Dust Control Techniques in the Canadian Asbestos Mines

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Summary

After a discussion of the varieties of asbestos produced commercially, with special reference to the Canadian abestos mining industry, the different grades, the classification system, the health risks inherent to asbestos mining and processing, and the elements of environmental control at the workplace are outlined. Various factors for the successful design of a dust control system are given, as well as design criteria for screens, conveyors, bucket elevators and the air-handling system.

1. The Mineral Asbestos

1.1 Introduction

Asbestos is a commercial term applied to fibrous varieties of several specific minerals. In Canadian mining, the asbestos industry assumes considerable importance. Its contribution to Canadian mineral production not only outranks all other non-metallics, but also ranks fifth in value of all metallic and non-metallic minerals. The importance of the asbestos industry is reflected in the largest mine in the Western World, the Jeffrey Mine at Asbestos, Quebec, Fig. 1, with an output of 700,000 tons of fibre per year.

In 1980 the USSR contributed 47 % of the world's 5.2 million tpa of asbestos fibre production compared with Canada's 29 %. The real importance of the Canadian asbestos production lies in the fact that Canada is responsible for almost two thirds of the world's exports whereas the USSR and the Comecon countries consume themselves virtually all they produce, Fig. 2.

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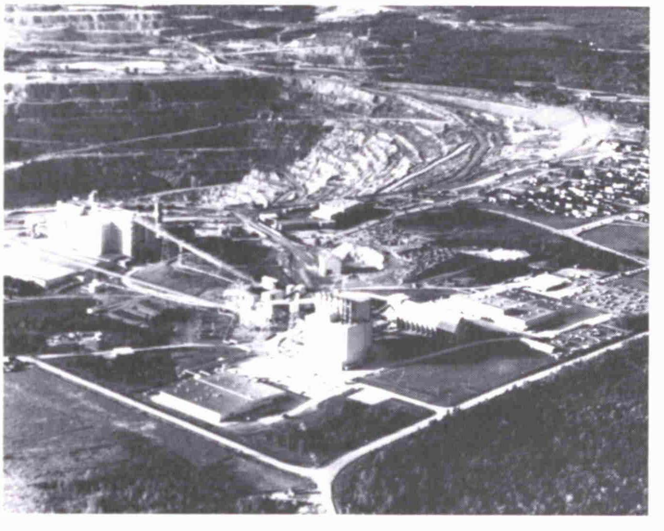

Fig. 1: Aerial view of Johns-Manville's mine and mill at Asbestos, Quebec

1.2 Chrysotile and the Amphiboles

The varieties of asbestos produced commercially are chrysotile, crocidolite, amosite and anthophylite. Chrysotile makes up 90 % of the world production of asbestos and is the only variety that is mined in Canada. Crocidolite and amosite are of significant commercial importance, partly because of the occurrence of large deposits in one particular region (South Africa) but more importantly because of their properties. Chrysotile, amosite, and particularly crocidolite all have extremely high tensile strengths and are therefore used extensively for their reinforcing properties when combined with materials such as cement, resins, and plastics.

Chrysotile is the sole species classified in the serpentine group of hydrous magnesium silicates, whereas the amphibole group contains five known varieties — namely crocidolite, amosite, anthophyllite, tremolite and actinolite. The chemical formulae of these minerals are as follows:

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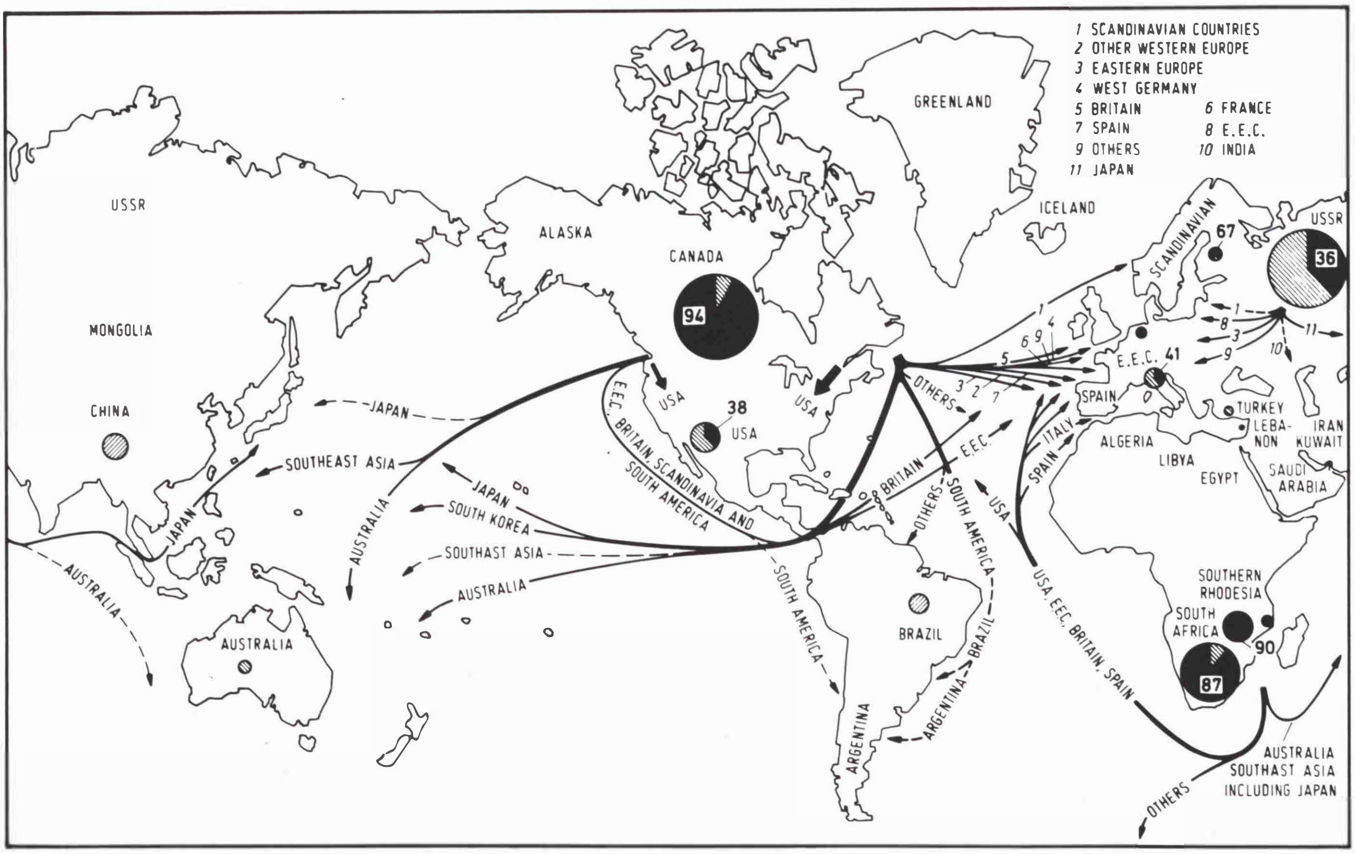

Fig. 2: World asbestos production and trade

Chrysotile (also known as white asbestos): $3MgO \cdot SiO_2 \cdot H_2O$.

Crocidolite (or "blue asbestos"): $Na_2O \cdot Fe_2O_3 \cdot 3FeO \cdot SiO_2 \cdot H_2O$.

Amosite: $5\ 1/2FeO \cdot 1\ 1/2MgO \cdot 8SiO_2 \cdot H_2O$.

Anthophyllite: $7MgO \cdot 8SiO_2H_2O$.

Tremolite: $2CaO \cdot 5MgO \cdot 8SiO_2 \cdot H_2O$.

Actinoite: $2CaO \cdot 4MgO \cdot FeO \cdot 8SiO_2 \cdot H_2O$.

Chrysotile, a fibrous form of serpentine, is normally associated with massive serpentine. The recovery process is, therefore, unique in that it usually involves separation of a fibrous mineral from a massive form of the same mineral. Because the fibre has the same density and chemical composition as the host rock, advantage is taken of the physical difference of the rock and fibre after the latter has been released under impact and fluffed up in a dry state. In this state, the asbestos is lighter in bulk density and is amenable to separation from the serpentine rock by screening and air suction.

1.3 Asbestos Producers in Canada

The importance of mining and milling of asbestos ores in Canada is emphasized when it is realized that, in 1981, the asbestos mines produced 1,600,000 tons of fibre. About 94 % of the milled fibre was shipped to markets throughout the world. The actual Canadian asbestos producers are listed in Table 1.

Production of asbestos from the Eastern Townships of Quebec has been continuous since 1878. The mineral's unique mode of occurrence, in well defined veins in a matrix of gangue, enabled early workers to separate the fibres by the most primitive methods. They followed a practice known as "cobbing", breaking the rock followed by manual separation. The method was not only time consuming but gave poor recoveries. Earliest attempts at mechanical treatment were carried out during 1889 and 1890. By 1895, mechanical treatment was well established. Through the years, many refinements have taken place to improve the recovery and efficiency of the process. Today, leaktight equipment, industrial exhaust systems and dust filters are used to control dust exposures in mining and milling.

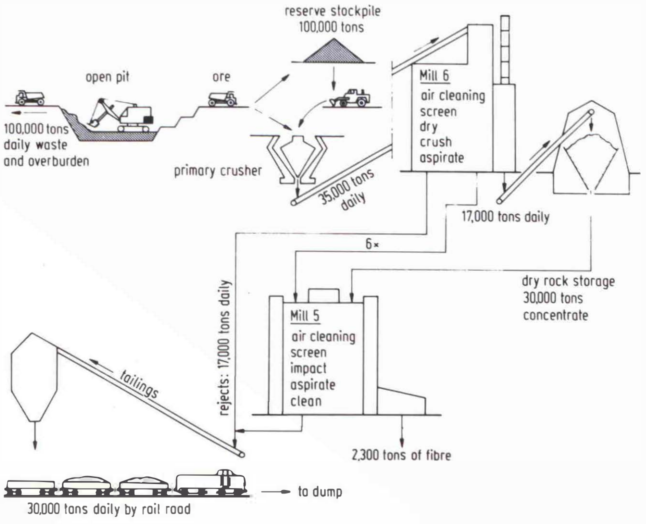

Fig. 3: Ore flow sheet of the largest mine in the western world; Asbestos, Quebec

The essential stages of present-day operation are shown in a simplified representation in the flow sheet of Fig. 3: breaking — loading — haulage — crushing — air cleaning — screening — aspirating and cleaning.

1.4 Grades and Classification

Apart from the differences of mineralogical type described above, there are naturally differences in the quality of different deposits of the same type of asbestos. For instance, Cassiar chrysotile is generally purer than Quebec chrysotile and is therefore particularly valuable for applications which require an absence of contaminants. However, such considerations are generally restricted to the more specialised applications, and the main system of grading asbestos is based on fibre length rather than on quality. For chrysotile the most widely used system of grading is the Canadian system developed under the auspices of the Quebec Asbestos Mining Association (QAMA). There are 9 groupings (see Fig. 4):

— Groups 1 & 2 (or Crude No. 1 and Crude No. 2)
refer to the longest fibres, with lengths of over 3/4-inch and between 3/8-inch and 3/4-inch respectively. These long-fibre grades are not separated into individual fibres at the mine-site but instead are shipped crude to the customer,who separates the fibres himself for use in preparing asbestos textiles, etc.

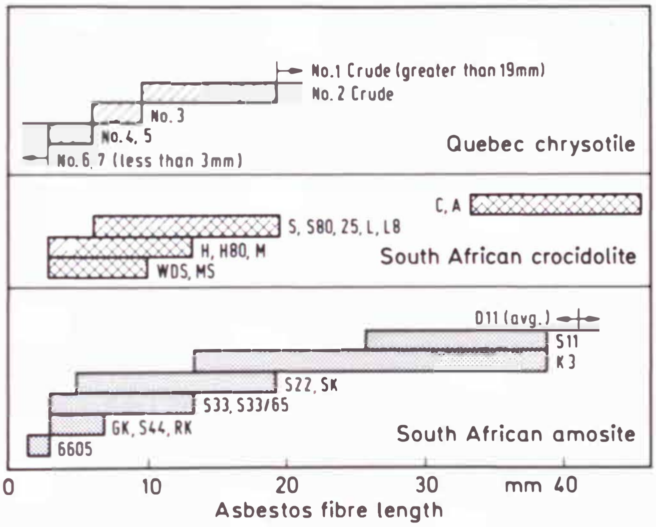

Fig. 4: Asbestos fibre lengths (mm)

— Groups 3 to 7
consist of milled fibres classified by means of the Quebec Standard Testing Machine. This machine consists of three screens (1/2-inch mesh, 4-mesh, and 10-mesh) and a box to catch the short material. Groups and sub-groups are classified according to the proportion by weight retained on each screen. Hence Group 3 material will

Table 1: Asbestos producers — present, without prospective (per 1981)

Producer	Mine location	Mill capacity (tonnes) ore/day	Mill capacity (tonnes) fibre/year	Remarks
	Quebec			
Asbestos Corporation Ltd.				
— Asbestos Hill mine	Putuniq	5,400	90,000	Annual rated capacity 227,000 tonnes concentrate, final processing of fibre in West Germany
— British Canadian mine	Black Lake	11,200	—	
— King-Beaver mine	Thetford Mines	—	210,000	Underground and open pit
— Normandie mine	Black Lake	6,800	—	Reserves exhausted, Mill processes King-Beaver open pit ore
Bell Asbestos Mines Ltd.	Thetford Mines	2,700	55,000	Underground
Lake Asbestos of Quebec	Black Lake	8,200	235,000	
National Mines Division	Thetford Mines	3,200	—	
Carey Canada Inc.	East Broughton	5,000	210,000	Mainly produces groups 6 & 7
J.M. Canada Inc. Jeffrey mine	Asbestos	30,000	645,000	Western world's largest asbestos deposit
	Newfoundland			
Advocate Mines Limited	Baie Verte	6,800	80,000	Produces groups 4 & 6
	British Columbia			
Cassiar Resources Ltd,	Cassiar	3,000	100,000	
	Yukon			
Cassiar Resources Ltd.	Clinton	—	—	Closed since 1979
	Ontario			
United Asbestos Inc.	Matachewan	3,600	10,000	Inactive

have a very high proportion of long fibres retained on the larger aperture sieves, whereas Group 7 material ends up mostly or totally in the box. In terms of applications, Group 3 fibres are used almost exclusively in textiles (except for a small proportion used in specialised papers, gaskets, etc.); Groups 4—6 are used in asbestos cement products, insulating boards, asbestos paper, friction products, etc., where the choice of grade — or mixture of grades — depends on the required properties of the finished product; Group 7 fibres are used in what are essentially filler applications, such as in floor tiles, plastics, paints, adhesives, etc.

— Groups 8 and 9
contain in preponderance of rock and sand and are sold as cheap fillers in constructional applications.

Amosite and crocidolite are graded by somewhat similar methods although a greater variety of long fibres is offered.

2. Health Risks and Standards of Concentration and Measurement

The first reports of asbestos-related disease were described as early as 1907. However, it was not till 1930, that a relationship between years of exposure, dustiness of the environment, and lung fibrosis was reported. There are three diseases which may be associated with exposure to the risk of inhalation of asbestos in the working environment. These are asbestosis, lung cancer and mesothelioma.

Epidemiological studies throughout the world have demonstrated that pathological effects increase in relation to the amount of dust inhaled; exposure to high dust concentrations over a relatively short period of time may involve similar risks to exposure over a long period of time to lower levels of dust. This is generally described as a dose-response relationship. Since bronchial cancer may result from similar conditions with the multiplicative effect of cigarette smoking as a co-factor, this may also be said to be related to the dose.

Environmental hygienists have tried to calculate at what dose level no excess risk will occur, so that manufacturing processes and conditions can be measured and the need and extent of remedial action assessed. In many industrial countries working standards have been established on the basis of the number of fibres in the fine dust range present in a measured quantity of air; for example, in many countries a maximum acceptable concentration of two fibres per millilitre average concentration over a normal working period (four or eight hours) has been adopted. The now proposed control limit is one fibre depending on the fibre species.

Unfortunately, owing to changing test methods, errors in test methods and the long period between exposure and the onset of disease symptoms, it is extremely difficult for an engineer to correlate control methods with the environment required to reduce health effects to a minimum. In such an atmosphere, the only moral stance is to use the best methods of control available to us and to constantly seek to improve those methods. In any process involving the use of asbestos fibres or in the use of any materials containing asbestos, where dust in excess of the stipulated standard may be given off, technical measures should be devised to prevent the emission of asbestos dust into the atmosphere of the workplace.

3. Elements of Workplace Environmental Control

3.1 Principles of Dust Control

The methods used in the asbestos mining industry for the control of asbestos are the classical methods used by dust control engineers in all industries:

- Enclose any dust source as fully as possible.
- Place all dust-producing equipment under negative pressure by connecting to exhaust ventilation of adequate capacity.
- Design and install a properly designed duct system.
- Filter the dust-laden air adequately.
- Move the air with fans of the proper types, having adequate volume and pressure capabilities.
- Where normal principles of dust control are difficult or expensive to apply, process changes must be considered.

Describing how all the principles of dust control are applied to the field of asbestos mining and milling is a job beyond the scope of the present paper. Examples illustrating the principles given above will be described. Some of the methods are unusual and may be fruitfully applied to other industries, e.g. asbestos cement manufacturing plants.

Dust control systems are devices for capturing contaminants at their source and preventing their discharge to the atmosphere.

The primary components of any dust control system include:

- An enclosure around any potential dust source such as conveyor belt transfer, crusher, screening machine, bin loading and loadout.
- Ducting including hood take-offs (transitions) to convey the collected dust-laden air away from the source of dust generation to a convenient location.
- A dust collector for separation of particulate matter from the air stream prior to its discharge to the atmosphere.
- A prime mover, generally a fan, to draw air into an enclosure and to overcome resistance to flow in the ducting and dust collector.

Plant operators prefer to be able to see the primary ore processing machinery in operation such as feeders, screening machines and crushers. They realize that it is necessary to enclose this equipment to prevent dust escapement, however, the primary objective of plant operation is to efficiently process a given tonnage of ore. Dust control is a necessary consideration creating a better working environment, healthier and safer climate and useful for extending the life of mechanical equipment. It is very important that the enclosures, duct routing and collector location result in the least amount of interference to plant operation. Hinged quick acting inspection doors, preferably self-closing, and peep holes should be located to allow easy inspection of process equipment. Enclosures should be designed to allow quick access, ease of maintenance and adjustment to equipment. Enclosure panels, hoods and duct sections may be constructed for fast, complete removal.

In the design of any successful dust control system, several factors must be taken into consideration at the outset. These include:

- Volume of air withdrawn from a given potential dust source adequate to prevent localized discharge.

— Velocity of air. This includes velocities at slot openings in enclosures and equipment high enough to prevent localized discharge, and duct transport velocities adequate to convey all collected particles without settling.
— Enclosures. Designed to contain the dust at its source, allow settling of larger material and air withdrawal commensurate with the process contained therein.
— Ducting transitions, branch entries, routing, method of balance (either belanced draft or damper control) and construction materials.
— Dust collector type commensurate with plant operation, sizing equipment and specifying operating conditions. One should determine early in the design phase what types are acceptable, since there are appreciable differences in physical size, electrical requirements and collected dust handling that can seriously effect other areas of plant design.
— Fan operating conditions, size and type, and method of control. This item is frequently included with the collector bid package. In the case of ore dryers and other processes requiring specific conditions for process reasons the fan and control system should be carefully investigated to be sure of volume and pressure operation over the desired range.

The most widely used pieces of mechanical equipment in asbestos mills are screens and belt conveyors. In early milling operations, before about twenty-five years ago, these pieces of equipment were not always covered to prevent dust generation in the asbestos mills.

3.2 Screens

Different types of screens are used in the asbestos industry. These include: Gyrating screens, rod-deck screens, vibrating screens, shaking screens, etc.

Screens have been notorious dust generators. Considerable progress has been made in enclosing screens with leak-tight enclosures and installing flexible connections, generally made of nylon cloth, which attach the screen to the feed chute. Similarly, the chutes carrying away the various screen products are also attached to their respective chutes by means of similar flexible nylon cloth. The dust connection to the screen cover may be a 6-inch or 7-inch pipe exhausting about 800 to 1000 cubic feet of air per minute from screens about 4 feet by 10 feet. The pipe is connected by means of a large, flexible connector, reducing the velocity at the connector to approximately 200 to 300 ft/min, Fig. 5.

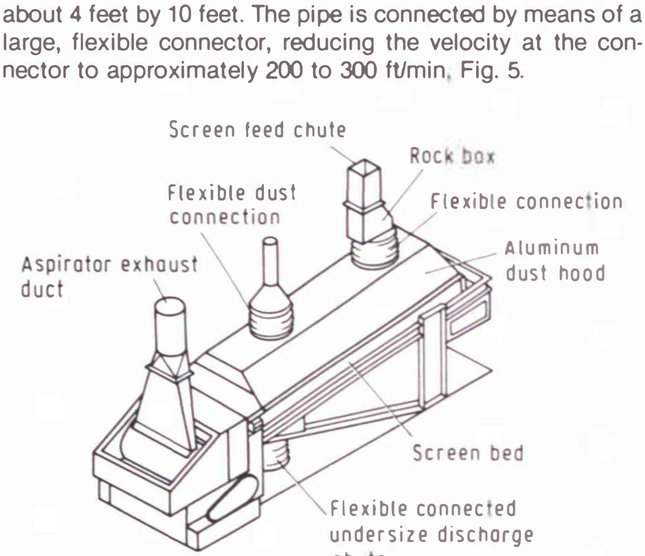

Fig. 5: Gyratory fibre screen and rotary aspirator

Screen cleaning is of great importance to the screen surface. Mechanically operated brush cleaning systems show satisfactory cleaning effects. However, a considerable amount of maintenance and spare parts have to be applied to these systems.

The acceleration of linear swingers with large stroke and high number of revolutions is so high that rubber balls can be used successfully to clean the screen. The rubber balls are resistant to abrasion and so reach a long service life, there is no need of maintenance, the system is favourable as to costs.

3.3 Conveyors

The dust problems caused by belt conveyors are as follows:

— Dry materials carried on the belt conveyor, at high speed, generate dust in the mill.
— Chutes feeding either from one belt to another, or from other equipment onto the belt, generate dust.
— The return belt is a serious source of dust contamination in asbestos mills. Dust carried on the bottom of the return belt is deposited on every idler carrying the return belt. Each idler becomes a source of dust generation.

Fig. 6 shows an enclosure that is often used to enclose the top portion of a conveyor. It is particulary used at the location of chutes feeding either from one belt to another or from other equipment onto the troughing conveyor. This enclosure normally has a sheet metal section that encloses the belt on three sides. Rubber skirting on the two vertical sides bears against the surface of the belt. This skirting is adequate to prevent dusting from the material that rides on the belt. Of course, the belt width and the speed of the belt must be adequate to carry the material load within the skirt boards; otherwise the value of the skirting is negated by material forcing its way under the rubber skirting and out of the conveyor enclosure.

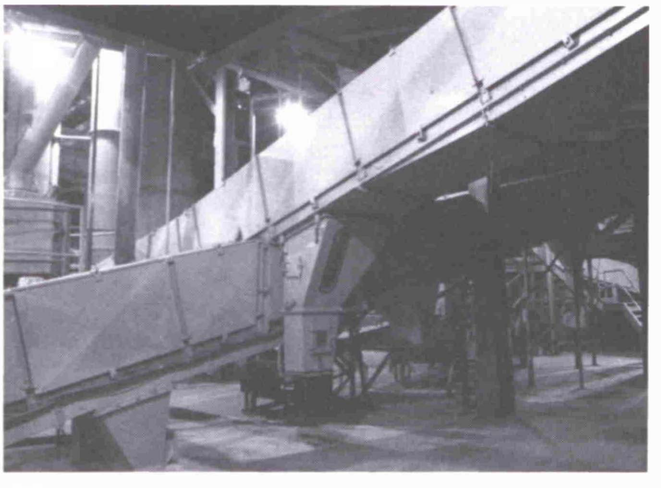

Fig. 6: Typical conveyor to conveyor transfer with dust covers

Chutes feeding the conveyor should feed axially onto the belt. The material should not be forced against the skirting. If possible, the chute should also be arranged so that a rock box may be placed at the base of the chute. Long, vertical chutes must be avoided. Chutes should be run at angles so as to reduce the velocity of material feeding onto the conveyor.

The return belt must be cleaned, e.g. by scrapers. However, in spite of all cleaning equipment on the market, the return belt often carries dust to the idlers. In extreme cases, it is necessary to enclose the return belt with a complete leak-tight enclosure and to clean that enclosure by means of scraper conveyors.

Dust connections are used at strategic points on belt conveyor enclosures. These dust connections should always be attached to the conveyor enclosures by means of a settling box, which reduces the velocity so as to minimize the exhaust of material and especially valuable products. These dust connections should generally be installed in areas where conveyors feed from one to the other or where several chutes feed onto the conveyor. The movement of material at the feed points generates windage and air pressure that must be relieved. Dust connections should also be installed at points where the conveyor enclosure ends, as serious dust pumping into the mill can be caused by material exiting from the enclosure.

3.4 Bucket Elevators

Bucket elevators are well known mechanical conveying devices which are frequently in use. One example of enclosed design is shown in Fig. 7. The sitting of the exhaust point on the enclosure is highly important.

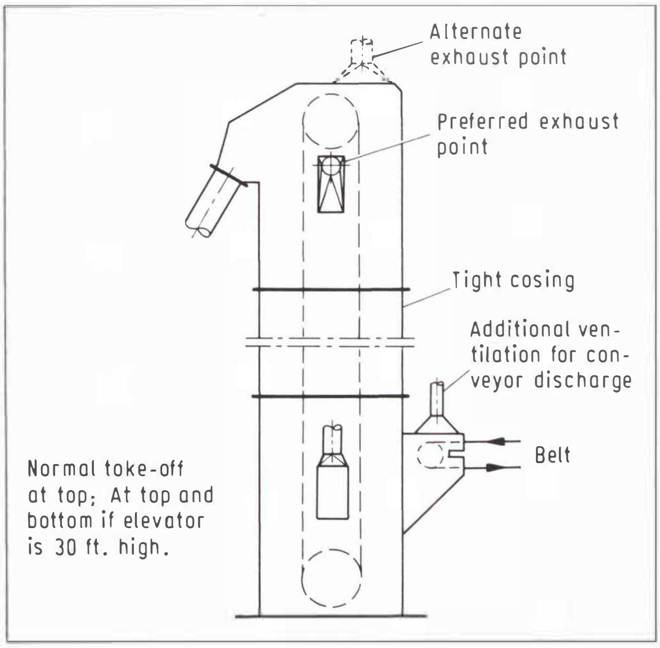

Fig. 7: Bucket elevator ventilation

4. Air-Handling System and Dust Control

Large quantities of air are handled by the air system which, using a pull-through method, circulates a flow of air through the fibre processing and dust control systems (Fig. 8). These systems are made up of a multitude of suction hoods to collect fibre or dust, ducting to convey the collected material, and separators and cyclone collectors to separate fibres from the air stream. The flow of dust-laden air from the outlets of the cyclone collectors or directly from the dust control system is pulled through the air filtering and fan assembly section. The dust-laden air passes first through a plenum chamber, which serves as an air-redistributing manifold to

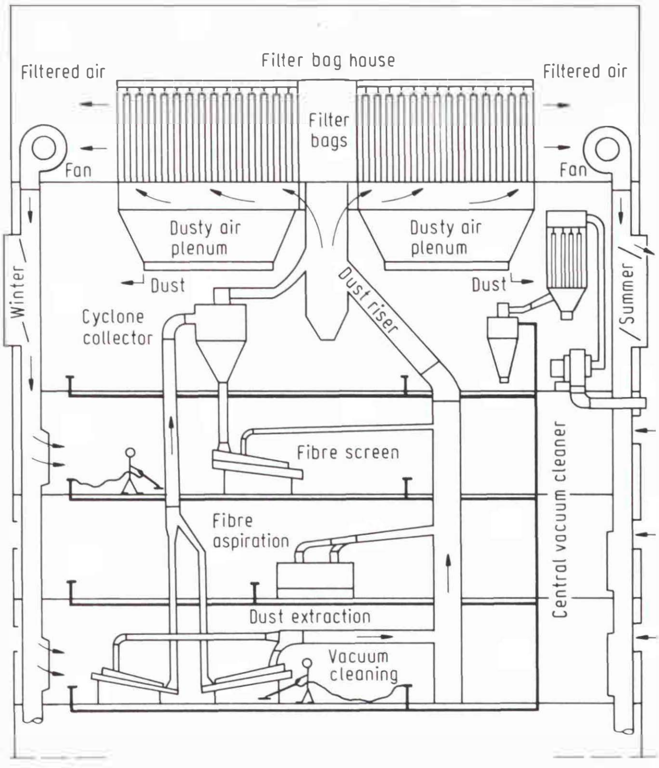

Fig. 8: Schematic of air-handling and central vacuum cleaning system

the bag filter compartments, and acts as a dust settling chamber (Fig. 9). Air velocities drop from about 4000 ft/min to as low as 200 ft/min with a consequent considerable pressure drop and expansion of air which cause the heavier dusts to settle out in the plenum chamber. This reduces the dust loading for the bag filters, which operate at an air-to-cloth ratio of about 2.5 to 1. Dust is shaken out of the bags by an automatic shaking device at predetermined intervals dependent on the number of compartments.

There is a complete air change throughout the mill, about ten times per hour. The filtered air can be either discharged to atmosphere during warm weather or recirculated to the mill as heating air during cold weather. Sufficient heat is picked up from the heat dissipated from the equipment and dried ore to maintain a reasonable temperature within the mill building during cold weather, with consequent energy savings.

The amount of air required has increased over the years as lower grade ores have been milled, more fibre grades produced and improvements to dust control made. The early mills used about three tons or about 80,000 ft^3/min of air for each ton of ore milled, whereas today 12 to 15 tons of air or about 320,000 to 400,000 ft^3/min are used per ton of ore milled, with more than half being for dust control.

A dry asbestos milling process, by its nature in handling dry and fine material, can be an extremely dusty operation. An asbestos mill contains a great variety of equipment, such as crushers, screens, impact mills, fiberizers, conveyors, bucket elevators and packers, which must be dust-controlled. Because of this great variety of equipment, it is necessary to design special dust collecting equipment for the various processing units and materials handling equipment in the mill.

The dust collection equipment must be designed to confine the dust at its source, to maintain adequate suction to capture the dust, and to effectively remove the dust once it is caught. The design, using recommended practices, must also provide for an easy and quick access for inspection and repairs to equipment and ensure due regard for the normal operation of the equipment.

In most mills, a central vacuum cleaning system has also been installed to collect, in one system, all the dust as it is captured throughout the mill. This eliminates the use of brushes and brooms for cleaning, handling and disposal of the dust at the collection points.

Fig. 9: Main air system filters

5. Monitoring the Workplace

To determine the dust situation at workplaces, to check the dust control measurements, and to control the proposed limits, an international reference method has to be applied. A correlation between dust measurements of the past years or decades and the actual diagnosis statistics is not possible. In some cases different dust parameters have been measured, in other cases different measuring methods have been used. Among the sampling instruments are the konimeter, the midget impinger, the thermal precipitator and the membrane filter collector.

An example of the present measuring techniques in the Canadian asbestos mines will be given by way of the Cassiar Mine, British Columbia: Cassiar Asbestos, a company of Brinco Mining Limited, adopted, in 1970, the midget impinger — the best known device for sampling air-borne dust at that time. Cassiar used this method to conduct its own first plant-wide survey in 1971. The midget impinger bubbles dust particules through isopropyl alcohol, impinging the particles to the bottom of a collection tube. Dust samples thus obtained are then mounted on slides and counted using a 100x microscope and recorded in million particles per cubic foot.

Subsequently, in 1973, the improved filter membrane technique was adopted. This method enables the actual asbestos fibre to be counted, whereas the midget impinger includes all types of dust. This filter membrane technique which was developed by the National Institute of Safety and Health in the USA, is now used throughout the asbestos industry. It is recommended by the Asbestos International Association, London, UK, as reference method for the determination of airborne asbestos fibre concentrations at workplaces.

Measurements are taken by drawing a known volume of air through a membrane filter. This filter is then made transparent, and the number of fibres fitting a standard definition of size and shape which are in the deposit are counted using a phase-contrast microscope. The mean fibre concentration during the sampling period can then be calculated. Where fibre identification is needed, different types of sampling filters and analytical techniques may be required.

Fig. 10 shows an operator at the face of the Cassiar Mine wearing personal sampling equipment. The instrument attached to the person is completely portable and the air sampled in the breathing zone of the person concerned. This provides what is known as a "personal" sample. Normally, a shoulder harness or a lapel filter holder is used with the sampling surface facing downwards or vertically. Upwards-facing filters are avoided because of the high risk of contamination. In addition, the filter may be protected by a cap, or by leaving the end on the Millipore holder, in order to prevent contamination from extraneous sources such as dusty overalls.

Fig. 10: Operator wearing personal sampling equipment