FILE NAME: National Safety Council (NSC)

DATE: 1932 Oct

DOC#: NSC055

DOCUMENT DESCRIPTION: Transactions of the NSC - 21st Annual Safety Congress

1932

TRANSACTIONS

National Safety Council

Incorporated

TWENTY-FIRST ANNUAL
SAFETY CONGRESS

Washington, D. C.

October 3 to October 7, 1932

The Wardman Park and
Shoreham Hotels

Orig. papers in Transfer Cabinet.

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Although the National Safety Council endeavors to eliminate from discussion at its conventions matters which are not pertinent to its purposes or which are contrary to its policies, the Council accepts no responsibility for the views expressed either in the papers presented or in the discussions thereon.

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NOTE: The sessions of the Street and Highway Traffic Section, the Child Education Section, and the Home Safety session are published in a separate small volume of these Transactions, available on request.

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Council Purposes and Policies

The fundamental purpose of the National Safety Council is to conserve human life. It seeks this goal through a continuous campaign of accident prevention that is nationwide in scope, applies to all lines of hazardous activity, and directly or indirectly reaches our entire citizenry. It is a non-profit organization, non-sectarian, and free from political affiliations. Since its organization in 1913, it has won respect as an essential national institution.

Inseparable from accident prevention is the Council's work in improving health conditions and preventing vocational diseases in American industry.

Today there are 4,000 members, representing every state in the Union, and many of the Canadian Provinces. There are 500 foreign members. The membership includes industrial corporations, firms, individuals, public officials, schools, chambers of commerce, clubs and civic organizations. About 70 per cent are industrial concerns, including the big steel companies, the oil companies, most of the railroads in the United States, the automotive industry, and others of outstanding importance in our national industrial field.

Thus the National Safety Council is like a fruitful tree with many branches and firmly imbedded roots that reach out in all directions, lending strength and permanence to the organized safety movement.

Pioneering in Safety

The history of the Council is an absorbing story. Unfortunately it cannot be detailed here. Suffice to say that the First Co-Operative Safety Congress was held under auspices of the Association of Iron and Steel Electrical Engineers in Milwaukee, in 1912, and, as a result, the National Safety Council was organized in New York the following year with fourteen members. During the first year the membership increased to 971.

The pioneers of American safety went to work on the sound premise that accidents were an unnecessary part of our social order and that through application of proper remedial measures they could be avoided. They set about to nationalize this theory, and to develop the detailed methods and materials through which accidents could be prevented. The members of the organization now are more than ever convinced that accidents are unnecessary and that they can be and are being prevented. Striking examples of reductions in many different fields during recent years prove this contention.

Results of Organized Safety

Since the National Safety Council was organized in 1913, the national accident death rate in all fields excepting motor vehicle has been reduced 40 per cent. The motor vehicle accident problem is a comparatively new one, yet there are evidences of progress. Recent studies show that accidents among commercial vehicles have decreased; that grade crossing tragedies have considerably decreased during recent years; that deaths of school children have decreased; that deaths in states having effective license laws with centralized administration and in cities having community safety councils have increased much less than in other states and cities; that deaths to pedestrians of all ages throughout the country increased very slightly last year. These facts indicate the engineering, educational, and legal remedies for the highway accident problem are producing results where conscientiously applied.

Since the National Safety Council started as an industrial safety organization, the best results are to be expected in this field. Here spectacular achievements have been made. The steam railroads, for instance have reduced accidents among employees 74 per cent during the past 11 years. A group of our largest steel industries have cut their accidents 90 per cent since 1913. During 1931, 41 plants of the Portland Cement Association went through the entire year without a single lost-time accident among thousands of workers. Two, three, four, and even five year "no-accident" records among smaller plants and in certain departments of the larger plants are not at all uncommon.

Along with these reductions the whole psychology of accidents has changed. Employer and employee both look at the proposition from a different viewpoint than they did 20 years ago. Accidents now are really out of date. In many plants they are considered a disgrace that casts a cloud over good management and efficiency. There is very little room today for the careless worker in modern industry.

Looking Ahead

The safety problem is a universal one—and always will be—just as long as human beings inhabit the earth. Safety applies to everybody and to everything, physical or material; to every human act, to every man, woman, and child. It is only natural, therefore, that the idea which seems to have so firmly taken root in the United States should branch forth into other countries of the world. Organizations similar in purposes and activity to that of the National Safety Council have sprung up in many countries. Council posters have been widely copied for foreign use and several Council publications have been translated into other tongues.

All of these are hopeful signs of the times in the world of Safety. The National Safety Council is still young—as institutions go. A great amount of worth-while work has been crowded into its short life. Foundation work is always slow, whether one is building safe skyscrapers or safe men. The National Safety Council has been digging away at the bed-rock of public consciousness. It has made real progress and its achievements furnish ample inspiration for continuing its humanitarian efforts.

To bring the accident situation under control there must be a wider interest in the Safety Movement; a much larger membership in the Council, and the active co-operation of all industrial, business, civic, and governmental bodies.

* * *

Cooperation

The purposes and policies of the National Safety Council are not always understood by those not in close touch with the Council's work. To meet the need for a brief and definite presentation of the Council's objectives, the following has been approved by the Executive Committee as an official statement of policy:

"The National Safety Council's objective is the elimination of accidents to men, women and children, as being deplorable, unnecessary and wasteful. It seeks memberships, cooperation and contacts to insure that its services may provide the instrumentalities and finances to accomplish this objective.

"Through education it seeks to demonstrate that the safe way is the right way and the best way, from the standpoint not only of human satisfaction but of social efficiency and economy. It seeks those ways and means for safety that satisfactorily fit into the practical affairs of life.

"Its financial policy is to return in service all moneys received, so operating without profit, and to undertake only those activities which can be assured of reasonable permanence. Much of its administrative personnel consists of volunteer workers.

"The National Safety Council holds itself open to give fullest and most cordial cooperation to all individuals, industries, organizations, communities, states and nations that are in accord with the principles and objectives of the organization, and the National Safety Council likewise asks and seeks cooperation from all these in carrying out its purposes."

Orig. paper - Du94

Dust—An Engineering Problem

By LEONARD GREENBURG

Yale University, New Haven, Conn.

The speaker said in part: From the broadest viewpoint the dust produced in industry may be regarded as all of the particulate matter actually used as a part of industrial processes. It may be helpful to classify this material from the health viewpoint as follows: (1) Those dusts of a toxic nature or possessed of toxic properties. (2) Those dusts which are chiefly irritants of the upper respiratory tract. (3) Those dusts which, when respired, produce changes in the lung tissue, that is, pulmonary pathology which may or may not be associated with tuberculosis.

Powdered lead and arsenic salts and compounds may be cited as examples of the first group; wood dust and certain organic fibres are representative examples of upper respiratory tract irritants; and silica and granite dust may be cited as among the important members of the third group of dusts.

The toxic dust group is composed of those materials which, when taken into the body, produce pharmacological changes of varying degree dependent on the quantity absorbed. The degree of damage done to the organism depends as a rule on the quantity of the substance taken up by the body, its relative degree of toxicity and the susceptibility of the host. The route of absorption of toxic dusts is of fundamental importance. Ten years of research work in this field have led to the conclusion that in general the respiratory tract is the chief absorbing organ for most of the particulate poisons. Absorption through the respiratory tract, in the case of lead dust for example, is at least ten times more rapid than that by way of the intestinal canal. Moreover, a toxic dust deposited in the lungs is removed practically entirely by way of solution in body fluids, whereas dust taken into the intestinal canal may, in a large part, at least, be excreted directly.

It becomes obvious from these facts, that the prevention of poisoning in industries where such toxic dusts are generated, consists in the prevention of atmospheric pollution, which in turn resolves itself into prevention of dust formation or of dust dissemination or the simultaneous prevention of both formation and dissemination. In fact, no matter what type of hazardous dust is concerned the objectives of the hygienist are the same and the efforts of the engineer are directed along more or less similar lines.

The health problems brought about by the third group of dusts, the pulmonary irritants, are commanding the largest share of the industrial hygienist's attention at the present time. As a result of the industrial dust studies which have been conducted during the last twenty years there has emerged a small, but exceedingly valuable body of fundamental data which serves to guide the hygienist in his evaluation of the problem in a given factory or process. Briefly, we know that the industrial health hazard resulting from the inhalation of dust depends on four factors: (1) The chemical and mineralogical nature of the dust. (2) The size of the particles. (3) The quantity of dust breathed, (a) the concentration of the dust and (b) the duration of exposure.

We are indebted to the British investigators Gye, Kettle, Cummings and Collis for emphasizing the importance of the mineralogical nature of dust from the health viewpoint, and now as a result of the studies in the United States, South Africa and Australia it is generally held that the health hazards associated with the respiration of a given type of dust, all other things being equal, is to a certain extent correlated with its quartz content. It is not to be inferred from anything said by the speaker that dust counts and quartz content bear a mathematically interchangeable position. For example, without actual proof it should not be said that a dust concentration of 10,000,000 particles of 20 per cent quartz is equivalent in hazardousness to 5,000,000 particles of 40 per cent quartz content. What we do know is that if we compare a series of dusty trades in which the concentration of dust is known, the more hazardous have a higher quartz content and the less hazardous present a lower quartz content. Asbestos appears to be a striking exception to this rule. Here we have a dust often containing very small percentages of quartz and yet it is responsible for definite cases of pulmonary fibrosis terminating fatally.

So far as the size of the dust particles is concerned it is generally held that dust over ten microns in size is seldom produced in industry and is seldom found in the lung tissues. Again asbestos is a striking exception to this rule. The lower limit of the particle size of dust which is significant is a much more difficult matter to evaluate. The point in which we are interested as public health workers is the differentiation in dust content between the ordinary normal atmosphere and the air of dusty factory workrooms such as we know (from statistical studies) to be dangerous to health.

In a single dusty trade such, for example, as granite cutting, it has been found possible to compare the mortality of workers exposed to different concentrations of the same dust. Such comparisons clearly show that there exists a direct relationship between the dust concentration breathed and the duration of trade life.

The industrial hygienist is chiefly concerned with the study of health hazards in industry and their control, and in this work the engineer and engineering techniques play a major role. In 1921 Dr. Winslow and the speaker published a lengthy contribution dealing with the problem of industrial dust in the "Journal of Industrial Hygiene." In this paper we said:

"There are, in general, four different methods of protecting the worker against the influences of industrial dusts, which may be classified as follows: The substitution of wet processes for dry processes; the conduct of dust producing operations in enclosed chambers; the removal of dust by hoods equipped with exhaust draft; and the use of respirators and helmets." Today, nearly 12 years later, the problem has undergone no fundamental change. Indeed there has been an accumulation of data which serves to add to the validity of the statements made in our earlier work.

The problem of a mitigation of the dust hazard, be it toxic or irritant dust, may be recapitulated as follows: (1) Substitution of non-hazardous substances so that any dust which may be formed is of a relatively non-hazardous character. (2) Suppression of dust by the use of techniques which prevent dust formation. (3) Prevention of dust dissemination, by (a) enclosures and exhausts, (b) dust removal at point of origin. (4) Provision of separate sources of air supply for the worker in dusty atmospheres.

In the whole field of industrial hygiene the substitution of non-hazardous substances for those of a hazardous character stands preeminent as the solution of the problem at hand. It must be obvious, even to those who have had little or no actual intimate contact with such problems, that where a dangerous gas, liquid, or solid can be replaced by a non-hazardous substance the most satisfactory possible solution of the problem is achieved. Indeed, if the substitute is not completely harmless but relatively less so, it is a desirable substitute provided, of course, it is feasible from the view-point of the industrial process at hand.

In 1920, Dr. Winslow and the speaker advocated the substitution of dry grinding with synthetic (carborundum) grinding wheels for the process of wet grinding on natural sandstone wheels as the solution of the dust hazard in an axe factory in the State of Connecticut. The substitution of synthetic abrasives of low quartz content in place of sand would be of material aid in the solution of the problem of the health hazard in certain sandblasting processes.

The chief methods available for the prevention of dust formation consist in wetting the material with water as in the white lead industry and in the mining industry as conducted in South Africa. In the white lead industry the lead grids or buckles are placed in the grinder and water is added during the complete tumbling and grinding process. A final step in the process consists in the introduction of oil which forces the water out of the mixture and results in the desired end product. In the South African gold mines, silicosis is a very important health hazard, and for many years the South African research workers have been studying this problem and attempting to mitigate its health hazards. Water has been used extensively and, while it has not by any means resulted in a complete solution of the problem, it has been of immense aid in lowering the content of atmospheric dust.

Still another example of the suppression of dust is the use of a foaming compound made in Germany. The method consists of supplying the drill holes with a foaming mixture which serves to convert the drillings into a mud, thus preventing the contamination of the atmosphere. The mud does not interfere with the efficiency of drilling but collects on the outside of the drill holes. On drying, this mud is converted into a hard cement-like substance and does not release dust into the air.

While it is not possible to completely enclose certain dusty processes, it is often possible to enclose them to a very large degree. Such enclosures, when kept under negative air pressure so as to maintain leakage inward and prevent outward leakage, often serve to reduce greatly the dust hazard. The hygienic sandblast cabinet is a form of enclosed device and the results of studies made with such equipment disclose the fact that atmospheric pollution is kept at a comparatively very low level by this type of equipment. Naturally, when the hygienic cabinet or tumbling barrel is being loaded with work, there is real opportunity for atmospheric pollution, but this again is a matter of careful engineering design and care in maintenance and use of the equipment.

When it is impossible to suppress the formation of dust and when it is also impossible to enclose the process and keep the dust from seeping into the breathing zone of the worker there still remains one highly satisfactory method which the engineers may use for the removal of dust. This consists in the provision of local exhaust hoods provided with suction ventilation. In a study of this problem made by the speaker in 1919 and published in the Public Health Reports, it was demonstrated that the minimum velocity at the throat of such exhaust hoods should be 1500 feet per minute. It was evident from these studies that the design of the hood was of vital importance in achieving the desired end. It should be so constructed as to enclose the grinding wheel in so far as possible, the dust should be removed as nearly as possible from the point of origin on the wheel, and the branch pipe should be so located as to catch the dust and thus make use of the velocity with which it is delivered in the hood to aid in its removal by the exhaust air stream.

Another example of localized dust removed at the point of production is the Kelly dust trap. This apparatus is used for the removal of the dust in rock drilling and consists of a split metal can placed over the drill holes. To this hood is connected one end of a flexible hose, the other terminating in the suction apparatus. A hole pierces the top of the hood for the passage of the drill rod. In practice, the hood serves to confine the dust produced by the drilling operation, the dust thus being carried off by the suction current to an air-cleaning device. The air is then discharged relatively dust free into the general atmosphere.

The method of dust control by removal from points of production by means of enclosures provided with suction ventilation is probably the most common type found in industry. When the enclosure and ventilation system are properly designed and maintained the method yields excellent operating results. The design and construction of such systems demand the serious consideration of the trained engineer and this field possesses exceptional opportunities for the well-trained engineer.

When it is impossible to limit or remove the dust produced by industrial processes and the worker is forced to labor in a dusty atmosphere, it becomes necessary to resort to personal protection, namely, the use of respirators or positive air pressure helmets. Many types of respirators are in every day use. They operate on the filtration principle, the filtering medium used commonly being sheets of filter paper, sponge or layers of cotton flannel. The filtering efficiency of paper and cotton flannel is high, but in spite of this the use of the ordinary respirator is attended with much risk since the contact of the device with the face of the worker is a poor one and usually dusty air leaks in around the edge of the mask.

The positive pressure helmet, on the other hand, completely surrounds the head of the worker and this makes it possible to provide him with a supply of clean outdoor air by means of the tube connected with the helmet. The positive pressure helmet is often cumbersome to use and is frequently objected to on the ground that the movements of the worker are limited by the length and weight of the hose which serves to convey the worker's air supply. In spite of these objections, which are often real and important, the positive pressure helmet serves a very useful function in the protection of the worker who is forced to enter the dusty atmosphere. Recent studies on the efficiency of positive pressure masks and helmets made in conjunction with the abrasive blasting research indicate that with a fresh air supply of six cubic feet per minute the worker is well protected against the inhalation of injurious dusts.

ADJOURNMENT

a proper staff, and not by some enthusiastic person who has not been trained for the work. Why not use more registered nurses in the smaller plants? The registered nurse is much better qualified to interpret a physician's plan of medical service than any lay attendant.

Much depends upon the physical condition of the employees. I am of the opinion that the physician, by reason of his professional attainments, is best qualified to handle some of the problem cases among employees. Mental symptoms, brought about by worry over home affairs, quite often produce accidents. In many cases the fear and worry of sickness in the family can be greatly allayed by a talk with the doctor or the nurse. Many of these cases have come under my personal observation.

It should also be absolutely the part of the physician to say when a man shall return to his regular employment after injury, and this decision should not be influenced in the slightest by its possible affect on any "no-lost time accident" contest or record. These contests are proper and have brought about outstanding results in the reduction of lost-time frequency figures. However, there have been cases of injured employees being urged unduly to return to some form of work merely to prevent the marking up of a lost-time accident. Nothing should be allowed to interfere with the employee's welfare. The physician has every motive to return the employee to his regular work as promptly as possible, but his higher duty is to conserve both the physical and economic welfare of the employee as well as the employer.

The safety director has need of the medical service, and the two should earnestly co-operate and seek to bring about a mutual feeling among the employees. Both departments are striving by all possible means to prevent economic waste chargeable to the disabilities and hazards of industry.

TUESDAY AFTERNOON SESSION

October 4, 1932

The delegates first attended an informal luncheon, and then gathered for the afternoon meeting in a Joint Session with the Metals Section. This session was devoted to a symposium on the dust problem in industry. Chairman Greenburg immediately introduced the first speaker.

The Effects of Inhaled Mineral Dusts

By LEROY U. GARDNER

Director, Saranac Laboratory for the Study of Tuberculosis, Saranac Lake, N. Y.

As long as men have worked in stone it has been appreciated that an unusually large proportion of them suffer from disease of the lungs. It was natural to assume that such disease would be caused by the dust generated, and this belief was strengthened by the discovery of black, grey or red pigments in the lungs, sometimes accompanied by the formation of scar tissue.

The term, pneumonokoniosis was introduced to describe the lung pigmented in this manner. With further observation pathologists attempted to classify various forms of pneumonokoniosis on a basis of the type of dust inhaled and such names as anthracosis, siderosis, chacicosis and even byssinosis and tobaccosis made their appearance. It was recognized that some forms of the disease were attended by severe symptoms and result in death but there was no correlation between the clinical and pathological pictures and the causative dust. Finally, statistical study demonstrated that of all kinds of industrial dusts silica generally produced a definite type of disease with a characteristic pathological lesion and complex of symptoms.

Today the clinical entity known as silicosis is one form of pneumonokoniosis which is quite clearly defined. Moreover, within the last three or four years asbestos dust has also been shown to produce another specific type of reaction attended by symptoms differing in some respects from silicosis.

The other forms of pneumonokoniosis still lack complete definition. The widespread use of radiography has brought together a mass of descriptive data from individuals exposed to many kinds of occupational dusts but these findings have not yet been correlated with pathological anatomy, chemical studies of the tissues and detailed analyses of industrial atmospheres. There is a tendency to assume that many of these pulmonary changes are due to the action of silica perhaps modified by the chemical components of the dust. We shall only be in a position to speak with assurance about them when the pure types of dust and their various combinations have been studied in human beings or in experimental animals.

For the sake of clarity no mention has been made of the infections which so frequently complicate some forms of pneumonokoniosis. In the prebacteriological era of medicine the use of such terms as "grinders' consumption" and "miners' phthisis" reflects the popular association of pneumonokoniosis with tuberculosis. The names were justified both by clinical and pathological observation for it has been subsequently shown that, in silicosis at least, a super-imposed tuberculosis may cause death in perhaps 75 per cent of the cases. Some observers even go so far as to state that silicosis itself does not develop unless the lungs are previously damaged by a latent tuberculous infection. This is probably an exaggeration, for typical silicosis can be produced in the experimental animal by the inhalation of silica without infection.

The role of asbestos dust as an excitant of tuberculous infection is not as clear cut as that of pure silica. While there are numerous reports of death in asbestosis due to a terminal tuberculosis, nevertheless surveys of living workers have failed to demonstrate any excess of such infection. Simple anthracosis is said to prevent the progression of tuberculous infection. Statistics from coal mining districts do show a tuberculosis rate much lower than that "normal" for the age group. As yet corroborated experimental proof of protective action of coal against tuberculous infection is lacking.

Not only the tubercle bacillus but other bacteria seem to develop with special facility in the tissues previously damaged by silica. For example, the pneumonia rate among silicotic native laborers of South Africa is many times that in non-silicotic natives living under similar conditions. In coal miners, likewise, pneumonia is a common and often fatal complication.

What has been said of the effects of inhaled inorganic dusts would indicate that the reaction of the tissues is not merely a response to mechanical irritation by particulate matter. Today it is generally accepted that the injury is chemical in nature and that only certain of the common types of industrial dusts possess properties capable of exciting reaction. In the cases of silica and the silicate of magnesium or asbestos the slightly alkaline body fluids probably effect a slow solution of the dust particles liberating silica in colloidal form. This substance irritates the connective tissue cells which respond by multiplying. The result is an overgrowth of the supporting framework elements at the expense of the more delicate cells specialized for specific functions.

For these two types of dust the character and form of the pathological changes has been carefully worked out. In *silicosis* the essential tissue change consists of nodules of connective tissue which develop first in the lympoid tissues situated in the drainage apparatus of the lungs. These nodules interfere with the physiological removal of foreign bodies and subsequently inhaled particles accumulate in the framework of the lung itself. Such reaction gradually decreases the normal elasticity of the organ and encroaches upon its functional elements. As a result the cardinal symptom of the disease, dyspnoea or shortness of breath develops. Because of the excessive amounts of scar tissue formed in the lungs the right side of the heart encounters increasing difficulty in forcing blood into the organs. In an attempt to compensate the overworked heart muscle becomes thicker and heavier and unless infection intervenes the time eventually arrives when the heart fails and death occurs from this cause.

The reasons for the prevalence of infection in the silicotic lung are not altogether clear. It is obvious that when the drainage system is so obstructed by nodules of scar tissue that more dust particles can only be removed with difficulty, the same must be true of bacteria which may be inhaled. As a consequence they remain in the lung and set up progressive infections. But this is not the whole story. The silicotic tissue apparently offers a peculiarly favorable soil for the continued multiplication of tubercle bacilli and perhaps other bacteria. Experiment has shown that even attenuated organisms of this type will produce rapidly fatal tuberculosis in a silicotic guinea pig. Furthermore, inhaled silica dust will cause a pre-existing latent tuberculous focus, harboring a few attenuated bacilli, to become progressive and spread.

The cause of this effect upon tuberculous infection has not yet been ascertained but probably it is in some way associated with the death of tissue caused by the toxic silica. Associated with this factor is an increased activity of the phagocytes which are stimulated by the irritating silica so that these cells tend to migrate rapidly and carry tubercle bacilli into previously uninvolved portions of the lung.

Asbestos dust, perhaps because of its fibrous structure, is not transported very far within the lung. It tends to lodge along the walls of the finer tubes and little of it is removed by the lymphatic drainage system. Tissue reaction, probably initiated by the solution of the fibers, occurs in their immediate vicinity. As in the case of silica this reaction consists of an overgrowth of the connective tissues which is later transformed into leather-like scars.

Aluminum oxide will serve admirably as an example of a non-siliceous dust whose particles are as hard and sharp as those of crystalline silica. When a measured quantity of such particles, 1 to 3 micra in diameter, are injected into the ear vein of a rabbit the majority of them come to rest in its liver and spleen. There they remain, apparently harmless, collected in large phagocytic cells and producing no reaction of the connective tissues for at least two years. Injection of the same quantity of the same sized quartz particles excites the formation of so much scar tissue that the functional elements are almost completely destroyed and the organs are reduced to nodular masses of leather-like consistence.

Carborundum, the carbide of silicon, when inhaled by guinea pigs for periods as long as four years, likewise fails to excite significant overgrowth of the connective tissues. It produces only a low grade inflammatory change with no nodules.

Instances such as those cited constitute the basis for believing that the cellular response to dust particles is not due to their hardness and sharpness but to chemical substances liberated by the action of the tissues upon them. The case for solubility has not been proven directly, for the detection of soluble silica in the tissues offers technical difficulties which today are unsurmountable. Nevertheless this substance is known to be a cell poison and in weak concentrations it will provoke an overgrowth of the connective tissues.

Mention should be made of the effect of inhaled coal dust. Most city dwellers breathe in sufficient quantities of this material during an average life-time to pigment considerable areas of their lungs. Deposits of grey or black dust will be found along the course of the lymphatic drainage system but this pigmentation is associated with little or no new growth of connective tissue. The coal miner's lung is much blacker but in most instances it also develops no deforming scars. When such reaction does occur analysis usually reveals appreciable amounts of silica in the lungs. The presence of excessive quantities of carbon dust apparently influences the localization of moderate amounts of silica so that the latter is not deposited in nodules as in pure silicosis but in streaks along lymph vessels as pure coal would localize.

Coal miners' fibrosis, due to relatively small amounts of silica, is therefore different from that of the pure quartz worker. When the amount of inhaled silica is excessive, the effect of the coal is negligible and the reaction approximates that in pure silicosis. There is said to be more reaction to hard coal than to the bituminous variety but there is evidence to suggest that this is due to the greater amount of siliceous rock which must be worked in mining anthracite coal.

Finally, consider the silicosis of granite cutters. This develops somewhat more slowly than that of the pure quartz miner and it has been maintained that this is due to the relatively small amount of uncombined silica in granite (25 to 40 per cent). But it is believed that other components of the glomerate granite may neutralize or at least inhibit the effects of the silica so that only after prolonged exposures to high concentrations does significant reaction occur. While typical silicotic nodules develop in guinea pigs inhaling pure quartz for a year, not even the earliest suggestion of nodules have appeared in the lungs of animals inhaling comparable concentrations of granite (40 per cent silica) for four years.

This brief discussion of some of the problems involved in pneumonokoniosis draws attention to the limitations of our present knowledge. It indicates that the reaction to an inhaled dust is determined by the chemical and probably physical composition of that dust. It emphasizes the need to further study of different types of dust both in the pure state and in measured combinations. The ultimate aim of such a study should be the neutralization of the toxic action of such dangerous substances as silica.

The Dust Content of the Atmosphere in Various Dusty Industries

By J. J. BLOOMFIELD

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The speaker said in part: The properties of a given dust which determine its capacity to produce pulmonary pathology are, the nature of the dust, that is, its chemical and mineralogical composition, its particle size, and finally the quantity of the dust dispersed in the atmosphere.

One of the outstanding results of the last 20 years of research in the field of dust inhalation is the demonstration of the fact that, in general, the degree of health hazards associated with the inhalation of any dust, all other factors remaining constant, is dependent upon the mineralogical composition of the dust. For example, it is now well established that the inhalation of certain types of dust, such as granite dust, will in time produce fibrosis of the lungs, at times associated with tuberculosis. In other cases exposure to dust may result in the production of much less fibrosis without notable tendency toward subsequent tuberculosis; this is true of cement dust. And finally, there are certain types of dust, as typified by marble dust, which in the quantities and lengths of exposure so far observed produce little lung fibrosis. In general, it has been found that those dusts which are high in quartz content are the ones which produce a disabling fibrosis of the lungs most readily.

So far as the size of the dust particle is concerned, it is apparent that in order for any given dust to produce injury to the lungs, it must gain access to the parenchyma of the lung, the site where the harmful effects of the dust take place. It is known that not all of the particles of inhaled dust gain access or are retained by the human lung. In this connection it is of importance to have regard to the size of the dust particles present in the industrial atmosphere.

With reference to the quantity of dust present in the air of a workroom it is apparent that when the dust concentration is high the exposed person will inhale a greater quantity in a given period of time than he will when the dust concentration of the atmosphere is relatively low, and since the rate of production of the fibrosis is partially dependent upon the rate in which the dust is inhaled, this latter item plays an important role in predicting the relative danger of different environments. Hence the need for the evaluation of the quantity of dust in the industrial atmosphere is obvious.

Research on the problem of industrial dust inhalation has indicated that so far as their fibrosis producing qualities are concerned, dusts may be divided into three groups: (1) those composed completely of combined silica, that is silicates, such as pure asbestos; (2) those containing free silica in the crystalline form known as quartz, (granite contains approximately 35 per cent of quartz); and (3) dust containing free silica in a non-crystalline form such as diatomaceous earth. In general, it has been found that the harmfulness of a quartz containing dust is in direct proportion to its quartz content. For this reason, in attempting to evaluate the harmfulness of a dust, it is of the utmost importance to ascertain its exact mineralogical composition.

It has been our experience that to determine accurately the exact mineralogical composition of a dust one should resort to a combined chemical and petrographic analysis. By no other method have we found it possible to determine the amount of quartz present in a given sample. In certain instances, such as when one is dealing with a mixture of quartz and pure potash feldspar, it is possible to determine the amount of quartz present in such dust merely by a chemical analysis. However, most dusts which come into question are mixtures of quartz and silicates. Take granite for example. The average granite is made up chiefly of three minerals in about the following proportions: feldspar 60 per cent, quartz 30 per cent, and mica 15 per cent. Chemical analysis shows that this average granite contains 70 per cent of silica. Of this 70 per cent, 30 per cent is present as quartz (free silica) and the other 40 per cent is present as combined silica, in chemical combination with the other minerals that make up granite; it is possible to determine these proportions only with the aid of the petrographic microscope.

We find in practice that samples of dust settled out of the asmosphere at the breathing level of the worker serve admirably for both chemical and mineralogical determinations. Table 1 presents the quartz content of dusts obtained in various industries which we have studied.

TABLE 1

Percentage of Quartz Present in Various Industrial Dusts

Kind of Dust	Percentage of Quartz
Rock drilling dust (bituminous coal mine)	54.0
Granite cutting dust	35.2
Rock drilling dust (anthracite coal mine)	31.0
Brass foundry dust	19.0
Dust from raw mills in cement plant	6.5
Slate mill dust (Vermont red slate)	3.0
Silverware polishing dust	1.7
Anthracite coal dust	1.5
Bituminous coal dust	1.2
Cement dust	1.0
Slate mill dust (Vermont green slate)	trace
Talc mill dust	none
Marble cutting dust	none

It is evident from this table that rock drilling occupations in the coal mining industry and certain occupations in the granite cutting industry and in brass foundries would be in the hazardous class as judged by the proportions of quartz in the atmospheric dust.

It has been demonstrated that particles of dust of a size greater than 10 to 12 microns in longest dimension are very seldom found in the lungs. This absence of larger particles is partly due to the fact that the numbers of such particles greater than ten microns in size present in industrial air is, as compared with the lower sizes, comparatively small; furthermore, these larger particles do not penetrate to the terminal portions of the respiratory tract. Hence we need only concern ourselves with those dust particles that are less than ten microns in longest dimension.

In order to ascertain whether or not an industrial dust is capable of gaining access to the lungs, it is necessary to know something of the size of the particles in the dust under consideration. In practice the samples for particle size studies may be obtained by the use of the Owens jet dust counter. The advantage of this instrument over other devices is that the Owens apparatus projects the atmospheric dust in unaltered condition directly on a microscope cover-slip. This cover-slip may then be properly mounted and examined by any one of several methods. In another method a microphotograph of the dust is made at a high magnification; the particles revealed on an enlarged print or screen may be measured by means of a millimeter scale. No matter which method one uses for particle-size measurements the results may be treated in the customary manner. The particles may be grouped in classes according to size, from which a percentage distribution curve is easily obtained.

As pointed out earlier, a knowledge of the quantity of dust dispersed in the atmosphere is very important, since with any given dust the rate of production of the injury will be dependent upon the total quantity inhaled.

From the practical hygienic viewpoint, the particle count is at present the best quantitative index of the degree of atmospheric pollution. The decision as to the size range of the particles which should be included in the dust count is a question requiring careful consideration. Obviously the size of the smallest visible particle will depend on the magnification and type of illumination used in the microscope, the refractive properties of the dust and to some extent on the visual acuity of the observer. We must bear in mind that our chief interest in this problem is in the industrial hygienic aspect. Primarily we are interested in differentiating between the dust content in the ordinary normal atmospheres, not yet known to be harmful, and certain industrial dusts which are known to be associated with lung damage. This difference is sharply marked so far as the dust particles between approximately one-half and ten microns in diameter are concerned; but the difference between such normal and abnormal air is masked and lost when we include in our determination the particles of ultra-microscopic size which are present in vast numbers in all air.

So far as the upper limit of particle size is concerned it has been demonstrated by the South African studies that particles greater than ten microns in longest dimension are, as a rule, of negligible importance. The data concerning the lower size limit of potentially hazardous dust is not so conclusive. Moir of South Africa, who examined microscopically 120 dust particles obtained from two specimens of silicotic lung, found that only 13 per cent of the particles were less than 0.5 microns and about 36 per cent of the particles were less than one micron in diameter. The majority of the particles, 60 per cent, were between one and three microns in size. The median size of the dust was found to be 1.2 microns in diameter. Drinker, in comparing the size frequency of the particles measured by Moir with the particles measured by him of the dust found in the sputum of men employed in ore mills, found a close correspondence. These findings have also been corroborated by Navrogordato.

In connection with the lower limit of particle size of dust of pathological significance the following pertinent question arises: Aside from the evidence direct or indirect of the non-retention of minute particles of dust by the lungs, what

TABLE 2

Average Dust Counts in Certain Dusty Trades

Industry and Occupation	Dust exposure in millions of particles per cubic foot	Average per cent of quartz in dust
Talc Mining and Milling:		None
Jack-hammer drillers	2,160	None
Packers	50	None
Muckers	45	None
Crushermen and cylindermen	14	None
Slate Finishing Mills:		3
Floormen	1,598	3
Loaders	1,276	3
Disc crusher operators	312	3
Quartz Grinding Plant:		99
Mill operators	173	99
Laborers	83	99
Packers	55	99
Granite Quarrying and Finishing:		35
Leyner drillers	144	35
Jack-hammer drillers	112	35
Hand pneumatic tool finishers	59	35
Machine pneumatic tool finishers	36	35
Plug drillers	37	35
Attendant labor (indoors)	17	35
Anthracite Coal Mining:		1.5
Miners and helpers	232	1.5
Attendant labor	31	1.5
Bituminous Coal Mining:		1.2
Coal cutters and loaders	112	1.2
Attendant labor	4	1.2
Marble Cutters	33	None
Cotton Cloth Manufacturing:		None
Carders	9	None
Weavers and spinners	5	None
Silverware Manufacturing:		1.7
Dusty trades	5	1.7
Non-dusty trades	2	1.7

evidence is there that appreciable percentages of ordinary industrial dusts ever fragment into those minute sizes less than 0.5 microns in diameter? The best answer to this question would be data of actual measurement of such dust. Unfortunately we have but scant published data on the particle size frequency of dusts in the air of industrial establishments. In 1929 Fehnel made some particle size measurements in connection with the dust study of hard rock drilling in New York City. He reported the findings on three samples, which showed the dust which was less than 1 micron in size to vary from 1 to 15 per cent. Most of the dust in these hard rock drilling operations was between 2 and 5 microns in size. Badham, in studying the dust hazard among sandstone workers in Sydney, Australia, measured some 16,000 particles of dust in the air of work places and found that 67 per cent of these particles were about 1 micron in size. In a particle size study of twenty-five samples of eleven different kinds of aerial industrial dusts made by the filar micrometer method at a magnification of 1,000 diameters, the speaker found that practically all of the dust was less than 5 microns in size. Only 2 per cent of the particles were less than 0.5 microns, 21 per cent were less than 1 micron, and the majority of the dust, 71 per cent, was found to be between 1 and 3 microns in diameter.

From all of the evidence therefore, and in the absence of conclusive proof to the contrary, it is apparent that we need only be concerned with those dust particles between one-half and 5 microns in size, and from a practical standpoint the lower limit of particle size to be counted may well be taken at about 1 micron. Many methods have been devised and used for the purpose of determining the quantity of dust in air. Suffice it to say that for the purpose of dust sampling in either high or low dust concentrations, the Greenburg-Smith impinger apparatus now finds universal favor. This instrument has been used by the United States Public Health Service in all of its dust studies during the past nine years and is also being used by other workers in this field in this country and abroad.

During the past nine years the writer has made numerous investigations of dust hazard in many industrial establishments throughout the country. In Table 2, a summary is presented of the average dust content of the air in a few of these dusty industries. This table clearly shows that the highest dust exposure was in the talc mines, slate finishing mills, quartz grinding plant, coal mining and granite cutting industries. Owing to the high percentage of quartz present in the dust of the quartz grinding and granite cutting plants, as compared with the dust in the other industries listed in Table 2, quartz grinding and granite cutting are revealed to be the most hazardous of the occupations we have studied.

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Clinical and Statistical Aspects of Silicosis

By **ALBERT E. RUSSELL, M. D., F. A. C. P.**

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It would be difficult to estimate with any degree of accuracy the number of people in the United States who are engaged in dusty trades. It is evident, however, that more people are exposed to dust, which constitutes the greatest single industrial hazard, than is generally supposed. Certain dusts contain poisonous elements, such as lead, arsenic, mercury, etc., which give rise to general conditions resulting from their absorption. This paper however will deal only with those dusts which are known to be direct factors in the production of pulmonary diseases.

Economic Aspects of Silicosis

The economic problem presented by silicosis is tremendous. The suffering and loss of life due to it cannot be adequately measured. In the gold mining area around Johannesburg, South Africa, during the period 1911 to 1929, more than 53 million dollars have been paid in compensation alone. The costs of medical care, hospitalization, and legal proceedings further augment this enormous figure.

Mines in Australia are reported to have been bankrupted by payment of silicosis compensation. I know of a company in our own country which has claims amounting to more than a million dollars for disability due to dust inhalation. There are other plants in the East which will be bankrupted if all the claims which are filed against them are allowed. In most of the industrial states the number of claims filed has greatly increased in recent years.

It is clear that dust-prevention work, like any health-promoting activity, would pay many times in money, good health, and efficient operation.

Strangely enough, only during the past 25 years has dust received much attention as an etiological factor of disease. The rapid development of industrialization within that period partly explains the impulse toward the study of this source of industrial hazard. The advances which have been made in all branches of industrial medicine have helped to center attention on dust and its effect upon the health, inasmuch as the number of the workers in dusty trades is larger than that of any other group exposed to a single industrial hazard; and an additional reason for increased interest in this subject is gathered from the study of mortality statistics, which reveal the fact that workers in dusty trades have an excessive death rate from tuberculosis, as well as from other respiratory diseases.

The most notable studies of silicosis have been made in the gold mines of South Africa, where the disease, with its complications, has been most commonplace among the miners. It became necessary either to study the disease and devise methods for its control or else to abandon mining. Consequently, funds, personnel and clinical material were made available for the first time on a large scale. Investigators in South Africa have become foremost in this field of research; their scientific work is widely known and has served as a basis for legislation, compensation rates, and further study of the disease silicosis.

There are almost 300,000 workers in the South African mines. It was because of the excessive incidence of silicosis among the miners around Johannesburg that the International Labour Office of the League of Nations selected that city for the first International Silicosis Conference.

In the United States the first study of the effect of dust was made by Dr. A. J. Lanza, an officer of the Public Health Service serving with the Bureau of Mines. His observations, made on miners in the Joplin, Mo., district and published by the Bureau of Mines and Public Health Service, have been confirmed by subsequent studies. Agencies which have done and are now doing investigative work are the U. S. Public Health Service, the Bureau of Mines, and the Universities of Harvard, Yale, and Pennsylvania. Private persons have also contributed valuable information on silicosis.

The word "pneumonoconiosis" is of Greek origin and means "dusty lungs." It is an inclusive term and is being used now more than previously with a designation as to the type of dust responsible for the pathology. There are few instances where a pure dust, i. e., one unmixed with other elements, occurs in industry.

The intelligent consideration of the relation of dust to the etiology of pulmonary disease must include the following: 1. Chemistry and petrography of dust, 2. Concentration, 3. Size of particles, 4. Condition of worker at beginning of exposure, 5. Length of exposure, and 6. Effects produced.

The dusts most frequently met with in the industries are inorganic—incidentally, more harmful. It has been shown conclusively that silica, one of the most common dusts encountered, alone produces more permanent pulmonary damage than all other causes combined.

Condition of Worker at Beginning of Exposure

Reference has been made to the manner in which a tuberculous infection is augmented by the presence of silica. It follows that a worker having a tuberculous infection, either latent or active, will suffer more from the effects of dust than a person who is not so infected. It is highly necessary for workers to be examined thoroughly before being permitted to engage in a dusty trade. Experience with miners in South Africa has shown that a worker having a latent tuberculosis, or a worker in whom such infection was not demonstrable, or if a worker was of the so-called "phthinoid" type, he developed silicosis more rapidly and a tuberculous complication earlier than did the normal worker.

The length of exposure to dust is evidently a great factor in the production of disability. It has been found that the occurrence of silicosis is in direct relation to length of service and concentration of dust.

Effects Produced

In order to determine the effects produced by dust inhalation, a number of studies were made. These observations included a study of the sickness of workers with especial reference to respiratory diseases, physical examinations supplemented by x-ray and laboratory tests, and a study of the mortality records.

I am presenting here some of the recommendations of the International Silicosis Conference on diagnosis and classification. The disease can conveniently be divided into three stages, designated "first," "second," and "third" stages.

"In the diagnosis of every stage of silicosis a history must be established of exposure to inhalation of silica dust in a quantity commensurate with the clinical and radiological findings.

"In the first stage, symptoms referable to the respiratory system may be slight or even absent. Incapacity for work may be slightly impaired. There must be a departure from the normal in percussion and auscultatory signs, and the radiogram must show an increased density of linear shadows and the presence of nodular shadows.

"In the second stage there must be an increase of all the physical signs observable in the first stage, and the radiograph must show an increase in the number and size of the nodular shadows with a tendency to confluence. There must be some degree of definite impairment of working capacity.

"In the third stage all the above conditions are grossly accentuated, and there is total loss of working capacity.

"Tuberculosis may be present in any of the above described stages, altering the symptoms, physical signs, and radiographic appearances, and the degree of working incapacity. Its presence must therefore influence the stage classification."

Patients with silicosis in uncomplicated form are usually well nourished and apparently healthy, except, of course, in the advanced stages.

Limitation of chest expansion is a very consistent finding, and unless the patient has engaged in athletics, the extent of limitation is usually in proportion to the length of service. The restriction of the chest was found (each side was measured with obstetrical calipers) to be symmetrical, in contradistinction to the assymetry occurring in pulmonary tuberculosis.

Symptoms

Dyspnoea is usually the first symptom and most constant complaint in silicosis, and it increases with length of exposure and even after exposure ceases, if the disease has become well established. Dr. Lanza, the American pioneer in the study of silicosis, observed a very great amount of dyspnoea among the miners with silicosis in the Joplin District, Missouri. I do not know of any clinician who has failed to mention this finding when describing the symptoms of silicosis.

It has also been my observation that pains in the chest were a common complaint. A cough, which was usually non-productive, and frequent colds were also in evidence.

Diagnosis of Silicosis

Most of the physicians with whom I have worked or have discussed silicosis are prone to rely solely on the x-ray findings for diagnosis. These men had not been doing tuberculosis work, however, and were not particularly adept in the usual procedures employed in making physical examinations of the chest. The x-ray does give more information than any one other means. However, much can be learned by physical examination, which can usually be confirmed by the x-ray.

The following are some of the principal points in diagnosis by physical examination:

Percussion usually reveals a general impairment of resonance, the intensity of which aspect varies as a rule with length of service. This finding is consistent with the character of a generalized fibrosis, which is a common characteristic of silicosis.

Tactile and vocal fremitus were not changed appreciably in the earlier stages, but as the generalized fibrosis of silicosis increased these were decreased in intensity.

Fibrosis of tuberculosis causes an increase in both tactile and vocal fremitus. The condition is, however, localized, whereas the fibrosis of silicosis is general throughout the lungs.

In my cases of granite cutters there was no marked change to any particular variety of breath sounds in uncomplicated cases, but rather a softening (or "soft pedal" effect) on all the breath sounds, which naturally brought out the vesicular type of breathing.

Rales were absent in the uncomplicated cases. No toxemia was present, which is accounted for by the absence of infection.

Tuberculosis as a Complication of Silicosis

It is not surprising that workers who have latent tuberculosis infections become disabled earlier than the average individual. It was our experience that these cases developed silicosis more rapidly, and that when they developed the clinical tuberculosis, they were still young people and the disease ran a more prolonged course. This was not true of the cases which developed silicosis first. The South African investigators, too, have observed that the cases which they classify as "phthinoid" break down with tuberculosis early in their mining careers.

Physical examination of silicotic patients who are breaking down with a tuberculous complication provides information which is not always available with the x-ray. Dr. Pancoast stated in a talk on pneumonoconiosis at the local (Washington) medical society recently that during this transitional stage the differential diagnosis is often impossible. When the tuberculous complication has advanced, diagnosis is, of course, easy.

Inquiry into the patient's condition will usually reveal symptoms which are common to uncomplicated tuberculosis. It was our experience that early complaints were fatigue, night sweats, increase in dyspnoea, pains in the chest, and an afternoon rise in temperature. There was frequently complaint of a cough, which was productive. Many patients had hemoptysis and later in the disease, frank hemorrhages from the lungs. Loss of weight did not seem to occur so early as in uncomplicated cases, but when this symptom became manifest, it was marked. Tubercle bacilli were usually found in the sputum early in the disease.

The later stages presented no great differences from those fulminating types of uncomplicated tuberculosis.

The physical signs presented variations from those in uncomplicated cases, inasmuch as there existed already a general pulmonary fibrosis. The latent or post-tussic rale was constant and not unlike the same valuable pathognomonic sign in uncomplicated cases of tuberculosis.

The x-rays of cases in this stage usually revealed areas of conglomeration, or fusing, of fibrotic markings. They were less distinct in character than in uncomplicated silicosis. This fact will be demonstrated in the slides.

The diagnosis of silicosis is not an easy task. The patient's history, careful analysis of his occupational life, a study of his physical condition and reliable x-rays are necessary to determine the presence of silicosis and to attempt to evaluate the extent of disability present. It is obvious that it is difficult for physicians to do this and a greater task for a lay jury. It seems to me that it would be better to have the suspected case examined at a reliable clinic or general hospital by a group of unbiased physicians and to abide by their findings rather than to have these cases fought out in courts. In most every manufacturing city large general hospitals and tuberculosis clinics are available and the use of these institutions will, it seems, insure better decisions both to the patient and to the industry.

Course of Silicosis Among Workers no Longer Exposed to Silica Dust

In the study of silicosis one of the most important questions which has arisen is the health history of those individuals who have worked in the granite industry for a number of years and then left, to find occupations in other trades where there was no further dust exposure. It was possible during the course of the study at Barre to observe 24 such cases.

The latency of silicosis has been referred to by other investigators. The South African workers found that "a steady fall over a period of years in dust concentration is not associated with the corresponding fall in the silicosis incidence." Dr. Watkins-Pitchford also records cases of miners who had been exposed to dust for a long period of time, apparently sufficient to develop silicosis, but who went into the war apparently not silicotic. He asserted that such cases were liable to develop tuberculosis. Doctor Pancoast presents a case of advanced pneumonoconiosis in a quartz miner who had been exposed to dust for eight years. He had been out of the mining industry for ten years, yet the x-ray showed extensive pneumonoconiosis with irregularities of diaphragm, and by fluoroscope he found the diaphragm restricted on each side. There was, perhaps, a tuberculous infection intervening at the time.

Britton reports two cases of workers who had been exposed to dust between seven and eight years. They changed occupations and had been away from siliceous dust for eight and nine years. They developed pulmonary symptoms and were found to be suffering from silicosis and tuberculosis. Tattersall also observed cases of latent silicosis in his studies: "Some of the men (rock drillers), moreover, had changed their occupation for various reasons quite apart from health, but in due course the inevitable dyspnoea came on. One man, for instance, worked eight years regularly with rock drills, from 1906 to 1914, then joined the Army, was passed as A-1; but in spite of his open-air life, dyspnoea came on in 1918, and from then until his death six years later his illness was a typical case of silicosis."

The influence of dust in mortality from tuberculosis is clearly indicated in the following table. New methods of manufacturing stone which created excessive dust by the use of pneumatic tools, were introduced in the granite industry about the beginning of the present century, and the tuberculosis rate has increased rapidly with their use. The rate has risen in direct proportion to the length of time during which they have been employed as follows:

1.5 per 1000	1890-1894
10.8 per 1000	1910-1914
19.5 per 1000	1924-1926*

(*during period of our observations.)

A consideration of the mortality statistics of Barre, Vermont, shows that there has been an excessive death rate from pneumonia and other respiratory diseases (tuberculosis excluded) during this period.

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Methods for the Control of Dust in Industry and for the Protection of the Worker

By THEODORE HATCH

Instructor in Industrial Sanitation, Harvard School of Public Health and Harvard Engineering School

The speaker said in part: The health hazard associated with exposure to industrial dusts varies with the industry and depends upon a number of factors, chief of which are the physical characteristics of those exposed, the chemical and physical properties of the dust, and its concentration in the atmosphere of the work places.

The evaluation of the hazards in a given industrial plant must therefore be based upon a thorough investigation of the factory conditions and a careful interpretation of the results. The investigation should include physical examinations of the men and a study of morbidity and mortality statistics, chemical examination of the dust, and determinations of its physical properties such as particle size. The sources of dust and the concentrations produced by the dusty processes must be determined by a complete dust survey. This should be accompanied by an occupational analysis to determine the extent and frequency of exposure of the workers to the hazardous dust. A knowledge of the plant processes and the characteristics of operation of the dust producing machines is also necessary.

In the present state of our knowledge, the manner in which these factors combine to determine the dust hazards cannot be subjected to an exact analysis. The health hazard will be reduced, however, by the introduction of any measures that tend to lengthen the time of exposure necessary to produce the damage, and the object of any program of prevention, therefore, is so to control conditions that the limited time for safe exposure is extended beyond the ordinary span of exposure.

The most direct means of controlling the hazard is by reducing the dust concentration to which the workers are exposed. The efficiency of the required dust control depends upon the allowable concentration in the atmosphere which in turn is determined by the toxicity of the dust and the tolerance of those exposed. The standard of permissible dustiness may be increased by careful selection of the men, by means of physical examination, and limiting their exposure through a system of rotation of employment. It may be further increased by reducing the percentage of toxic material in the dust and otherwise controlling its chemical and physical characteristics.

Standards of permissible dustiness have been proposed for a few of the dusty trades. From a study of the sickness and death rates among the workers in relation to the dust concentrations to which they are exposed, safe concentrations have been determined for the cement and granite cutting industries in the United States, the gold mines in South Africa, and the sandstone industry in Australia. The permissible concentration of zinc oxide has been determined direct by studying its effect upon experimental subjects.

A standard for lead mining which has been proposed was based upon the conditions found in that industry. This list, while it is not complete, serves to indicate the limited nature of the data and emphasizes the importance of careful interpretation of factory conditions in the evaluation of the dust hazard. It often requires years to demonstrate the hazardous nature of certain dusts, and immediate results therefore may have little value. In the absence of definite knowledge, the safe course is to consider all dusts dangerous until proved innocent.

The dusty processes encountered in industry differ widely and exhibit a considerable variation in the restrictions placed upon the design and operation of devices for the control of the dust. No single method of control can be universally applied; on the contrary a number of methods have been developed to meet the needs of the dusty trades and the choice of methods must be based upon a thorough study of local conditions. The common methods may be listed as follows: (1) substitution of a non-hazardous process, (2) isolation of hazardous process, (3) general ventilation, (4) control of dust at point of origin.

The silicosis hazard has been reduced in a number of industries by substituting for the dusty process one which is dust-free or which produces a relatively harmless dust. In the granite industry the surfacing machine, a heavy dust producing tool, has been replaced to some extent by the gang saw and the artificial abrasive wheel. These are wet processes and have reduced the dust concentrations associated with the surfacing of the stone to a figure well below the hygienic safe limit. In grinding and polishing jobs, the sandstone wheels have been replaced by artificial abrasive wheels containing little or no free silica and though dust is still produced, exposure to it does not lead to the high tuberculosis rate formerly found among grinders and polishers. Another example of this method is the substitution of steel shot and other silica free abrasives for sand in the blasting of castings. To give satisfactory results, the foundry sand must be removed from the castings before blasting, otherwise it is broken up and scattered as silicious dust.

This method of control is decidedly limited in application since it usually involves fundamental changes in the manufacturing process. Moreover, great care must be taken in substituting the so-called harmless dust, to make sure that a new hazard is not replacing the old one.

It is possible to isolate the dusty process in many cases. This may consist merely in confining the hazardous stages of manufacture to a separate building or room, thereby reducing the number of men exposed to the dust (and these men may be protected by masks), or it may mean complete isolation for the workers in an enclosed space. Complete isolation of sandblasting operations within a cabinet is now common practice. Escape of dust is prevented by keeping the cabinet under a slight negative pressure, and by means of suitable controls and windows, the operations may be directed from the outside. For some processes automatic blasting, requiring no direct operation, may be employed, although the entrance and exit locks for the material must be carefully maintained in order to prevent the escape of dust at these points.

In a few instances of generalized dust production throughout the factory, the use of general ventilation may prove satisfactory as a means of dust control. Under such conditions, the introduction of large quantities of dust-free air serves to reduce the dust concentration by simple dilution. This method is used in certain mining operations, also for purposes of removing heat and toxic gases as well as dust. In general, it involves the installation of large fans and is expensive to operate. In cold climates it becomes prohibitive owing to the great increase in the cost of heating. General ventilation should be looked upon as an adjunct to other methods of control, rather than an independent method.

Effective control of the dust at the point of generation prevents it from reaching the breathing zone of the worker and hence offers a positive means of reducing the dust hazard. It may be effected by the use of water or other liquids for capturing the dust, or by means of local exhaust ventilation.

The use of water for laying dust is an old method of control. It has been used extensively in connection with grinding wheels and is commonly employed in mining and tunnel operations in the form of wet drilling and water sprays. In operation, some of the particles are carried off immediately by the stream of water whereas others are thrown into the air with the water spray. The latter, however, are suspended in water droplets and therefore settle out rapidly. This method of control undoubtedly reduces the dust concentration but investigations have shown that it does not always give the high degree of protection required. Its efficiency depends primarily upon the completeness with which the particles are wet. In some cases the fine particles are surrounded by envelopes of gas and may pass through the liquids without coming in contact with it. Others, escaping with the water spray, may remain suspended in the atmosphere after the water droplets have evaporated. The wetting efficiency has been increased in some cases through the use of oils and other liquids.

Local exhaust ventilation consists in removing the dust through a suction hood placed close to the point of generation. This method of control is widely used in industry and is most effective when applied to a stationary dust producing machine or when it is attached to a moving tool, thus keeping it at a fixed distance from the point of dust origin. Its general application has been recognized and most states have incorporated specifications for the design of local exhaust systems in their industrial codes. Surveys in certain industrial plants, however, have demonstrated that many systems do not have the required efficiency of dust removal. This can be attributed, in most cases, to improper design and location of the collecting hoods and failure to provide sufficient and proper distribution of air flow through them. In some plants the systems have been rendered useless through lack of maintenance.

The design of local exhaust hoods is complicated by the fact that the conditions under which they operate vary greatly from one process to another. The basic principle of operation, however, remains the same and certain fundamental rules of design exist which should be followed in all cases.

The dust particles thrown off at the point of generation possess kinetic energy by virtue of their mass and velocity. The function of the exhaust hood is to introduce into the area of dust production a counter force in the form of air velocity which overcomes the energy of the particles and draws them into the collecting system. The air velocity required varies with the nature of the process since it depends upon the size, shape and density of the particles and their speed of travel.

This function is common to all exhaust hoods and the object of their design is to create the required air velocity with a minimum total air flow and power consumption, but at the same time without obscuring or otherwise interfering with the manufacturing process. To this end four rules of design may be formulated:

1. Enclose the process as far as possible. Properly located housings or baffles to intercept the particles reduce their energy, and hence decrease the air velocity required for their collection. Enclosing the process also reduces the area of the hood opening and for a given rate of air flow increases the velocity at the face. The use of housings and baffles is limited to processes that do not require close attention and manipulation. The Kelley trap employed with pneumatic rock drills is a good example of a complete enclosure.

2. Locate the hood opening in the path of the dust stream. In many instances the dust is thrown off in a well defined direction, and by proper location of the hood the energy of the particles can be made to carry many of them directly into the collecting system. This is especially important in the case of high speed grinding wheels, for example, which throw the dust particles off at velocities of 10,000 feet or more a minute.

3. Locate the hood as closely as possible to the point of dust generation. The air velocity decreases rapidly with distance from the opening, and hence, the distance to the dust source has an important bearing on the rate of air flow necessary to produce the required air velocity at this point. In the case of a four-inch round opening, for example, the rate of flow required to develop a given velocity at a point six inches out is ten times greater than that required in the same velocity two inches from the face. It is important to note in this connection, however, that the rate of decrease of velocity with distance is less for the larger openings. Moreover, the distribution of flow is more uniform. These facts point to the desirability of using as large an opening as possible.

4. Choose a hood having a uniform velocity distribution over the area of dust production and a minimum flow from the dust-free or so-called ineffective areas. To this end, the size and shape of the hood should be determined by the extent of the area of dust production. For example, one opening of moderate size may be satisfactory for a concentrated dust source, but for an extensive area of dust production, the larger opening or even one rectangular in shape would give better results. Also, by placing a flange around the hood the efficiency of the air flow is improved and the rate of flow necessary to create a given velocity at this point is decreased.

Owing to the great variety of conditions under which exhaust hoods are employed, it is impossible to formulate a set of rules of design which are universal in application. On the contrary, every problem must be solved independently. In spite of their limited applications, however, the foregoing rules serve to emphasize the need for a careful study of the characteristics of operations of the dusty process and the importance of the aerodynamic characteristics of an exhaust hood in determining its efficiency. They also suggest the impossibility of employing any single measure of operation as the basis of design.

State codes commonly specify exhaust hood requirements in terms of the negative static pressure at the hood throat. In some cases a single value has been adopted for all dusty processes and an examination of existing codes reveals a considerable variation in the suction requirements. In some cases the diameter of the throat is also specified.

The use of this index arises from the fact that it constitutes an approximate measure of the rate of air flow into the hood. This is true, however, only when the area of the throat and the shape and size of the hood are also specified.

The inclusion of these factors in the specifications, however, is not enough since the efficiency of an exhaust hood is not a function of the rate of air flow, but rather of the air velocity at the point of dust generation, and this in time is determined by the nature of the process and the design and location of the hood. Furthermore, the rate of air flow necessary to develop the required air velocity also depends upon the shape and size of the hood and its distance from the dust source.

Thus the static suction at the throat bears little relation to the dust collecting efficiency of an exhaust hood and has no place in legal specifications. On the contrary, the only satisfactory index of operation is the efficiency of dust removal itself. Industrial codes should therefore be written in terms of permissible dust concentrations and approval must be based upon actual dust determinations in the factory. In this connection it must be emphasized that visual inspection is not enough since with the ordinary conditions of illumination, concentration below 50-60 million particles per cubic foot of air cannot be detected by the eye alone. In general, concentrations of this magnitude are well above the hygienic safe limit.

Satisfactory data upon the design of exhaust hoods can be secured only through experimental investigation and experience, combined with actual quantitative measurements of dust collecting efficiency and carefully executed investigations of this source must replace the present uncertain methods of design.

Methods of Protecting the Worker Against Dust Inhalation

By PHILIP DRINKER

Associate Professor, Industrial Hygiene, Harvard School of Public Health, Boston, Mass.

The silicosis problem in this country is not a pleasant spectacle for those of us concerned with industrial hygiene and safety measures. Painful as the cure may be, it consists of two perfectly definite steps: (a) medical examinations of new employees and routine examinations of all persons exposed to dangerous dust concentrations; and (b) reduction of dust concentrations breathed by workers to what are considered to be safe limits.

If dustiness can be controlled by local exhaust fans and dust collecting equipment, protective devices such as respirators or positive pressure helmets have no place except as emergency equipment. However, many processes like abrasive (sand or steel) blasting, paint and enamel spraying, porcelain manufacture, stone cutting, sand grinding, and the like, will not, in all probability, be made reasonably dust free for some years to come. In work of this type, respirators and other protective devices have an important place. The safety man should understand thoroughly what can be expected of protective devices, and above all, should be able to check and observe whether the workmen are getting the protection they require.

One sees occasionally statements to the effect that respirators have no place in industry because they filter out only large particles and let pass the small ones which are always the more harmful. Against this is the indisputable fact that the dust catching efficiency of several makes of respirators exceeds 90 per cent on silica dust with particles less than 2 microns. A careful measurement of the size of dust particles entering and leaving respirators shows a slight but unimportant reduction in average size of the dust particles. But by far the most convincing proof that well built respirators remove dust is the microscopic examination of the nasal discharge and sputum of a man who wears a respirator in a dusty atmosphere, and of one who does not.

Requirements for Respirators. Up to the present time our only U. S. specifications for respirators have been formulated by the Bureau of Mines. Respirators submitted to their Pittsburgh Experiment Station are tested according to a schedule which is the direct result of their pioneer war work in gas masks. The Bureau requires *for approval* that a gas mask canister (which includes respirators) have at least 50 per cent filtering efficiency against tobacco smoke, measured at 85 liters per minute, and a resistance *at all times* of less than four inches of water gauge, and that the filter shall not plug readily and thereby make the breathing resistance prohibitive. They require also a "man test" in which the respirator shall give adequate protection to men performing light work in an atmosphere containing an irrespirable suspension (not silica) of definite concentration.

A paper by Katz, Smith, and Meiter of the Bureau of Mines, has made it clear that these specifications are inadequate for respirators in daily use in industry. A resistance of four inches at 85 liters per minute is too high for any but the trained subject such as the soldier in war time or the rescue squads of our mines and public utilities. Katz showed that respirators with high efficiency and low resistance were entirely practical to manufacture and to use.

The Bureau determines tobacco smoke efficiencies by estimating photometrically the smokiness of air entering and leaving the filter of the respirator. The actual density or concentration of the smoke particles in air is not estimated. By a similar photometric procedure, the filter can be tested for silica dust efficiency. The test is rapid and reasonably accurate—hence, its appeal to the laboratory worker. For tobacco smoke testing, the method works nicely but for dusts it is not, in the writer's opinion, satisfactory. A dust concentration far higher than that ordinarily met with in dusty industries is essential to the test, and unless special measures are used, the actual concentration is unknown.

For some time, there have been used in this laboratory the following test methods:

1. Definitely known concentrations of finely ground silica (less than 2 microns) within the concentration limits of approximately 50 to 200 million particles per cubic foot are drawn through the respirator at 28.3 liters per minute, the effluent air passed through a standard impinger, and the impinger sample compared against another sample, taken at the same time, of the unfiltered air. Comparisons of the two samples can be made by the standard dust counting method by turbidimetry or photometry. The last mentioned is much the quickest and is sufficiently accurate for all practical purposes. A ten to twenty minute dusting should give an efficiency of at least 90 per cent.

2. Finely ground calcium carbonate (less than 2 microns) in the form of "whiting limestone" or of magnesium oxide smoke (less than 1 micron) from burned magnesium ribbon can be determined either chemically or photometrically, both procedures being quicker and more accurate than the counting method. A 90 per cent minimum efficiency is required, the test concentration varying from 25 to 150 mgs. per cubic meter.

3. By burning yellow phosphorous, a wet white suspension of about the texture of tobacco smoke is obtained. A filter which shows 50 per cent efficiency against this substance usually exceeds 90 per cent against fine silica. Estimations can best

be made either by using two impingers in series or by electric precipitator and determining chemically the quantity of smoke collected.

4. Smoke made by burning various kinds of pipe tobacco are a little easier to catch than the smoke formed by burning the special mixture used by the Bureau. By drying thoroughly ordinary pipe tobacco and using chemically dried air, a smoke approximating that used by the Bureau is apparently obtained. A filter which shows 50 per cent efficiency against smoke from dried tobacco will generally exceed 90 per cent against all dusts.

5. Resistance to airflow, by the Bureau's set-up, should not exceed 0.3 inches before silica dusting (item 1) nor 0.4 inches after dusting, both resistance tests to be made at 85 liters per minute, using an inclined manometer and suitable flowmeter. (The Bureau now permits any resistance less than four inches.)

A more exacting resistance test is obtained by drawing through known amounts of magnesium oxide fume which has an extraordinary tendency to plug filters.

6. For the man test, a small hole is punched through the face piece of the respirator and a small bore, dust free tube is connected to a special type of impinger or to an electric precipitator. A man, wearing the respirator, performs moderate work in an atmosphere of known dustiness and air from within the face piece of the respirator is sampled for dustiness at a steady known rate of about 15 liters per minute or less. The dustiness of the sample thus collected should not exceed 2 million particles per cubic foot or have an efficiency of less than 90 per cent, whichever rating is the more exacting. The sampling rate, in this case, must be about 15 liters per minute, in order not to interfere with the natural respiratory efforts of the subject. If it is desired to sample by impinger, a tube with a nozzle diameter of about 1.6 millimeters (instead of the standard 2.3 millimeters) should be used, with which instruments a rate of 15 liters per minute is suggested.

Requirements for Sandblast Helmets. Winslow, Greenburg, and Reeves have shown that positive pressure sandblast helmets can be tested while actually in use by the sandblaster. An improvement of their technic has been made by Greenburg and Bloomfield, so that anyone familiar with the standard impinger outfit can perform the necessary tests. All admit that sandblast helmets should be tested under practical sandblast conditions and not in the laboratory.

A hole is made in the helmet, a suitable rubber tube connected, and the air within the helmet sampled by the standard impinger, at 1 cubic foot a minute, for a reasonable period—preferably at least twenty minutes. The subject should be sandblasting throughout the period of sampling. The dustiness thus found should be less than two million particles per cubic foot, regardless of the abrasive used or the condition of the objects being blasted. As a control, it is advisable to sample the compressed air supplied to the helmet in case the air supply is itself also dusty.

Requirements for Paint Spray Masks. As paint spraying is carried out only with a convenient source of compressed air at hand, it is natural that masks supplied with positive pressure should be used. Like the sandblaster, the paint sprayer moves about but little and is not greatly inconvenienced by a light air-line attached to his back or clothing. While spraying under practical conditions, air within his mask should be sampled and the protection afforded by the mask rated in terms of the concentration inside the face piece. The device should give the same measure of protection as afforded by the sandblast helmet.

The manufacturer of protective equipment should be allowed all possible license in modifications and improvements having to do with appearance, obstruction to vision, comfort, ruggedness and practicability of his equipment. If the manufacturer desired his product to be certified as to its performance under the conditions for which he designed and built it, the prospective purchaser and safety engineer is equally desirous of knowing the performance data.

In view of the past work of the Bureau of Mines, the unquestioned integrity of its personnel and the uniform high caliber of its work, the Bureau's laboratories at Pittsburgh seem the logical place for such certification to be done. The manufacturer of protective equipment welcomes definite specifications he can meet, no matter how rigorous, and expects to pay the testing bill whether his equipment is passed or rejected. No private testing laboratory would be expected to undertake this type of work without charging the manufacturer a fee adequate to give the laboratory a reasonable profit. The Bureau's fees in the past, for this type of work, have been modest, but the funds reverted to the U. S. Treasury, and not to the Bureau's laboratory. Unless an absurd and wholly unnecessary hardship is to be placed upon the Bureau, it should be permitted to do such work on a cost, or *pay-as-you-go*, basis.

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General Discussion

Chairman Greenburg after delivery of the papers invited discussion, which was lengthy and spirited. This may be summarized as follows:

Dr. H. K. Pancoast, Philadelphia, pointed out that while X-ray presents the best method of observing changes in the lungs and also for determination of their incapacity, most examinations are not thorough. This point is frequently overlooked. Expert evidence is very important in making a diagnosis and grading incapacity.

The point made by Dr. Russell, of the advisability of special boards to decide the physical status of employees exposed to silica hazards, was also emphasized by Dr. W. J. McConnell, Metropolitan Life Insurance Company, New York City. In this connection Commissioner R. G. Knutson, Wisconsin Industrial Commission, spoke of the difficulties experienced in handling compensation cases. He suggested amendments to the occupational disease laws in various states for the complete coverage of occupational diseases, so that claims can be decided by the commissions rather than by common law. The conflict of testimony by so-called experts appearing before the commissions is sometimes remarkable. In some cases a final decision has been necessarily withheld until after an autopsy. John Roach, Deputy Commissioner of Labor, New Jersey, advocated the appointment of a Medical Board to be paid by the State whose opinion in compensation cases should be final.

There is a great difference of opinion about these cases, said Chairman Greenburg; the compensation commissions differ, the doctors differ, and on the other hand, industrialists have not been alert to the situation; but they can do a great deal in the future. Compensation Boards in the past have been somewhat arbitrary in their decisions. Some time ago I suggested in Connecticut that the commission should be made up of a lawyer, a physician specialist, and an engineer; but this suggestion did not meet with very much favor.

Asked to outline how silicosis cases are handled in Canada, Dr. J. G. Cunningham, Toronto, Ontario, said: Our laws define the terms silicosis and tuberculosis, and they further define the industries and occupations affected, but they refer to mining especially. The cases come from the individual physicians and are referred to the silicosis board. When the claim is received, the board examines the records and the claimants, to see if the regulations of exposure have been complied with; if so, the claimant is personally referred to the silicosis board; two or three of the members examine the case personally, and then each case is decided by all three members of the board. The claim is then referred back to the compensation board.

Two other points of interest occur to me, he said further: first, we have had a number of stone cutters with 15 years exposure to limestone, contacting tuberculosis, but in every case the occupational history showed that they previously had cut sandstone; second, in an extensive examination of workers exposed to silica dust and alkaline powders, reports in the literature have shown the rapid development of silicosis, but in our experience an examination of two small groups with similar exposure has shown only a small amount of fibrosis. The importance of exposure to coal dust also has not yet been sufficiently realized.

Dr. J. P. Leal, U. S. Public Health Service, Washington, D. C., emphasized the point made by Professor Drinker concerning the use of masks, that the minimum pressure necessary to operate such a mask should be used, that a decision should be made as to what this is, and that we should be sure that pulmonary excursion does not operate against appreciable pressure and against proper and continuous lung ventilation.

It is important to find some workable protective device, said Mr. Roach, that will protect workers in sixty or seventy different industries where the exposure exists. It is possible that in laboratories a well made apparatus will work fairly well, but in the various industries workers are found who have sharp and irregular features, and many times a mask or respirator will not work on these faces as on other workers with round, smooth features. The protective device thus becomes a menace rather than a help. We are also very much concerned whether the filter is satisfactory and will properly strain out the particles.

It has been mentioned, said Dr. Russell, that some limestone and sandstone workers have had silicosis. We must remember that granite workers and others have shown the presence of silicosis, although they have not been directly exposed, and other workers beside cutters have shown the presence of silicosis, all of these cases being due to previous occupational exposure involving silica hazards. Recently we had a case of a man with silicosis and tuberculosis, his job having been loading coal (not a real silicosis exposure), but previously he had been a gold miner. He is now 50 years old, has tuberculosis, and three of his five children also give positive tuberculin reactions, which is against the usual conception that tuberculosis from silicosis is transmissible.

Professor Drinker said: I have been asked whether I consider a respirator a good protection if no other apparatus is available. My answer is that it would not be. In a high concentration of dust, if the respirator is functioning properly, it should reduce the amount of dust breathed. But a respirator is not really an eight-hour day apparatus. In other processes, however, where the work is intermittent and a workman is not obliged to wear his respirator continuously, it should function as an efficient protective apparatus.

WEDNESDAY MORNING SESSION

October 5, 1932

For the record of this joint session of delegates of the Industrial Health Section with the Chemical Section, see page 166 of this volume.

WEDNESDAY AFTERNOON SESSION

October 5, 1932

Chairman Greenburg, on the opening of this session, called for the report of the Nominating Committee and officers were chosen as follows:

For Chairman, Dr. R. G. Leland, American Medical Association, Chicago.

Vice-Chairman, Dr. W. R. Redden, American Red Cross, New York City.

Secretary, Dr. C. O. Sappington, Chicago.

Chairman Greenburg then introduced the first speaker.