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Silicosis: Occurrence and Control

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Chem. & Met. INTERPRETATION

In this article the author, dealing with the chemical engineer's role in controlling fibrosis-producing dusts, presents the third of his installments on combating chronic poisoning in chemical operations. Next month's article, which will deal specifically with industrial toxic solvents, will conclude the series.—*Editors.*

Silicosis should be of particular interest to engineers because the control is chiefly an engineering problem. The chemist also has an interest since the problem of detecting the hazard is partly a chemical one. Medical science has accomplished much in the diagnosis and description of the various stages of silicosis. The medical profession can give logical explanations of the action of silica in the lungs, but at the present the physician can do little for the silicotic with tuberculosis except to estimate the number of months he may live. Inasmuch as silicosis is a progressive incurable condition, the engineer is the one person who can accomplish much in its control, since dust production is generally the result of poor engineering practice.

Silicosis is a condition of the lungs caused by the breathing over a period of years dust containing silica. This condition results in: (1) lessened capacity for work; (2) shortness of breath; (3) increased susceptibility to tuberculosis; (4) characteristic early X-ray findings; (5) a progressive condition not dependent on continued exposure; (6) inability to combat tubercular infection once acquired.

STAGES OF SILICOSIS

Silicosis may be divided arbitrarily into three stages for purposes of discussion. These do not represent definite divisions, but are more in the nature of an expression of the gradual development of disability.

In first-stage silicosis the man may appear and feel quite well and show only a slight shortness of breath. This early type is generally detectable only by X-ray. The chest plates show characteristic mottling due to fine nodules of fibrous tissue.

In the second stage, although the man may be healthy in appearance, his ability to work is affected. His chest expansion is decreased and he becomes short of breath on exertion. The X-ray shows mottling due to slightly larger nodules than was the case with the first stage. It is also possible that there may be some joining of the nodules.

All of the symptoms of first and second stages are further developed in the third stage. On slight exertion there will be a decided shortness of breath. The ability to work is decreased, there is a loss of flesh and a frequent cough. The X-ray shows a more intense mottling as the nodules are larger and combine to show dense areas.

Silicosis as ordinarily encountered is an attempt of the body to counteract the inhaled silica. It is not, as some believe, a gradual filling up of the lungs with dust. The stage of silicosis which may develop depends on: (1) concentration of dust; (2) composition of dust; (3) size of dust; (4) length of exposure; (5) date of exposure; (6) individual susceptibility.

In any exposure to dust, the amount in the air at the breathing zone of the worker is important. Generally speaking, a concentration of five million particles per cu.ft. of silica dust will not cause silicosis even if inhaled over a long period of time. A concentration of 50 million particles per cu.ft. is considered excessive even if the exposure is to one of the so-called innocuous dusts.

DUST COMPOSITION

Percentage of silica in the dust has a bearing on the rate at which silicosis develops. Dusts containing under five percent free silica are considered harmless in concentrations under 50 million particles per cu.ft. Dust containing 35 percent free silica, such as granite, has a safe limit of 15 million particles per cu.ft. It is sometimes considered that the allowable dust concentration varies inversely with the free silica content. Considerable investigation has been made into the modifying effect of other dusts on the effect of silica with the hope of finding a preventative for silicosis. The investigations were based at first on the examination of dusts where the silicosis rate was low in spite of a high exposure to silica. It was found that aluminum dust had a very marked effect on the solubility of silica in laboratory experiments and on the silicosis rate in animals. The method has been tried on men and offers much encouragement.

Small quantities of metallic aluminum dust almost completely prevent a solution of silica. For example, one gram of 325 mesh quartz when allowed to stand in 100 c.c. of water, showed 50 p.p.m. of dissolved silica as compared to 1.9 p.p.m. when one milligram of fine aluminum dust was added. Animals dusted with quartz to which less than one percent aluminum had been added showed practically no fibrosis, while control animals dusted with quartz only developed silicosis.

Large particles are harmless since they tend to settle out of the air or are caught in the upper part of the respiratory tract. It is sometimes considered that the harmful dusts are between 0.5 and 3 microns in size.

LENGTH OF EXPOSURE

In an exposure to granite dust having a silica content of 35 percent, men developed first-stage silicosis in four years and second-stage silicosis in nine years when the concentration was 60 million particles per cu.ft. Perhaps one of the shortest exposures to develop silicosis was one in the manufacture of a hand abrasive soap. In one year the man developed third-stage silicosis and died in a short time. It is possible that the other ingredients of the soap may have been instrumental in hastening the action in this particular case.

Unfortunately, silicosis may continue to progress after the worker has left the exposure. We have record of a case which developed thirty years after the exposure terminated. The workman, beginning at the age of fifteen, worked for ten years at an extremely dusty grinding operation using sandstone wheels. The sandstone wheels were eliminated and the work was done for thirty years with exhausted wheels containing no free silica. At the age of fifty-five the man was found to have third-stage silicosis although he had not been exposed for thirty years.

These and similar cases indicate that the condition produced by the inhalation of silica dust is progressive. Hill reports on a group of 278 cases of very early cases of silicosis. Six years after they were removed from exposure 171 had died. Seventy-five percent of the deaths were caused by silicosis and tuberculosis. It has also been stated that life expectancy of silicosis associated with tuberculosis is eighteen months. Death may occur within a year and it is rare the patient lives over three years.

OCCURRENCE

Silicosis generally results from operations involving grinding, polishing, mixing, cleaning, pulverizing or drilling. The operations all tend either to produce fine particles or to disseminate in the air fine dust produced on other operations. The hazard, of course, will depend on the nature of the materials being handled and the amount of silica. Quarrying and finishing of granite for monumental stone produces a serious occupational disease hazard unless the greatest of precautions are taken. Similar operations with marble or limestone are considered non-hazardous from a health standpoint because of the much lower silica content.

Dry grinding operations when sandstone wheels were more generally used were especially hazardous. A number of metal polishing compounds contain appreciable amounts of silica. Unless the buffing or polishing wheels are exhausted the operation has a dangerous exposure. Typical of the exposure in mixing operations would be the manufacture of certain abrasive soaps, or wood fillers. The preparation of molding sand after the shakeout may be one of the severest exposures in foundry operation.

In a foundry where used sand was worked over with a sand cutter without adequate wetting of the dry sand, we have obtained concentrations as high as 300 million particles per cu.ft. Such exposures approach the point where the worker might be nearly drowned by the dust in the air.

Six men out of eight working for a contractor doing tile laying were found to have developed silicosis in five years. It was found that they did some dry polishing using a polishing material high in silica. An investigation, however, of the methods used by contractors in the field revealed that this was one of a very few who did dry polishing work.

In the control of the silicosis hazard, it is necessary to recognize the existence of the exposure and also to evaluate its severity. Unfortunately, this is not easy to do and it is necessary to employ techniques not ordinarily used in the chemical laboratory. It is first necessary to know the amount of free silica in the dust. In obtaining a sample, it is not sufficient to take a sample of the material being handled or processed as the dust being carried into the air may vary considerably from the original material due to difference in particle sizes or densities of the various ingredients. Rafter samples are more likely to be representative of the dust exposure, but even these may be misleading due to a difference in settling rates. Samples taken from the air over a long period by means of a vacuum cleaner would give representative samples. It is generally considered that rafter or ledge samples are sufficiently accurate if the particle sizes are uniform. An exception of this type is the type of dust encountered in a foundry. Molding sand is composed of coarse grains of silica surrounded by many fine grains of silicate. The fine particles contribute much dust because of their small size, number, and slow settling rate. However, an analysis of the original sand or the rafter sample is much higher in free silica than the dust in the air. This is because of the larger size of the silica grains which show up in the analysis but do not contribute as much in dustiness as the more numerous, smaller silicate particles.

Actual analysis is complicated by the difficulty of differentiating between free silica and silicates by chemical methods. It is necessary to use optical methods of petrography to obtain accurate information about the free silica. The refractive index can be determined on very small particles by the use of immersion liquids. This, with the information obtained under the microscope and a total silica obtained by fusion, gives a reasonably accurate picture of the free silica content.

It is also necessary to know the amount of dust in the air. Standard for the amount of dust in the air is generally based on the number of

In drilling operations, dust can be controlled by means of exhausted dust traps, as shown here. Impinger dust sampling flasks are also shown

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is necessary to use this equipment to determine whether or not an exposure exists, in operations such as foundry or granite cutting, it is not necessary to run dust counts to determine the hazard because it is perfectly obvious. It is sometimes necessary to run dust counts to check on the efficiency of the equipment used to control the hazard.

The instrument on which most of the American Standards are based is the Greenburg-Smith Impinger. The air to be sampled is drawn through a tube and impinged at a high velocity on the bottom of the sampling tube. This tube contains water which wets the dust and traps it. After a known amount of air has been sampled, a portion of the liquid is removed to a suitable counting cell for microscopic count to determine the number of particles. The cell is so calibrated that it is possible by means of an eye-piece micrometer to count the dust particles in a known volume of water. The instrument is bulky because of the air pump which is necessary, but it is the nearest thing to a standard and it is possible to compare results with a considerable amount of similar work. The Konimeter and the B&L Dust Counter are two of the more common type instruments which are also used for dust determination. They are small portable instruments which are well adapted to plant control grab samples. It is possible with these instruments to take large numbers of samples and obtain information on the effect of any particular operation on dust production.

CONTROL METHODS

Control methods vary depending on the operations. One fundamental is to limit the exposure to as few people as possible. The necessity of this is emphasized by the silicosis rate of moulders *in foundries*. These men are exposed to dust and have a poor record for silicosis although the actual moulding operation is not dusty. The dust comes from sand conditioning work, sand blasting tumbling or from poor housekeeping. The shake-out operation is sometimes started before the molders have finished pouring and is one of the worst dust generators.

Seriousness of the dust hazard during the shake-out can be appreciated by the amount of ventilation required when large castings are shaken out. In one case reported, the castings are as large as 350,000 out section each with a capacity of 83,000 cu.ft. of air per min. were provided to take off the dust. This particular case was unusual, but on any shake-out ventilation installation large amounts of air have to be moved. Where continuous molding and pouring is carried out, the molds are conveyed to a shake-out station and it is comparatively easy to install adequate exhaust ventilation. It is important to provide exhaust ventilation at central shake-out stations due to the large tonnage of sand handled at these points and the proximity of molders who would be otherwise unnecessarily exposed. It is possible for some foundries to have a centralized shake-out even though the mold-handling system is not utilized. This arrangement is only suitable where there is some provision for transporting of portmolds to the central station. In many cases the control is carried out by a night gang that does the work after the molders have left the plant. It is necessary to equip these men with respirators.

In drilling operations, it is possible to control the dust by means of exhausted dust traps or by using wet drilling methods. The wet method has the disadvantage of introducing a serious slipping hazard, particularly in northern stone quarries during the colder months. It has been found that the exhausted type of dust trap makes for more efficient drilling. The trap merely consists of an exhausted cone which fits over the drill and removes the dust. Tests indicate faster drilling and less sharpening of the tool due to the cuttings being quickly removed from the hole and not being ground up to fine sizes.

NECESSARY PRECAUTIONS

Sandblasting is a particularly hazardous operation because of the high concentration of dust to which the operator is exposed and also to the fact that the air is used under high pressure. The contamination is likely to stretch for some distance. The dust exposure may be as high as 241 million particles per cu.ft., although the accepted safe limit for this exposure would be about five million particles per cu.ft. This indicates the necessity for the use of positive pressure helmets and it has been found that with this type of protection (giving the worker a positive supply of six cu.ft. of dust-free air a minute) the exposure of the workmen will be reduced to around two million particles per cu.ft. air is discharged through a cyclone in an isolated location or is filtered if there is any chance of the air reentering the plant. Exhausts are desirable to maintain a negative pressure in the sandblast chamber to prevent the dust from leaking out. In addition, the operator should wear a positive pressure helmet. On some jobs the control is carried still further with steel shot being substituted for sand. On operations such as stone crushing, the hazard is best controlled by making the work as nearly automatic as possible. Dust producers are enclosed so as to prevent the escape of dust into the air. Any workmen who enter the dusty location are equipped with respirators. Respirators are only intended for emergency use or for short exposures. It is much better practice, if a man is required to work continuously in one area, to control the dust hazard by enclosure, exhaust ventilation or by substituting some non-hazardous material, if possible, rather than to require use of a respirator continuously.

In addition to silica, asbestos has been found to produce a fibrotic condition of the lung. The action is different from silica in that apparently there is no tendency toward tuberculosis. The condition developed by asbestos is a heart condition which is not curable and is likely to result fatally. Exposure to asbestos dust is limited to a much smaller group than those exposed to silica.

In the case of silica, an exposure may exist without the operators being aware of the hazard. It is for this reason that we have emphasized the serious results of the exposure and the steps necessary for its control. Silicosis can be best prevented by the removal of dust at the point of origin and control measures should be based on this principle.

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