ECONOMICS OF DUST CONTROL

D. W. Hills

Turner Brothers Asbestos Co., Ltd., Rochdale, England

A brief historical introduction is given about conditions in the U.K. asbestos textile industry in the late 1920's and early 1930's: reference is made to the 1931 conference between employers and the Home Office that resulted in a code of practice being established for dust suppression in asbestos textile factories. Details are given of the various methods used for dust control in the Company's factories together with the cost of these measures. Some figures are also given for the cost of dust control at the Cape Asbestos Co. Ltd.'s new amosite mill at Penge. Current work on improving dust control is discussed together with the part now played in this by the Asbestosis Research Council.

Although asbestos textiles form only a part of the asbestos industry their particular significance for this monograph is that, at least in the United Kingdom, the hazards associated with the processing of asbestos were recognized sooner on the textile side than almost anywhere else. This was because most of the processes were dry, and hence dust was readily formed, and also because the workers in some of the largest factories formed a close-knit population whose employment records went back for many years. Thus, when the hazard was first investigated an excellent sample of people with varying periods of exposure to dust was available.

Asbestos Textile Processes

Some crocidolite, or blue fiber, is made into textiles but the quantities used are small and most textiles are manufactured from chrysotile, or white asbestos and it is with the latter that this paper is mainly concerned.

At the mines, the fiber-containing rock is crushed and screened and the fiber lifted off by air currents; it is then milled to reduce the thickness of the bundles and fiber with a higher surface area is obtained; it is then dispatched from the mines and the textile manufacturer feeds it, with or without further milling or blending to the first process, carding, which is followed by spinning, weaving and braiding.

The carding machine cleans the fiber, opens it (i.e. divides further the fiber bundles) and converts it into a gossamer-like web or fleece. The web is divided into tapes at the output end of the carding machine and these are rubbed into sliver which is twisted into yarn on a spinning frame (ring or flyer type). Some of the yarn is then doubled (i.e. twisted together) with other asbestos yarn, or sometimes with wire. Yarns are then woven into cloth and tape or braided (plaited) into asbestos packings.

Asbestos was first processed on textile machinery in Rochdale in 18[illegible].

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...y conventional machinery was used and still is today. However, asbes- ...iber presents special problems to the textile processor because of its ... t length—the weight mean length of spinning fibers being in the ...ge 0.28–0.40 inches—and its inherent dustiness.

Recognition of the Dust Hazard

In spite of the large expansion of asbestos textiles in the U.K. over ...o years, it was only towards the end of the 1920's that the special biolog- ...al effects of asbestos were recognized. At this time, some machines were ...ventilated and the general conditions equalled those of the cotton textile ...ills of the period but they left a lot to be desired. Fiber was blended on the floor by hand and most machines were fed manually. Looms were only partly ventilated and a worker who remembers those days has said that asbestos fiber was literally knee-deep under them. The dirt and short fiber that dropped onto the floor under the carding machines had to be cleaned out by hand; this, and the stripping (or cleaning) of cards, also by hand, was a very dirty and dusty operation and whilst it was being carried out a man could not be recognized at a distance of six or eight feet. Fiber was screened on open vibratory screens, the short fiber being allowed to fall on the floor while the "overs" were bagged by hand. The ventilation system exhausted into settling chambers which were cleaned out by a gang of men every Saturday morning. The men, wearing respirators, went into the settling chamber, shovelled the dust into wheelbarrows which were then wheeled along and their contents tipped down a chute where it was mixed with water to form a sludge for disposal. The dust clouds formed during this tipping operation can be imagined.

It will be appreciated from this brief description of conditions in the 1920's that certain precautions were then being taken, namely the ventila- ...tion of some machines and the wearing of respirators during the perform- ...ance of particularly dusty operations. In the light of medical knowledge at that time these precautions were thought to be adequate. However, in 1928 the Factory Department of the Home Office in the U.K. instituted an extensive investigation into the effects of asbestos dust on the lungs and dust suppression in the asbestos industry. This investigation was undertaken because in February 1928 a case of nontubercular fibrosis of the lungs in an asbestos worker was discovered. The investigation continued ...to 1929 and a report was made to the Home Secretary in March 1930 by E. R. A. Merewether and C. W. Price.[1] This report is a classic of its kind: Merewether was a Medical Inspector of Factories and Price an Engineering Inspector so their investigation and report was an early example of the medical engineering collaboration that is essential for progress in this field. In 1928 it was estimated that about 2,200 people employed, mainly ...textiles and insulation, in the asbestos industry in the U.K. were exposed

to asbestos dust and 363 of these were examined during the investigation. The conclusion was that the inhalation of asbestos dust over a period of years results in a serious type of lung fibrosis. The effects of age and length of employment were examined and also the effects of working in different processes. The concentration of dust and the length of exposure necessary to produce fibrosis were investigated and the conclusion reached that probably these two factors in the production of fibrosis of the lungs were interdependent within certain limits. Merewether said:[1]

"While it seems necessary for the production of generalized fibrosis of the lungs that a definite minimal quantity of dust must be inhaled, the lower the concentration of dust in the air breathed, the longer the lapse of time before the fibrosis is fully developed, and within a certain limit, the higher the concentration of dust, the sooner the fibrosis becomes fully developed and the more intense the involvement of the lung tissue. If this hypothesis is correct, and the evidence points to it, the practical inferences are of very great importance, since it follows that the application of measures resulting in the reduction of the concentration of dust in air in the neighborhood of dusty asbestos processes will cause, firstly, a great increase in the length of time before workers develop a disabling fibrosis, and secondly, the almost total disappearance of the disease, as the measures for the suppression of dust are perfected."

These comments are as true today as when they were written 34 years ago.

A critical examination was made of all asbestos processes and dust control methods: recommendations for improving the latter were made as follows:

(a) application of exhaust draught at dust-producing points.
(b) substitution of enclosed mechanical methods for hand conveyance for dusty hand work generally.
(c) effective enclosure of dust-producing machines and plant.
(d) substitution of wet methods for dry.

The Merewether and Price report[1] had clearly exposed the hazard and it also put forward the basic principles to be followed in suppressing asbestos dust formed during processing. As a consequence of this report a Committee was set up consisting of three representatives of the asbestos textile industry and two Engineering Inspectors of Factories (it is interesting to note that the three industry representatives came respectively from the three Companies who founded the Asbestosis Research Council). In 1931 this Committee produced a report[2] which recommended in detail the dust control measures to be adopted at each individual textile process. The most important method recommended was the application of ventilation at dust-producing points. In the same year, the Home Office issued the Asbestos Industry Regulations, 1931, which laid down the statutory



FIGURE 1. Bag opening booth.

obligations of asbestos manufacturers with respect to the control and suppression of asbestos dust.

In the U.K., 1931 is regarded as the "turning point." As a result of the Merewether and Price investigations and then the pooling of information and experience by the manufacturers, rapid and significant improvements were made in dust suppression.

Examples of Current Methods of Dust Control

Methods of dust control in T.B.A. Co. Ltd.'s asbestos textile factories were described in detail by W. P. Bamblin.[1] It will be sufficient for our present purpose to describe some of the special features and difficulties associated with the ventilation of asbestos textile machinery and to give some examples of current practice in the T.B.A. Co. Ltd. asbestos textile factories.

As mentioned previously, the fiber as received at the asbestos textile factory is either fed directly to a carding machine or, prior to this, is further opened and blended with other grades of fiber. The old method of blending, which was the dustiest process reported by Merewether[4] was to lay the various grades of fiber in horizontal layers on the floor and then a vertical slice of the layers of fiber was cut off by hand and shovelled

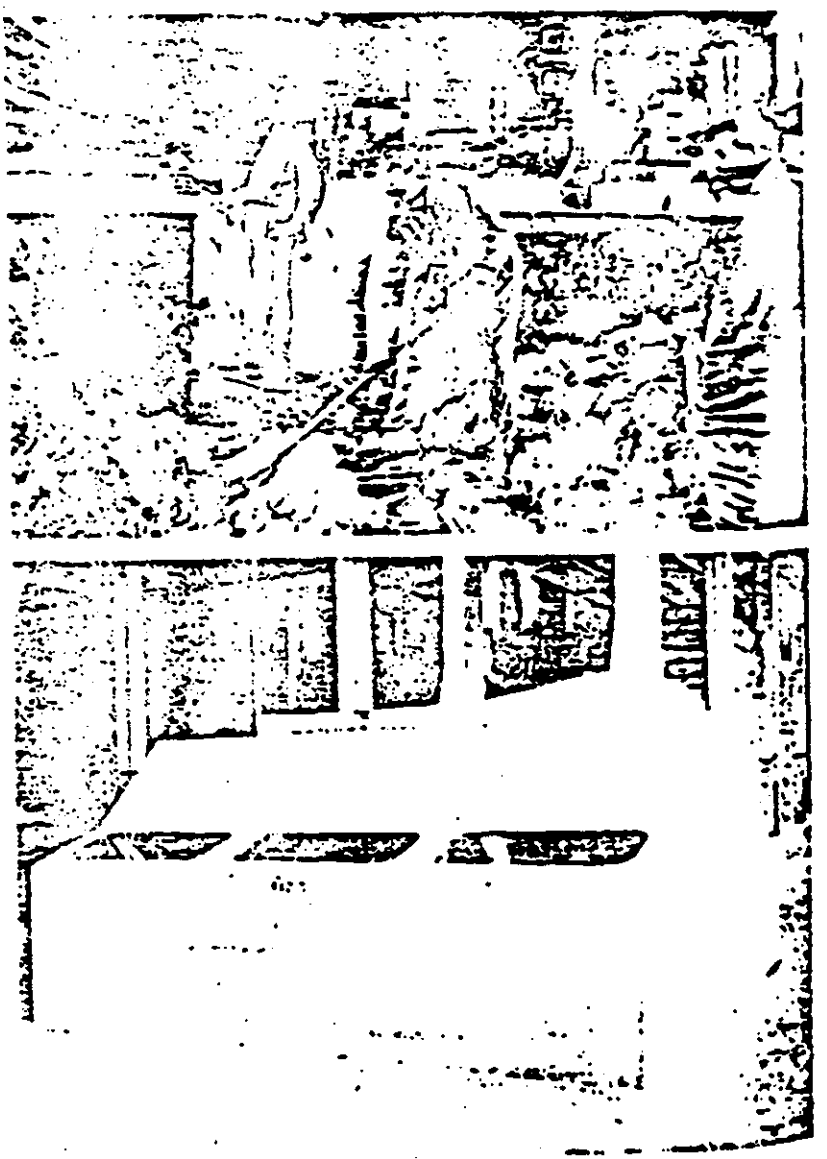

FIGURE 2. Old floor mixing method and present totally enclosed mixing drum.

down a chute into an opening machine. The method developed and now in use at T.B.A. Co. Ltd. is entirely mechanical. The bags of fiber as received from the mines are cut open and emptied in a special booth — see FIGURE 1. The bag is trucked to the booth and tipped onto the roller elevator which is then raised and the bag slides onto a freely revolving table: it is cut open, the fiber emptied out and the bag scrapped. The booth is ventilated and the operator's head is well above the opening. The principles followed here are, firstly to apply ventilation at the dust-producing point and secondly to minimize physical effort. In the booth the fiber is fed onto a belt conveyor that carries it into a blending drum. FIGURE 2 gives a striking comparison between the old method of floor mixing and the new method in a drum. The mixing drum itself cannot be seen because of the high degree of enclosure. The doors through which the fiber is fed into the drum are opened and closed automatically and whilst mixing in the drum the fiber is treated with an oil emulsion. The sole purpose of the oil emulsion addition is to suppress dust. After blending, the fiber is subjected to an opening treatment and is then screened. FIGURE 3 shows a multiple screening machine: the degree of enclosure is again to be noted. After screening, the fiber is conveyed automatically to the carding machines or it is bagged. Packing opened asbestos fiber into bags is a dusty operation and previously the fiber was packed down into the

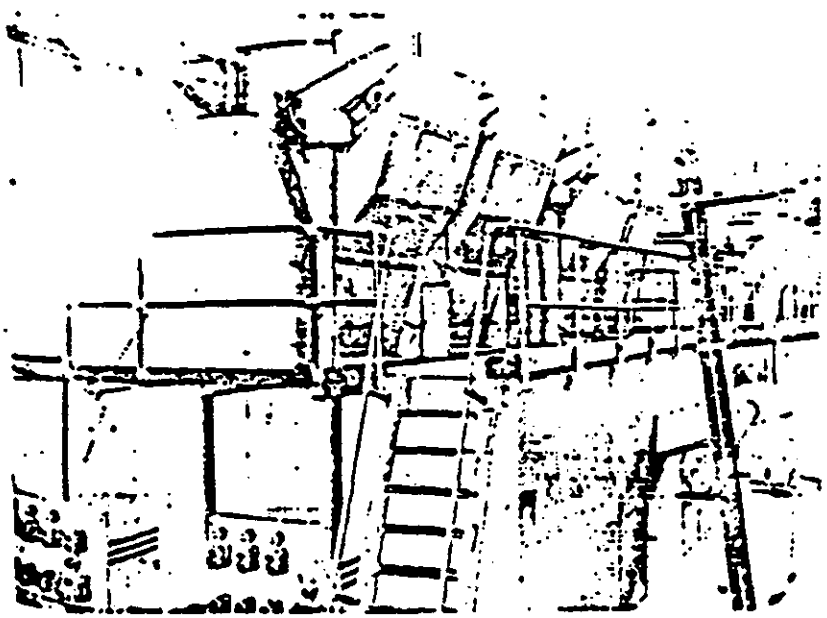

FIGURE 3. Multiple screening machine.



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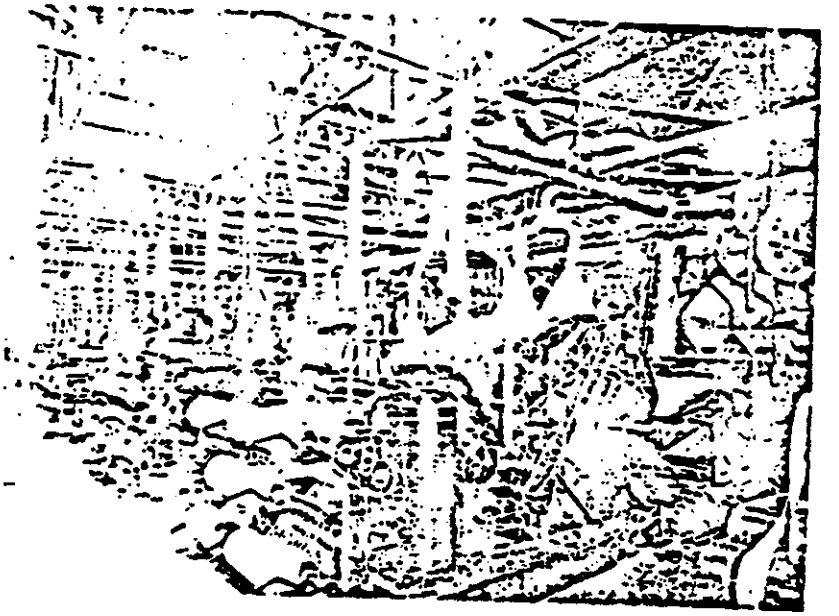


FIGURE 5. General view of card ventilation.

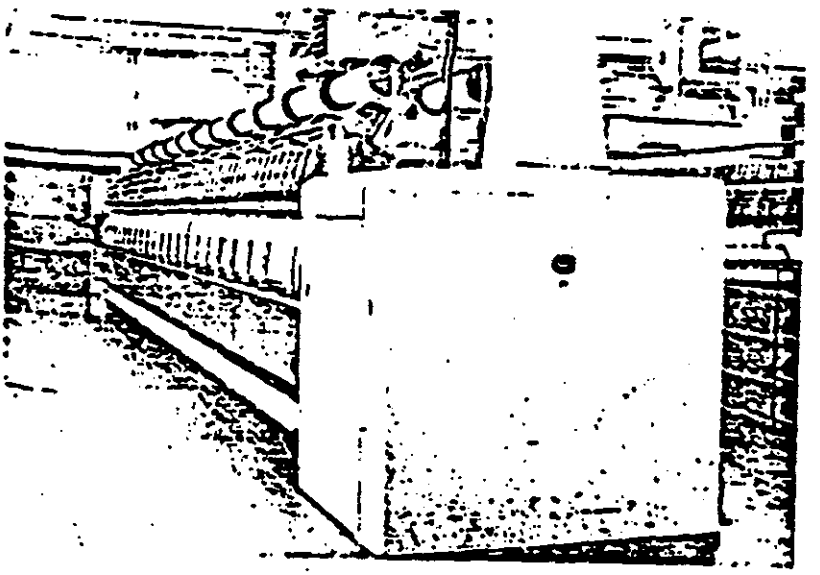


FIGURE 6. Ring frame.

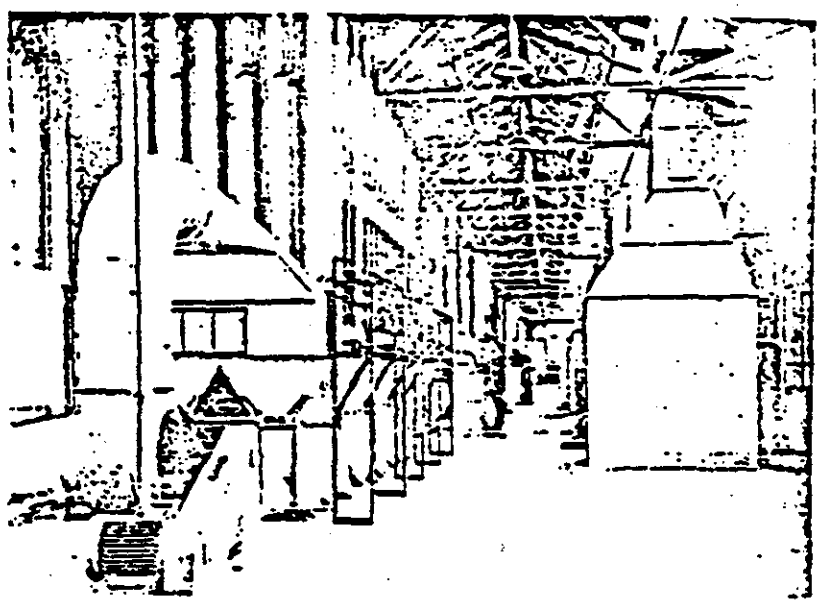
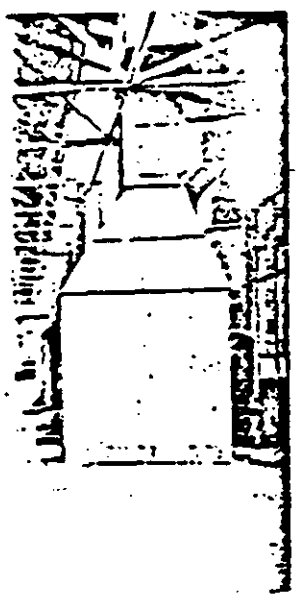


FIGURE 7. Sleeve filters.

Carding machines are difficult to ventilate because the asbestos fleece is very light (a typical fleece density being 20 gm./sq. meter) and can consequently easily be broken up and carried away by ventilating air currents; furthermore, there are eleven dust-producing points on a card and it has to be partly dismantled every ten days or so for cleaning. FIGURE 5 shows a general view of card ventilation. To prevent dust settling in any of the ventilation pipes an air speed of not less than 3,000 ft. per min. is maintained in all of them and 0.0026-lb. of dust is conveyed by each 100 cu. ft. of air exhausted. Cleaning, or stripping, of cards used to be done by hand and was a very dusty operation. It is now done by a revolving brush, fitted with its own exhaust ventilation, that traverses across the card cylinders.

The next process after carding is spinning and a ring spinning frame is shown in FIGURE 6. This is ventilated and again, the degree of enclosure of the machine is to be particularly noted. Enclosure of machines makes both maintenance and machine operation more difficult but this is a price that has to be paid to suppress dust effectively.

After spinning comes weaving and dust is controlled on the looms both by the application of ventilation and by damping the yarns. As an indication of the cost of ventilation, four times as much energy is required to ventilate the looms as to drive them. In 1928 dry weaving of asbestos was



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he dustiest process except for blending; today, in the T.B.A. Co. Ltd. factories, the weaving processes are the cleanest of all. In fact the present aim is to improve all working areas to the standard attained in the weaving areas. In the 1920's, 14 lb. per week of fiber and dust was removed by hand from under each loom; today, only one-half lb. per week remains to be removed.

The dusty ventilation air from the various machines is passed through fabric sleeve filters and the cleaned exhaust air is discharged to atmosphere. These sleeve filters are of T.B.A. Co. Ltd's design and FIGURE 7 gives an impression of the size of one installation. Apart from the mechanical maintenance of the filter plant itself, the sleeves themselves need regular cleaning and a machine was developed for this purpose. This is a typical example of the special efforts that have had to be made to perfect dust control techniques.

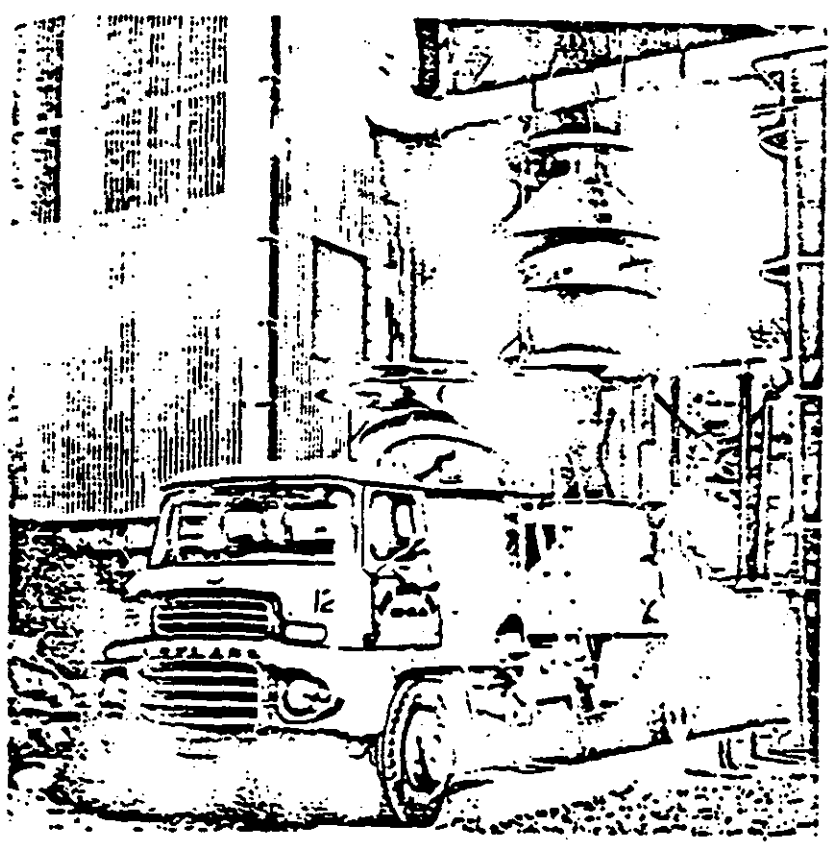

FIGURE 8. Special containers for loading crude material.

Dust control does not, of course, begin and end with the measures applied to machines. With respect to the operatives themselves, all those who work in asbestos textile areas are issued with nylon overalls. After trials of several materials nylon was preferred as asbestos dust does not cling to it and can readily be brushed off. Furthermore, respirators are worn for a few special operations and all respirators are regularly checked and serviced.

Cost of Dust Control

It is clear from the foregoing that considerable engineering effort has been devoted to dust control at the T.B.A. Co. Ltd. factories and substantial dust control plant has been installed. It would be inaccurate to say that all this has been done regardless of cost, but cost has never been the first consideration. The total capital expenditure on dust extraction equipment over the years totals approximately £500,000 ($1,500,000) and is a substantial proportion of the total expenditure on textile plant. Today the provision of ventilation adds, depending on the process, between 20 and 37 per cent to the cost of new textile plant. The cost of running all this plant is also considerable. The total volume of dust-containing air extracted from textile machines in both the T.B.A. Co. Ltd. factories is over 1,000,000 cu. ft. per minute or, over 700 cu. ft. per minute per operative. All this air has, by Government Regulation, to be exhausted to atmosphere and in winter this represents a considerable heat loss. From this air, 700 tons of asbestos dust is filtered every year, or 2.8 tons every working day. The running costs of the dust-extraction plant, including electric power, labor, depreciation on plant and other overhead (or burden) charges and the extra heating cost because filtered air cannot be recirculated, comes to £80,000 a year, or nearly $250,000. To put these figures into perspective, this cost of dust extraction is equal to seven per cent of the wages bill or 2.7 per cent of the total cost of converting asbestos fiber into asbestos yarns and cloth.

Dust extraction equipment at asbestos mines is also costly. One of the other Companies in the Asbestosis Research Council, the Cape Asbestos Co. Ltd., has recently built a new amosite mill at Penge in the Transvaal. The total installed horse-power of this new plant is 796 of which 230 h.p. is used to generate the air for the dedusting operation. A total of 90,000 cu. ft. per minute of air is needed for aspiration and dedusting, equivalent to 1,350 cu. ft. of air per pound of fiber produced. The most modern mill in Canada, which is ten times larger than the new mill at Penge, uses only about half this quantity of air. This is because air-swept mills are used at Penge together with air for the horizontal transportation of ore and fiber; gravity is used in the Canadian mills. The capital cost of producing all this dust elimination plant at Penge was considerable and at R 240,000

approximately $360,000) was equal to 27.5 per cent of the total capital cost of the mill. A dust-collecting plant which will operate at 99.9 per cent efficiency with five micron particles has been designed and installed. Approximately 24,000 tons a year of dust are disposed of at Penge and the approximate cost of running the dust collection plant there is £63,000 ($176,000) a year. FIGURE 8 shows the special containers that are used to load the crude material, from another mill in this instance, to the feed point of the mill. The screens and fiber classifying devices used at Penge are shown in FIGURE 9. It will be seen that the principle of totally enclosed conveying and handling has been used virtually everywhere.

The basic similarities in the techniques for dust extraction in this Cape Asbestos Co. Ltd. mill and in the T.B.A. Co. Ltd. asbestos textile factories are striking and both demonstrate that dust control of the highest order is an integral part of the U.K. asbestos industry's thinking.

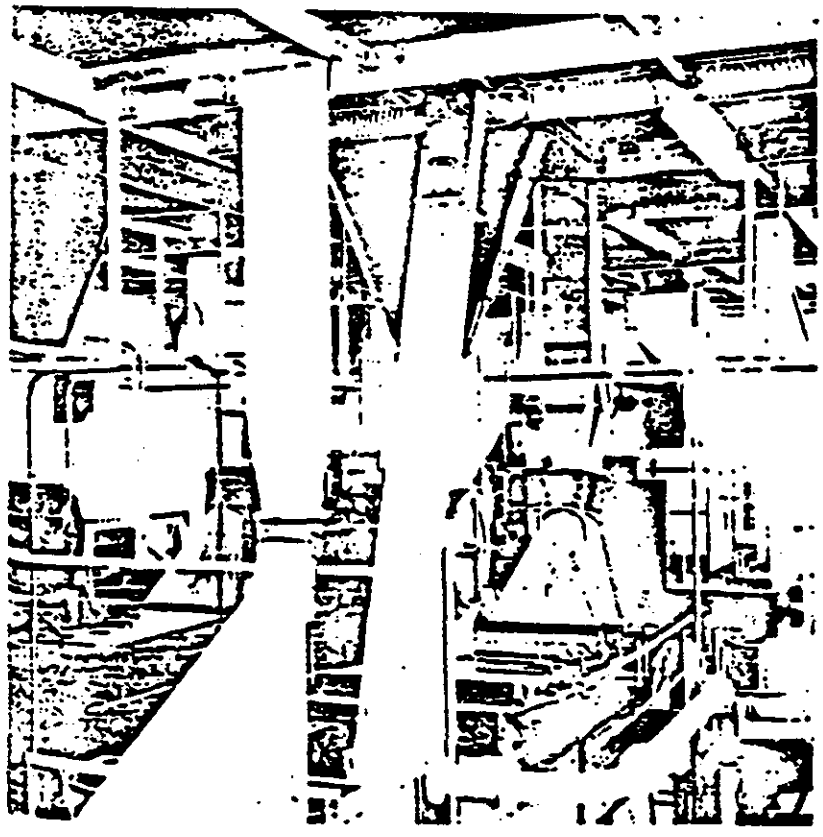

FIGURE 9. Screens and fiber classifying plant.

The Future

The asbestos textile industry in the U.K. is continuously striving to improve its dust control methods and this is being done both individually by the Companies concerned and also on an industry basis through the Engineering Committee of the Asbestosis Research Council. In T.B.A. Co. Ltd., a number of investigations are proceeding now including the total enclosure of a carding machine and the ventilation of beaming machines in yarn preparatory stage before weaving . the results of this work will be made freely available to the Engineering Committee whose function is to examine and develop methods of dust control in asbestos textile processes and to make recommendations for improvements. Visits are made by the engineers of each company to the plants of the others so that this is a real and live collaboration. The aim of all this work is to eliminate as far as is humanly possible the dust hazard in the asbestos textile factories in the U.K. and, at least as far as they are concerned, to make the subject of this monograph, "Biological Effects of Asbestos," a matter of pure academic interest.

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DISCUSSION

J. C. GILSON (*Pneumoconiosis Research Unit, Glamorgan, Wales*): I have a slight uneasy feeling about this meeting and it is a feeling I always have when attending this type of meeting, because I feel that it is really a form of the chicken and the egg. Everybody is unwilling to start using a particular method of counting or a particular instrument because they say we do not know whether it is the one that is the best. You never know unless you start using one consistently for a period of time, and observing the people whose environment you are measuring with a particular instrument. And it seems to me quite hopeless to go on expecting that some curious process which is quite undefined — perhaps the expectation that some animal experiments will somehow provide the philosopher's stone — will enable you to decide which instrument you should use.

Surely, the way to start is to choose a method at some time. I do not really think that any major change has been made in the last 30 years. If a decision had been made to make systematic measurements 30 years ago, with almost any instrument, you would by now, in fact, have got quite a long way to getting a dose-response relationship in this industry. I think Dr. Roach's suggestion that you should use, therefore, a gravimetric sampler of respirable dust has enormous merits because it does enable you to use it in many places where you cannot use any other kind of instrument.

We have heard earlier today that obviously the risks, taking the whole industry at the present time, lie very largely in the insulation workers. I cannot see how you would expect to be able to use a Royco instrument. I am not certain that Dr. Roach suggested you should, but, clearly, we need some instrument that has a very wide applicability throughout the whole industry.

C. G. ADDINGLEY (*British Belting and Asbestos Ltd., Cleckheaton, England*): I would just like to make one point. Dr. Roach said that in Britain mention is made of a safe limit of four fibers per milliliter, and that this is lower than the American limit. I would like to say that this is the first time that any limit has been specifically stated as far as the United Kingdom industry is concerned. We do not believe there is any safe limit. We have our ideas as to how low we can get and we are always striving to get right down to zero. We also have our ideas about the American limit of 5 million particles per cu. ft. as a safe limit. We know that there is no scientific basis for that limit whatever, and I think that if Dr. T. Hatch had been here he would have agreed with that, because it has been taken up with him in the past. Therefore, I would like it to be clearly understood that we do not accept four fibers per cc. as a safe maximum limit in the asbestos industry.

JOHN WELLS (*U.S. Rubber Co., Newnan, Ga.*): I would like to briefly

review the work that we have undertaken. The asbestos textile mill in Hogansville has been producing textile products since 1941. In 1941, using the Midget Impinger, dust counts were begun at many stations, many times a week and have continued to be obtained for some 22 years. During this time two people have done all the dust counting. The person who is now doing it was trained by the person who used to do it. I should say we do not know what we are counting. We are counting everything we get in the chamber, but we are counting in the same manner.

When this program started we hoped to get some meaningful results. In order to do that, we averaged out the number of counts that were obtained at each station during the year in terms of million of particles per cubic foot and multiplied them by the years. In so doing we arrived at a figure which we called million particles per cu. ft. years, and we did this with each worker, many of whom we have been able to follow.

We constructed a scattergram in which we placed on the ordinate the years of exposure, and on the abscissa the million particles per cu ft. years. Using this as a baseline - for whatever meaningfulness it had - when we got to a period of some 50 to 60 million particles per cu ft. years, we began to find people with pulmonary asbestosis. As the million particle per cu. ft. years mounted, we began getting more patients with pulmonary asbestosis.

In terms of what has been considered a safe dust count in the area, we started out with a theory — because everybody said it was so — that 5 million particles per cubic foot was a safe figure. Our own conclusion, as we began seeing what was happening in our own process, was that the only safe amount of asbestos dust exposure was zero and that the efforts in terms of achieving that lay basically in engineering, and, secondly, in education. But as far as a safe level of asbestos dust is concerned, our own conclusion in Hogansville, Ga., is that there is no safe level. The safe level is nil and anything above the safe level represents certain risk.

S. A. ROACH (*University of London, London, England*): I should like to say that the standards which we mentioned, four fibers per milliliter or 5 million particles per cu. ft., are simply standards, although I hope I did not use the word "safe." These are standards which are actually used, although they are not ever expressed as being safe standards. A further standard has been mentioned of 50 to 60 million particles per cu ft. years. I suppose this is the equivalent of some 2 million particles per cu ft. concentration. This would be another standard which might be used but it is not necessarily a perfectly safe level of dust.

L. SILVERMAN (*Harvard U., Boston, Mass.*): I have had some experience in specific uses of asbestos: in particular the asbestos tile industry which is a major consumer of asbestos fiber. With just a few simple applications of control such as switching from jute bags which were shaken out by the worker to be shipped back to the plant to paper bags which retain the

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moisture in the fiber, and then from that to full gondola cars with vacuum conveying systems, the total dust exposure of the bag-opening operation has been eliminated. The dust counts that were present when the jute bags were used and shaken were reduced by a factor of something like 10 by going to the paper bags, and then, when automated conveying operation was installed, it was eliminated. Incidentally, so was the worker.