and support of top hood showing dust cloud when exhaust air is applied

released into the atmosphere from the top when the saw broke through the material being cut. Attention was therefore concentrated on the suitable design and support of a top hood. Final comparative results may be seen in Figures 6.6 and 6.7. The first shows the dust cloud when the exhaust air is switched off, and the second result when the exhaust air is applied. The reduction in airborne concentration from 3,000 fibres per cm^3 to below 2 fibres per cm^3 gives the hood system a fibre collection efficiency of 99.93%.

(5) HOOD DESIGN

Few precise rules exist for the design of capture hoods and it must be remembered that whilst being designed for maximum collection efficiency they must not hinder the production process. In other words, the hood must not make the machine it serves inoperable. It is advisable therefore to involve shop floor personnel who can provide a useful source of first hand information and furthermore by being involved in the project, they are often much more sympathetic to additions being fitted to 'their' machines. Education by management of the work force to the potential dangers of asbestos dust and the control methods to be employed will also assist in the overall acceptance of the final installation.

Many of the machines used on asbestos were originally designed for other materials, often less hazardous. Consequently, it is often necessary to supplement standard hood designs and air volumes to achieve the required degree of collection efficiency. The following, therefore, are examples of commonly used machines together with recommended air rates:

1. Circular saw

Machine size	Pipe dia.	Air volume per connection
250 to 300 mm	Top 100 mm, Bottom 100	520–560 m^3 per h
300 to 500 mm	Top 100 mm, Bottom 100	600–600 m^3 per h
400 to 450 mm	Top 100 mm, Bottom 130	600–770 m^3 per h

As described earlier, the main difference in extraction equipment when using a circular saw on asbestos instead of wood, is the addition of a top hood. It is of course, important to pay much greater attention to hood sealing, particularly just below the table.

2. Band saw

Bottom connection	Rear connection	Table connection
100 mm Ø–600 m^3 per h	100 mm Ø–500 m^3 per h	115 mm Ø–680 m^3 per h

Normally a bandsaw is only fitted with one exhaust point positioned below the table. However, with asbestos material, it is necessary to place the machine casing under negative pressure and to fit a top hood to deal with the dust emitted above the table.

3. Lathes

Due to their versatility of operation, lathes are often extremely difficult to provide with conventional close proximity hooding. The difficulties experienced are due to the variety of component size and shape and the need to maintain a high degree of collection efficiency without impairing the production capability of the machine and its operator. Consequently, it may be necessary to consider a booth which encloses the working area of the machine. Provided an indraft of 80 to 150 m per min is effected over the open area of the booth, all of the airborne dust and particles should be contained. Although this is primarily a containment technique it has been found that by extending the exhaust air off-take connections through into the booth interior some close proximity exhaust can also be achieved. As containment control however, it is also desirable to provide a small bore flexible vacuum cleaner connection to allow periodic cleaning down of the machine and booth interior. The degree of enclosure of the booth form is obviously dependent on the machine type and component variety. For heavy waste removal it may be necessary to consider complete enclosure for glove box type operation, but in practice this has been the exception rather than the rule.

An alternative to the booth technique is a small high velocity hood mounted adjacent to the tool cutting edge. This solution, when possible, uses much less air and hence is more economical. In practice it has been found that this solution demands very close cooperation between the dust control and the production engineer to ensure that the resultant hood form does not impede the working of the machine. Figures 6.8 and 6.9 show a typical design where a heavy gauge square section hood has been mounted in the tool post and the cutting tool mounted

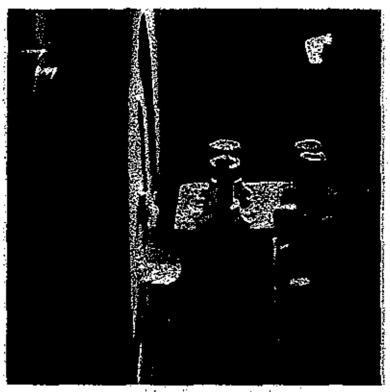

Figure 6.8 Typical heavy gauge square section hood which enables high velocity extraction to be achieved on three sides.

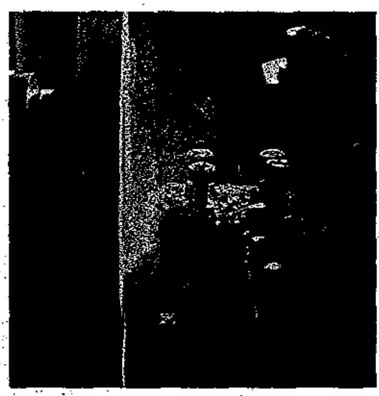

Figure 6.9 As Figure 6.8 but with extraction switched off.

inside the hood. This enables high velocity extraction to be achieved on three sides of the tool and consequently air sweep the cutting edge at around 2500 m per min. For small repetitive operations where the hood mouth can be designed to suit the application very high degrees of collection efficiency may be achieved using this method.

(6) ROUTING, MILLING, AND DRILLING MACHINES

All of these machines pose similar problems for the dust control engineer. Either a small close proximity hood with high face velocity has to be fitted around the cutting tool, or a booth form has to be considered. To achieve the high capture velocity required with a close proximity device, it is very often found that the operator's vision is completely obscured, despite the sophistication of windows and internal lights being fitted to the hood. Consequently, the table top booth has been developed, which for a reasonable air volume gives 100% containment, 70/80% extraction, and perfect vision for the operator. As outlined earlier the practice of extending the exhaust connections through the back (or side) of the enclosure to as near to the dust generation point as possible can provide some close proximity collection of the swarf and dust produced and this has been found to be as high as 70%. Figures 6.10 to 6.13 show milling and drilling machines which have been successfully fitted with perspex enclosures of the type described.

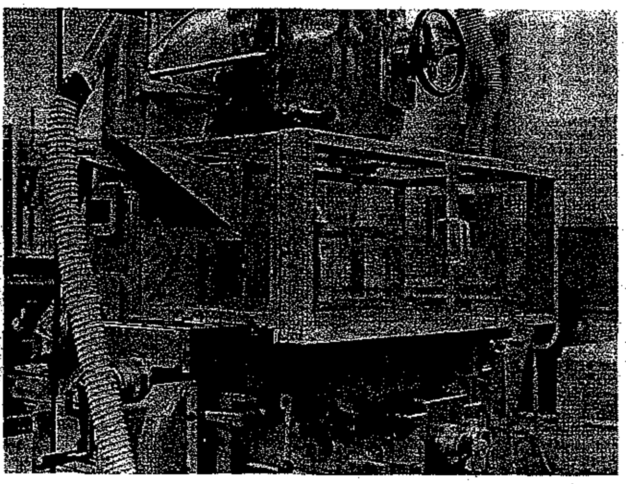

Figure 6.10 Milling machine fitted with perspex enclosure.

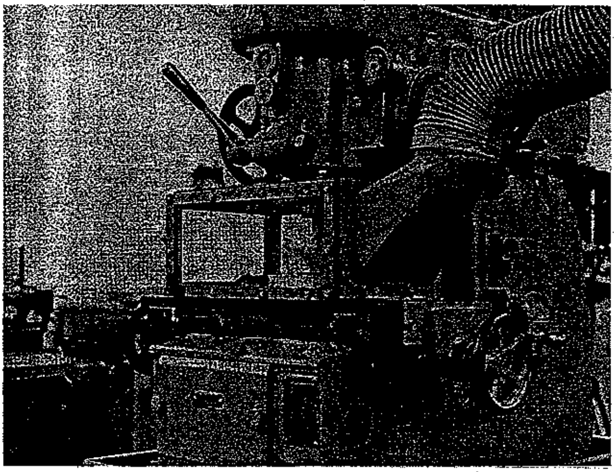

Figure 6.11 As Figure 6.10

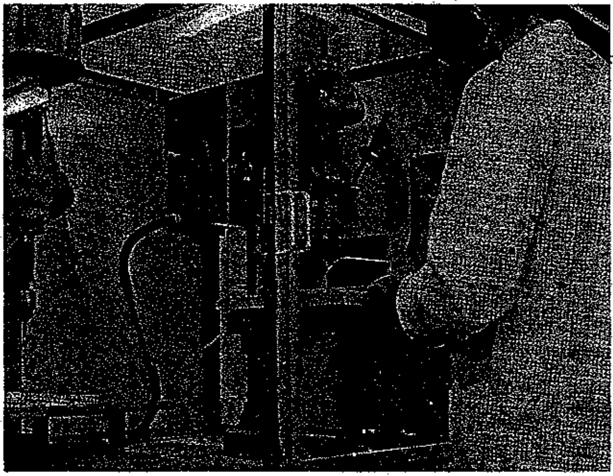

Figure 6.12 Drilling machine fitted with perspex enclosure

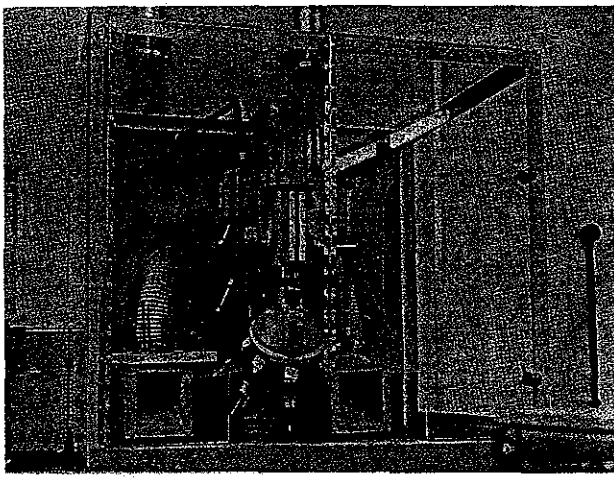

Figure 6.13 As Figure 6.12

(7) HAND-HELD MACHINES

For many years it was found impracticable to provide hand-held mechanical tools with efficient exhaust apparatus. Following the introduction of the 1970 Regulations a considerable amount of development work was carried out particularly on hand-held sawing and drilling machines in an effort to provide suitable equipment for wall and ceiling tile fixing. Initially many problems arose, in particular these were: operator resistance to the additional weight of exhaust hood and flexible ducting, and damage of the connections—particularly the lightweight flexible hose. However, a programme of operator education gradually overcame the difficulties and eventually a range of standard equipment was developed which has proved most satisfactory. Figure 6.14 shows a range of prototype drill nozzles and Figure 6.15 a drill and exhaust nozzle in operation on a wall panel fixing operation. The intake velocity of the nozzle is in excess of 3,000 m per min. For a well maintained set of equipment very high efficiencies were recorded: however once the drill bit broke through on the far side of the panel there was uncontrolled release of dust and fibres. There was some evidence of air and dust being pulled along the drill flutes but when drilling anything other than blind holes a rear exhaust trough must be used. The dangers of drilling straight through vertical asbestos partition walling, for example in ship or shop fitting and releasing uncontrolled asbestos fibre into the adjacent cabin or room are obvious and care needs to be taken to ensure that other unsuspecting workmen are not placed in jeopardy.

As an alternative to individual exhaust equipment some sites, and particularly the ship building industry have preferred to use a static drilling and sawing station

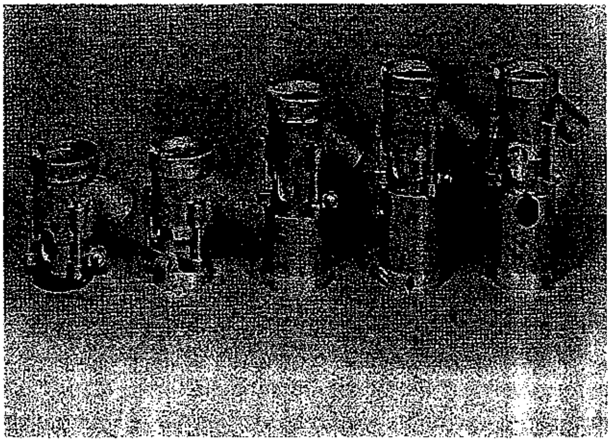

Figure 6.14 Range of prototype drill nozzles. Reproduced by permission of Cape Boards and Panels Ltd

Figure 6.15 Drill and exhaust nozzle in operation on a wall panel fixing operation

equipped with conventional extraction equipment to which the work is brought for sizing, forming, and predrilling.

(8) LAGGING STRIPPING

The removal of asbestos lagging from around pipes, valves, boiler faces etc., is perhaps one of the most difficult and hazardous operations involving asbestos-

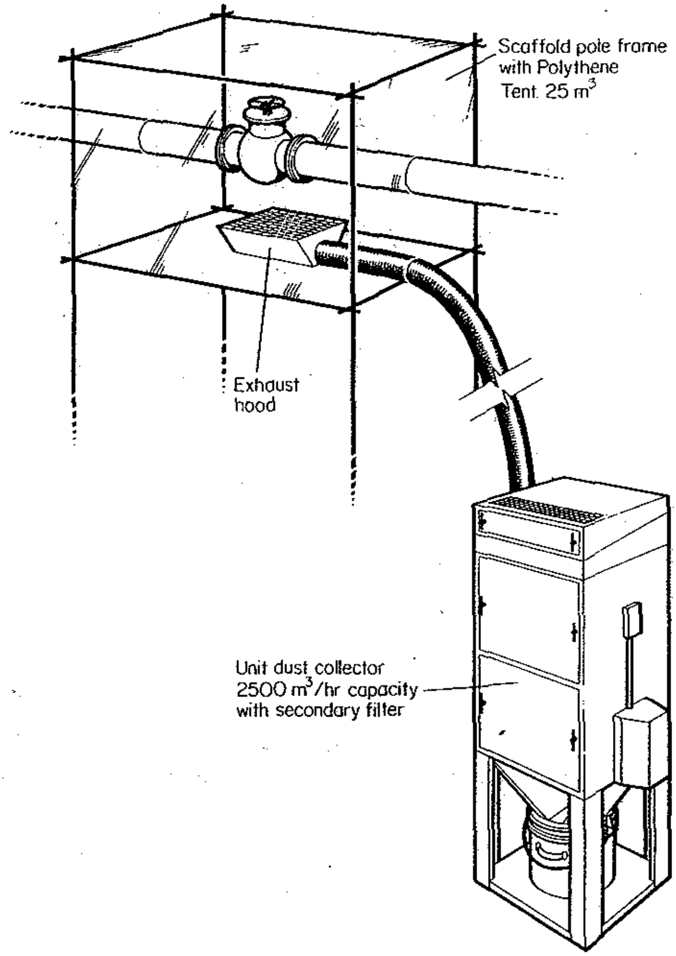

Figure 6.16 Asbestos stripping

based materials. Fortunately nowadays there are a number of companies who specialize in this unpleasant task. At worst it can mean closing a whole works whilst the offending asbestos is stripped and removed by personnel in positive displacement breathing suits: at best complete isolation of the section of premises involved with very strong security measures to ensure that there is no contamination of the remainder of the factory.

A technique using a scaffold pole frame work for a polythene sheet tented enclosure has been introduced which can isolate the contaminated working area and afford real protection to the rest of the work force. Figure 6.16 shows a typical enclosure with the extraction hood and duct in position under a length of asbestos covered piping. The intake of air into the extraction hood keeps the tent under negative pressure and thus contains the liberated dust and fibre within the enclosure. The larger pieces of asbestos lagging are collected up from time to time and bagged within the tent whilst the free dust may be disposed of directly into the exhaust hood. Care should be taken to ensure that the bags of collected waste are wiped clean before they are removed from the working zone and that all overalls, boots, and other contaminated clothing is left in the 'dirty area' and not taken through the main working area. Fibre counts of 50 to 100 fibres per cm^3 have been measured when a workman involved in lagging stripping has brushed against something or someone whilst still wearing dirty overalls.

Generally speaking the volume of the enclosure should be around 25 m^3 and the quantity of exhaust air 2,500 m^3 per h—thus giving 100 air changes per hour within the tented enclosure. Self contained unit dust collectors are capable of dealing with this amount of air and are generally small and manageable enough to be located in most areas of a factory.

(9) FILTER TYPE

There are basically only two ways of collecting and separating airborne asbestos waste. Firstly, the cyclone which due to its inherent inefficiency can only be used for preseparation duties and secondly the fabric filter.

The term fabric filter covers everything from simple open bags with no cleaning mechanism to sophisticated pad type reverse jet filters. Obviously the level of collection efficiency and the cost of different types of unit can vary widely.

However, for asbestos the filter used should have the following essential features:

(1) An adequate area of effective filtration media; the selection of the correct filtration area (and hence filtration velocity) is critical and the complete effectiveness of the separation and filtration process depends on it. Particle size and shape must be carefully considered as must the anticipated dust burden to the filter.
(2) Efficient and automatic filter cleaning mechanism.
(3) Suitable waste collection and disposal means. It is particularly important when handling asbestos to ensure that a secondary dust hazard is not caused when disposing of the collected waste from the filter unit.
(4) Safe and convenient access to the filter for maintenance and service purposes, ideally this should be on the 'clean' side of the filter element.

Fabric filter plants should be designed with a view to achieving an emission level of less than the threshold limit value for the dust handled. Although an emission level of 1 fibre per cm^3 could be regarded as satisfactory where the filtered air is to be discharged to atmosphere, if the air is to be circulated back into the working zone then the permissible fibre concentration should be reduced to less than 10% of the threshold limit value. This means an emission level of less than 0.1 fibre per cm^3 for chrysotile asbestos. On no account should exhaust air be recirculated to the working zone when crocidolite material is being handled.

Where isolated or scattered areas of localized emission are to be dealt with within a factory, self-contained unit dust collectors fitted with inbuilt fans, filters, and collection bins can offer excellent and economical service. Such units, usually with an exhaust capacity of up to 2,500 m^3 per h, may be sited adjacent to the piece of plant or machinery they serve and require only a small amount of ductwork between the unit and machine. Most importantly, they can be interlocked with the machine so that it is impossible to run or work the machine without the extraction unit first being in operation. This interlock not only protects the worker from himself but can also offer a degree of protection to an unskilled operator not familiar with the safety procedures in operation. A further advantage of this type of individual collector is that it can be extended or added to as and when it becomes necessary thereby maintaining complete flexibility for reorganization or extension. For asbestos-based materials the normal filtration technique is to employ a good quality natural cotton (of approximately 250 g per m^2) at a filtration velocity of 1.5 m per min. If there is evidence of moisture or corrosive chemicals in the collected air stream it is wise to consider using a woven polypropylene material which nowadays can offer a filtration efficiency equivalent to that of a woven natural yarn.

Considerable heat losses would occur if it were always necessary to discharge the cleaned air from the filter to atmosphere as a security measure. Consequently, a range of secondary filtration cells has been developed which may be fitted to the primary unit to ensure that the quantity of dust in the discharged air is below one-tenth of the TLV and to provide a 'fail safe' facility in the event of primary filter failure. To measure the continuing effectiveness of both the primary and secondary filter cells, simple and effective monitoring gear which may be linked to an audible or visual system has also been introduced. (See Figure 6.17.)

It has been the practice for many years on larger installations to use tubular stocking filters complete with mechanical shaking gear. Although this type of filter was capable of giving reasonable service, it could only do so on an intermittent basis because cleaning by rapping or shaking had to be done under conditions of no flow. Consequently, interruption of the exhaust air at some predetermined interval was necessary. In an attempt to overcome this defect in design, compartmentalized filters were produced whereby each cell of the filter could be isolated in turn by mechanical inlet and outlet valves to allow cleaning of that particular cell under no flow conditions. Although this tended to stabilize the pressure drop of the filter to some degree the increased maintenance required on this type of plant became excessive and uneconomic. It became necessary, therefore, to look for an alternative filter type which not only met the requisite criteria but was also

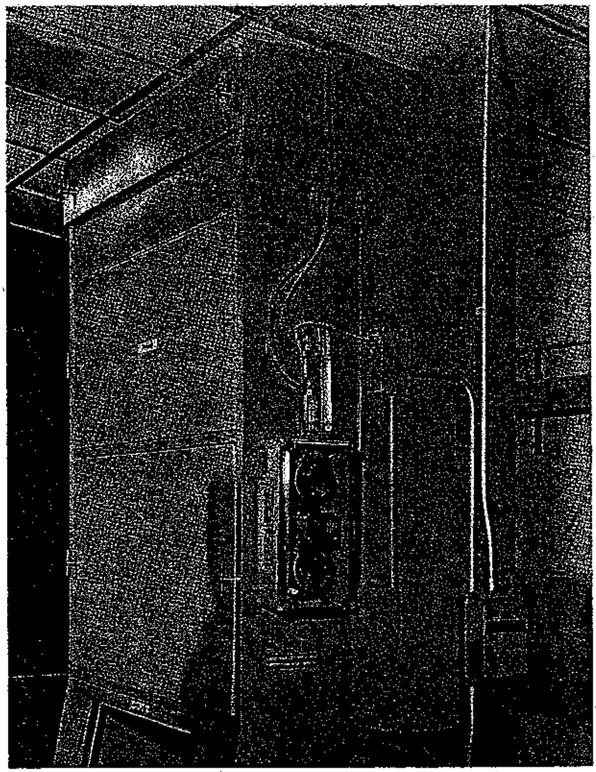

Figure 6.17 Unit Dust Collector fitted with Secondary Filter for Re-circulation of Air

capable of providing continuous extraction from any continuously rated production process. To satisfy this need, the reverse jet fabric filter was developed which uses small quantities of high energy gas, usually compressed air, injected into each filter pad in turn and on a recycling basis such that the whole filter unit is cleaned down every 60–90 seconds. This results in virtually constant pressure drop and hence constant throughput of air. The ability to stabilize the pressure drop of the filter to this high degree also permits much higher dust burdens to be introduced into the filter without preseparation equipment, so that inlet concentrations ten times that of an intermittently rated device are possible. Reverse jet cleaning also enables improved filter materials such as synthetic needle felts to be used, the normal material for asbestos filtration being felted terylene of 650 g per m^2 weight. Table 6.1 indicates the measured relative efficiencies of both small unit dust collectors and larger scale reverse jet filters, whilst Table 6.2 gives a typical cloth specification for both woven and felted filter media.

Table 6.1 Filter unit efficiencies

Unit type	Filter type	Filtration velocity	Dust	Unit inlet burden
Self contained intermittently rated unit dust collector	Woven cotten	1.5 m per min	Chrysotile asbestos-based material	5 g per m^3 maximum total
For the above conditions, filtration efficiencies have been measured which give an effluent *concentration of less than 1 fibre per cm*^{3}. With a resin impregnated wool secondary filter, the asbestos fibre collection efficiency improves and the emission is reduced to less than 0.1 fibre per cm^3.				
Reverse jet continually rated filter	Terylene Needlefelt	1.85 m per min	Chrysotile asbestos-based material	25 g per m^3 (total)
For these conditions fibre emission levels in the order of 0.5 fibre per cm^3 have been measured and with a secondary filter added, 0.2 fibre per cm^3.				

Table 6.2 Filter cloth specification

1. Cotton Sateen woven material for use on mechanically shaken or rapped filters.
   Weight: 255 g per m^2, Strength down; 19.6 kg per cm, Strength across; 14.1 kg per cm, Permeability: 48 l per dm^2 per 20 mm w.g. pressure drop.
2. Polypropylene 2 × 2 twill woven material for mechanically shaken filters.
   Weight: 297 g per m^2, Strength down: 31 kg per cm, Strength across; 36 kg per cm, Permeability: 62.5 l per dm^2 per 20 mm w.g. pressure drop.
3. Terylene needlefelt with spun 100% Polyester scrim for use on reverse jet filters.
   Weight: 645 g per m^2, Strength down: 22.3 kg per cm, Strength across: 22.3 kg per cm, Permeability: 150 l per dm^2 per 20 mm w.g. pressure drop.

N.B. The permeability figures quoted are laboratory obtained values for unsupported media only and should not be taken as a guide to possible application usage.

(10) CONCLUSION

The danger to health of working with asbestos has become a very emotive subject in many countries and reports by various branches of the media are occurring with increasing frequency. Unfortunately, these reports all too often concentrate on the failures rather than the successes and fail to note the genuine progress being made. Although the hazards to health are real enough they can all too easily be put out of perspective by the ill-informed. Although many of the larger asbestos processing companies are looking for alternative and less potentially dangerous materials, for many of its uses asbestos has no practical or economic alternative. Consequently, the industry and the dust collector manufacturer must continue to work together to develop the best equipment and technology to minimize the health hazards at reasonable cost. Much application experience has been gained during the last ten years in the sphere of asbestos dust control. Although it is unlikely that any major technical breakthrough will radically alter the processes and philosophies developed since the 1970 Regulations, those responsible for the work place environment must continue in their efforts to ensure that equipment installed embraces the best technology available, and continually update plant as new developments occur.

As with all service industries the onus is on the dust control supplier to satisfy the user that the solution he proposes will give the required degree of efficiency and safety as well as presenting value for money. In turn the user should satisfy himself that the supplier of his choice not only has the equipment range, but the research and development capability and experience to provide dust control plant that is both effective and economic.