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SILICOSIS AND ASBESTOSIS HAZARDS
ASSOCIATED WITH THE MANUFACTURE AND USE OF
PROPAX

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Silicosis and Asbestosis Hazards Associated with the Manufacture
and Use of Profax.

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Synopsis:

Recent literature on diseases of the lungs brought about by occupational exposure to silica and asbestos dusts has been surveyed, and discussions on recent developments have been held with members of a medical research unit operating in the United Kingdom.

The mechanisms causing these diseases are discussed. The nature and extent of the hazards associated with Profax 10 are considered, and it is concluded that the manufacture and use of this material are not entirely without risk. Means of obviating these hazards are recommended.

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INTRODUCTION.

Enquiries are being received from customers regarding the possibility of illness among steelworks personnel arising from the long-term use of Profax 10. Objections to a possible silicosis hazard have been arising during nearly the whole period in which Profax has been marketed, and it has been necessary in some cases to use olivine as a filler in substitution for silica flour. More recently, further objections have been received regarding a possible asbestosis hazard and its associated danger of cancer of the respiratory tract.

The material in this report comes from a survey of recent literature on diseases of the lungs and chest caused by exposure to toxic dusts, and from consultations with representatives of the Pneumoconiosis Research Unit of the Medical Research Council, Llandough Hospital, Penarth, Glamorganshire. The information gained has been used to illustrate the possible risk of pulmonary disorders accompanying the manufacture and use of Profax 10, and as a basis for considering ways of reducing or eliminating this risk.

Comments on industrial hygiene regulations and the legal aspects of silicosis refer to British practice. Different regulations may exist in other countries, and it is suggested that the reader should familiarise himself with these.

SILICOSIS

Description of the Disease.

Silicosis is a disease of the lungs caused by breathing air containing uncombined silicon dioxide dust. It produces nodules of fibrous material within both lungs, and can be detected at an early stage by X-ray examination. The disease may reach a serious stage before producing clinical symptoms. The most common symptom of severe silicosis is shortness of breath following exertion, and this symptom may increase to the point of causing complete disability. However, a mild to moderate degree of silicosis may accompany an otherwise apparently normal state of health. A persistent cough is not necessarily an early manifestation of the disease. When the disease has reached the stage where it causes shortness of breath to a disabling degree, there usually follow pain in the chest, loss of appetite, increasing fatigue and weight loss, eventually shortness of breath even when resting, and finally possibly death from pneumonia, heart failure or tuberculosis. The damage caused by silicosis is irreversible, and the disease has been observed to progress after exposure to silica dust has been terminated. It is generally believed that the disease reaches its

maximum development a few years after exposure has ceased; thus a worker with a non-disabling degree of silicosis may be subject to complications at some remote date.

There is evidence that the presence of silica in the lungs predisposes to tuberculosis. This condition is known as silico-tuberculosis. Experiments on animals have shown that the virulence of tubercle bacilli is enhanced when they are growing in a silicotic lung. However, modern diagnostic and therapeutic methods now make possible the protection of workers with silicosis from tubercular infection. Therefore, silico-tuberculosis is a preventable and often curable disease.

In some cases the victim is entitled by law to compensation. In any legal proceedings in the United Kingdom involving claims for compensation, the disease is only diagnosed when all the following criteria have been satisfied:

- 1) X-ray examination shows silicosis shadows.
- 2) There is a reliable history of prolonged exposure (more than 10 years) to respirable silica particles at concentrations in excess of the limits laid down by E.M. Factory Inspectorate.
- 3) Breathing disability must be demonstrated, and all other causes for the X-ray abnormality eliminated.

Mechanism of Silicosis.

Particles of any sort of dust may be breathed into the lungs and breathed out again, provided that they do not touch any of the surfaces of the lung tissue. However, the lung tissue is damp, and any particle coming into contact with it will be caught and remain inside the lung. Clearly, this situation could not be allowed to continue for any length of time, otherwise the lungs would become blocked up with foreign matter and cease to function. There are two mechanisms at play in removing unwanted matter from the lungs. The wind pipe and the wider air passages at the upper end of the lungs contain what are known as ciliary tracts. This means that the cells composing the tissue lining these tubes bear microscopic, hair-like protuberances which beat back and forth in a rhythm which produces waves of movement upwards along the surfaces of the air tubes. This action is termed "metachronal rhythm" and can be likened to the movement of a millipede's legs on to a gust of wind blowing across a cornfield. The effect is that a very thin film of mucus is continually pumped from the lower to the upper parts of the air tubes and eventually enters the mouth, together with foreign particles trapped in it, where it can be swallowed. Coughing aids this action.

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A different mechanism obtains in the lower parts of the lungs, where the presence of a layer of ciliary cells is impossible because it would too greatly impede the passage of oxygen and carbon dioxide through the lung tissue into nearby blood vessels. The scavenging mechanism here consists of single detached cells, called phagocytes, which are capable of moving about and engulfing foreign particles. They then carry these particles into lymphatic tissue areas in the lungs where they are disposed of.

This mechanism goes wrong when a silica particle is ingested by a phagocyte. The surface of the silica particle reacts with substances inside the phagocyte to form toxic products which kill the phagocyte and are released when it dies. The cells of the lymphoid tissue are poisoned by these toxins and react by becoming fibrous. The silica particle is released by the break-up of the phagocyte, and can be re-ingested by another phagocyte, and so on, being continually recycled. When the lymph tissue becomes fibrous, the normal passage of phagocytes is obstructed, and they may then migrate through the walls of lymph vessels and deposit their silica content in the gas-exchanging tissue near blood vessels. This latter tissue responds very quickly to toxic material, and produces large quantities of fibrous material, producing the typical nodular fibrosis which can be seen by X-rays. The blockage of the lymphatic drainage system by fibrous tissue makes it difficult for the lungs to dispose of further foreign material; this fact probably explains the increased susceptibility of affected lungs to such infections as tuberculosis.

Permissible Dust Concentrations.

The composition of Profex 10, and the general circumstances of its manufacture and use, will give rise to atmospheric dust concentrations approaching and possibly exceeding the limit suggested by the Ministry of Labour,* (Ref. 1.) The figures quoted by the Ministry may be employed as a useful guide, but they do not necessarily indicate dust levels which preffer complete freedom from the possibility of silicosis. No such claim is made by the Ministry, and their figures are derived from American opinion based on scanty case histories and animal experiments. Furthermore, the significance of the Ministry's figures is greatly weakened by the fact that no method of dust analysis, and no range of particle sizes, are specified. Thus, the limiting figures could include air-borne particles of any size, including those which are unlikely to enter or be retained by the lung. The scarcity of information arises

* Threshold limit for quartz- and cristobalite-bearing dusts =
 $250 + (\% \text{ SiO}_2 + 5)$ million particles per cubic foot, or
 $8525 + (\% \text{ SiO}_2 + 5)$ particles per c.c.

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Options on the significance of the period of exposure
very commonly, and any statement regarding the exposure period
must be qualified by defining the level of dust concentration.
Workers at the Pennsylvania Research Unit believe that acceptable
exposures to high dust concentrations is not likely to cause more
damage than occupational exposures to the occupational average dust
level. On the other hand, a former Superintendent Inspector of
Factories has suggested that a single exposure of, say, half an hour's
duration, to a heavy dust cloud may have permanent ill-effects.
(Ref. 2.) Only a small proportion of these workers which are
deposited in the lung, between 5 and 10% of the whole, are retained;
the rest are rejected by the body's phagocytes mentioned above.
Much of this rejected material is thought to be carried up the lungs
by the mucus-transporting system to the ciliary tract.

Long changes have been observed after exposures to silica
dust over periods ranging from a few months to 40 years, but the
normal period which lapses before clinical symptoms develop is
between 20 and 30 years, depending both on dust concentration and
individual susceptibility.

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From the fact that normal measures of labor, together with a progressively increasing amount in increased wages over a number of years, never caused in which the same individual is exposed to the same concentration of dust throughout his working life extremely rare or non-existent.

The relative toxicities of the various forms of silica are in the cases of quartz, cristobalite, quartz, amorphous silica, tridymite being the most toxic. Tridymite is not considered by the Ministry, and they draw no distinction between cristobalite and quartz. (See Appendix). Amorphous silica is considerably less toxic than crystalline silica; this fact is recognized by the Ministry, who set a concentration limit of 20 million particles per cubic foot (706 particles per c.c.) for amorphous silica. Again, no method of analysis is specified.

Particles found in the lungs of silicosis victims fall within the diameter range 0.5 - 10 microns, and the bulk of these particles are between 2 and 5 microns in diameter. Particles are removed in the nose or by the ciliary mechanism in the upper part of the lungs, and it is thought that the sub-microscopic particles behave like a gas and are readily exhaled. Such behaviour is illustrated when workers have been exposed to fine precipitated silica, such as "Oxobol" for long periods. No ill-effects have been observed in such workers, and this result has been confirmed by animal experiments at the Government's Research Unit.

ASBESTOSIS

Description of the Disease.

Exposure to asbestos dusts produces a type of lung fibrosis which is diffuse, unlike the nodular fibrosis caused by silica. Affected lung tissue contains "asbestos bodies" capable of identification in microscopic sections of lung tissue. An asbestos body consists of a fibre of the mineral surrounded by protein deposits. The clinical symptoms of asbestosis are very similar to those described above for silicosis. However, the first manifestations of the disease appear more slowly than those of silicosis, the minimum exposure period recorded before the appearance of symptoms being 2 years compared with a few months in some cases of silicosis. Unlike silicosis, the disease does not significantly progress once exposure to asbestos dust ceases, and there is some disagreement among medical authorities whether asbestosis predisposes to tuberculosis and other diseases of the lung.

Crocidolite (blue asbestos) and amosite are the two most suitable asbestos grades for high-temperature insulation, and they are the most dangerous. Chrysotile and other forms of asbestos are slightly less harmful.

Mechanism of Asbestosis.

It was formerly thought that the damaging effect of asbestos on the lungs was purely mechanical, the sharp ends of the fibres puncturing adjacent tissues. However, this view is in disagreement with the fact that other fibres, such as glass wool, do not appear to damage lung tissue.

The current view (Ref. 3.) is that the effect of asbestos fibers is chemical. The metal ions in asbestos fibers are readily removed by weak acids, such as orthoboric acid which is always present in the lungs. This reaction leaves a siliceous residue of silica, which produces changes in lung tissue by means of the mechanism described above for silicosis.

Cancer Associated with Blue Asbestos.

It has been known for a long time that there is a higher incidence of cancer of the lungs and adjacent tissues among asbestos workers than among the rest of the population, by a factor of approximately 10 to 1. (Ref. 3.) Recent work by the International Research Unit has confirmed this fact, and has shown conclusively (blue asbestos) to be the only form of asbestos giving this effect. Such information is not at present available outside research

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circles, and it would seem that the potential dangers of crocidolite are not fully realized. Animal experiments indicate that the dangers associated with blue asbestos are very real, and that the standards of industrial hygiene required for handling this material may eventually be comparable with those for beryllium and its compounds.

Carcinomata have been found in the pleura of persons who had been exposed only occasionally to low concentrations of blue asbestos dust. Extreme cases showed cancer developing up to 30 years after a single exposure. The Pneumoconiosis Research Unit have detected a very thin film of polycyclic hydrocarbons on the surfaces of blue asbestos fibres, and analysis shows that this layer contains carcinogenic substances which it is believed may be responsible for the unique effect of this material.

Permissible Dust Concentrations.

It will be obvious from the foregoing section of this report that no exposure to blue asbestos dust can be tolerated, however low the concentration and however short the duration of exposure. However, it may be presumed that during the ignition of Profax the carcinogens in the blue asbestos are burnt off, therefore asbestos present in Profax residues represents an asbestosis hazard only.

The Ministry of Labour (Ref. 1.) lays down a limit of 5 million asbestos dust particles per cubic foot (177 particles per c.c.) of atmosphere. As is the case with the Ministry's recommendations for siliceous dusts, the value of this recommendation is restricted by the limited information upon which it is based. The Ministry takes no account of variations in individual susceptibility, and does not specify the method of analysis, or give any details of the average dimensions of an asbestos particle. No distinction is made between the various forms of asbestos.

Fibres recovered from asbestos bodies in the lungs of asbestosis victims vary in length from 109 microns down to 25 microns, and in thickness from 0.2 to 1.0 microns. (Ref. 3.) It is probable that fibres 3 microns long and smaller are gas-like and not retained by the lungs.

PRACTICAL ASPECTS AND RECOMMENDATIONS

General.

The ideal solution is to replace toxic materials, such as silica and asbestos, by non-toxic materials, such as olivine and

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synthetic mineral fibres. Under pressure from H.M. Factory Inspectors, this course of action has been followed in a number of industrial processes, for example the replacement of sand-blasting by shot-blasting, and the elimination of silica from the composition of grinding-wheels. All Profax production in Sweden is now based on olivine instead of silica flour, and a small quantity of olivine-Profax is being supplied to some Fosco customers in the United Kingdom. The replacement of blue asbestos by amosite has been recommended by Fosco International Ltd. and undertaken by an increasing number of Group companies.

It should, however, be noted that there is a limit to the concentration even of non-toxic dusts which can be tolerated by the lungs. The Ministry of Labour set a limit for non-toxic dusts of 50 million particles per cubic foot (1766 particles per c.c.).

Unfortunately, these non-toxic substitutes are almost invariably more expensive than the material they replace, with the result that their use may not be a sound commercial proposition. Under such circumstances, steps must be taken to reduce the amount of toxic material entering the lungs of persons working with it.

Respirators are the least satisfactory method for protecting men working in toxic dusts. The efficiency of the conventional face mask with filter is questionable, particularly when the mask is used without reference to such factors as the dust level and the probable useful life of the filter. A respirator supplied from an external source of compressed air, for example, the shot-blasters' helmet, is superior to the filter type. However, respirators are not comfortable in use and it is very difficult to assume that they are worn continuously by workpeople, particularly those concerned in heavy operations. They also offer no protection against dust which settles in clothing, and is subsequently shaken out. Therefore, respirators should be regarded solely as a temporary measure.

Good natural ventilation in conjunction with a high standard of house-keeping offers a reasonable degree of protection against silica and asbestos dusts, and if the working space is large and open at the sides, no extra protection may be needed. Ventilation is almost invariably the only form of protection which exists in a steelworks. Accumulations of dust must on no account be allowed to build up, and it is preferred that dust should be removed via a built-in vacuum cleaning system, the cyclones or bag-filters of which should discharge into the open air well away from any working area. Failing such a system, the dust must be damped down with water and shovelled or brushed away. It is never sufficient merely to dampen or wet silica flour residues as a means of removing dust, because the hazard reappears when the residue dries out. Therefore the residues must be placed in bins rather than be left in open piles.

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However, natural ventilation can give rise to very unpleasant working conditions, particularly during the winter months. Furthermore, it does not give adequate protection against the cancer risk associated with crocidolite which may arise during the manufacture and finishing of Profax.

Powered dust-extraction systems can be made to control dusts very effectively, and should be considered seriously for any particularly hazardous operations such as cutting or grinding Profax. On a large scale, these systems can prove to be prohibitively expensive, and their use in steelworks is virtually ruled out for this reason.

Another possibility at the steelworks end of the operation is dust suppression at source. Investigations are at present being made into the possibility of supplying Profax bonded with sodium silicate, and striking a suitable balance between sintering of the burnt residues and the avoidance of slagging at the working face. (Ref. 4.)

Whatever protective measures are adopted, regular air sampling and dust counts, together with periodic medical examination of all personnel likely to come into regular contact with toxic dusts, may become necessary.

Profax Manufacture: Mixing Stage.

Silica dust may reach a dangerous concentration in the atmosphere when silica flour is changed into the hydropulper, and for a short while afterwards. The Profax Manual (Volume 9, Fosaco Handbook of Works Control) recommends changing the silica in its paper sack, and this procedure should be followed wherever possible. Failing this, ventilation of the mixing platform must be improved to the greatest possible degree.

It is at this stage that raw blue asbestos is handled. Under normal conditions of weighing and mixing, the amount of asbestos dust produced is very small because the fibres appear to be somewhat "dampened". However, whatever dust is produced is highly toxic, and the safest course is obviously to replace blue asbestos by white asbestos in pursuance of current recommendations from Fosaco International Ltd.

Profax Manufacture: Moulding stage.

It is possible that the mist developed during the de-waxing stage of Profax manufacture, due to escape of pressure between the two halves of an ill-fitting or dirty tool, causes atmospheric contamination. No actual measurements are available,

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but it is reasonable to assume that the water droplets in such a mist are capable of carrying silica particles within the respirable particle size range. Steps should be taken to eliminate the cause of spraying. Failing this, mists so formed should be quickly dispersed and removed by ventilation.

The clothing of the machine operators may become heavily soiled with slurry, etc., and a hazard exists when such deposits dry, particularly if the clothing is shaken out. Operators should avoid soiling their overalls, and operations tending to bring their clothing into contact with wet Profax, for example leaning across parts of the machinery which normally become wetted by slurry or spray, should be eliminated. Regular changes of overalls should be provided.

Profax Manufacture: Finishing Stage.

The long-term aim must be to produce Profax pieces of the correct size and shape for the customer's moulds, without recourse to cutting and grinding oversize or badly formed Profax to the required shape.

Where cutting, grinding, filing or finishing become necessary in Profax manufacture, atmospheric contamination by silica and asbestos can attain dangerous levels. Blue asbestos, if used, will now be in a dry, dusty state, and will consequently be very dangerous, even in a single exposure. Therefore, stringent precautions must be taken; these include dust extraction from the immediate point where dust is generated, and if extraction is not 100% efficient the operators must be provided with respirators, preferably of a type with an external air supply if this can be so arranged that it does not unduly hamper their movements. It must be emphasised again at this point that where blue asbestos is still used, it must be eliminated as soon as possible in favour of amosite.

Profax in the Customer's Works.

There is no doubt that in the present form of Profax we are supplying a product which, under unfavourable circumstances, can give rise to toxic levels of atmospheric contamination by silica and asbestos. The former principal risk associated with Profax, that of cancer resulting from inhalation of blue asbestos, probably would not have existed in the customer's works owing to the fact that the carcinogens present in the asbestos would have been burnt off during the ignition of the Profax. The later crocidolite-free formulations do not offer a cancer hazard.

It has already been stated that good natural ventilation, together with good house-keeping, offer a reasonable degree of protection against silicosis and asbestosis hazards. The cost of

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powered dust-extraction systems renders them impracticable on a steelworks scale, with the result that natural ventilation is almost always the only form of protection existing in a steelworks. Attention is drawn to the recommendations for dust removal above. (See page 9).

Whenever toxic materials are in use, regular air sampling and regular medical checks upon personnel likely to be affected may be necessary.

In laboratory experiments conducted at Foseco International Ltd. it was found that 1 lb. (454 gm.) of Profax ash contained a total of 0.142 gm. of respirable matter, of which 0.058 gm. was asbestos. To convert these weights into actual numbers of particles, an arbitrary assumption must first be made of the average dimensions of the particles. Assuming that the asbestos particles average 30 microns in length x 1 micron in diameter, this means that 1 lb. of Profax can give rise to 756 million particles of asbestos. To achieve the Ministry of Labour's limit concentration of 5 million particles per cubic foot of air, 151.2 cubic feet of atmosphere will be required for the safe dispersal of the asbestos in 1 lb. of Profax ash. A further 189 cubic feet will be required for the dispersal of the silica particles, assuming that these are spheres with an average diameter of 5 microns, and that the ash contains 95% crystalline silica, giving a total atmosphere requirement of 340 cubic feet per lb. of Profax ash.

By making some further assumptions it is possible to make a rough estimate of the volume of air required for the safe dispersal of the ash of a Profax assembly. Not all the ash from a Profax assembly is dispersed into the air, as a general rule about two thirds remain undispersed. As an example, an M.104 assembly may be considered. This weighs 44 lb., about 90% of which is ash. Presuming that one third of this ash is dispersed into the air the total respirable matter generated by the stripping of an M.104 assembly will need 4490 cubic feet of air for dispersal. This volume can be visualised as a cube of rather less than 16.5 ft. side, which should be easily attained in most steelworks. However, calculations of this sort can only be approximate and are not necessarily very convincing to customers. They are no substitute for proper dust sampling carried out at a level of 5 to 6 ft. above the floor. The type of calculation laid out above will probably be regarded by customers as being somewhat academic in nature, and it will become increasingly difficult as time goes by to convince them that the hazard involved in using Profax 10 is of a very low order. The only long-term solution likely to prove satisfactory is to supply a Profax manufactured from non-toxic materials.

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INVESTIGATION

1) The asbestos (crocidolite) must be immediately eliminated from the formulation of Profex 10. Asbestos is a perfectly satisfactory substitute.

2) In our own works, powered dust extraction must be applied to all locations where Profex is used or ground. Good ventilation must be provided at flying platforms. Overall must be regularly laundered to prevent dust accumulating and dried thoroughly.

3) Ideally, regular medical examinations should be conducted upon all personnel handling Profex, and periodic dust-monitoring of the atmosphere may be advisable.

4) Recommendations 1) to 3) would become imperative if Profex were formulated from non-toxic materials. Olvina is still the best substitute for silica so far examined. Current agreements indicate they chopped glass fibre of about 6" (5 mm.) length is a suitable substitute for asbestos, but this material is very expensive. Initial experiments with slag wool have been greatly successful, but durability has been encountered in forming the flange of a Profex slab this is probably associated with some strength, and will be investigated vigorously in the near future, particularly because slag wool is a very remarkably good material and costs less than the cheapest forms of asbestos.

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APPENDIX

Maximum Permissible Concentrations of Mineral Dusts in the Atmosphere.*

Substance	Millions of Particles Per Cubic Foot of Air	Particles per Cubic Centimeter
<u>Silica:</u>		
Quartz	$\frac{250}{\% \text{ SiO}_2 + 5}$	$\frac{8825}{\% \text{ SiO}_2 + 5}$
Cristobalite	ditto	ditto
<u>Silicates</u>		
Asbestos	5	177
Mica, Soapstone, Talc	20	706
Portland Cement	50	1,766
<u>Inert ("Nuisance") Dusts</u>		
Examples: Alumina, calcite, dolomite, lime- stone, marble, silicon carbide.	50 or 15 mg. per cubic meter, whichever is the smaller.	1,766

* Adapted from Reference 1.

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