CONTROL OF DUST PROBLEMS IN INDUSTRY

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The extent of dust control required for any particular plant area is determined by the predominating action of the contaminating dust or mixtures of dust on the body and the severity of dust exposure. The size of the particles of dust resulting from the break down or disintegration of solid materials through physical or mechanical means range from particles visible to the eye down to microscopic and sub-microscopic dimensions. Very often it is the invisible dust that causes the most harm. The particulate matter of fumes and smoke created by processes such as burning, sublimation, and the reaction of gases to form solids is usually less than one micron in size.

The concentration of dust particles dispersed within the breathing zone of workers is determined wherever possible by standard air sampling procedures, since not all methods are equally trustworthy. The better trained the industrial engineer or chemist the more reliable the results. The analyses of samples vary depending upon the nature of the materials and the information desired. The fibrosis-producing dusts, for example, are determined by a prescribed technique and expressed as number, size, and composition in a unit quantity of air. In some special instances the amount of dust is determined gravimetrically. Quantities of most of the other air-borne dusts are generally expressed on a weight-volume basis. Where indicated, chemical and spectrographic methods of analyses are used.

Air contaminants usually enter the body through the respiratory tract. Ingestion and absorption through the skin are less important portals.

Not all dusts in concentrations usually encountered in industry are harmful. Some are physiologically inert and lie free, others may be encapsulated in the tissues, or may be absorbed without producing any noticeable effects. Dusts, such as carbon and iron oxide, are believed to retard the onset and modify the progress of silicosis. Limestone and marble are examples of dusts which cause no injurious effects. However, harmless dusts in high concentrations may be of a nuisance nature and should be kept to a minimum.

Of the harmful variety of dusts some exert their effects locally on the skin, mucous membranes, conjunctiva, teeth, and through irritation to the upper respiratory passages. Many organic dusts produce allergic reactions in sensitized persons with resulting asthma, rhinitis, and other disturbances. An important group of dusts which are insoluble or only soluble with difficulty in the body fluids initiate fibrous changes in the lung tissues. These are limited, so far as we have evidence, to a few of the inorganic mineral dusts, such as silica and asbestos. An equally important group of dusts which are soluble or slightly soluble in the body fluids are inherently toxic when inhaled, ingested, or otherwise absorbed. Lead, manganese, arsenic and their compounds are examples. Included among the dusts of this group are those which may be irritant as well as toxic, as for example the explosive TNT trinitrophenol, and picric acid. A fifth group of dusts causing increasing concern are those arising from radioactive ores.

The diagnosis of any harmful effects to the worker induced by exposure to dusts is entirely a medical problem and is based upon a correlation of the patient's occupation, symptoms, and physical findings. Laboratory and X-ray examinations must be included when indicated. The periodic health examination offers the most effective means of discovering early not only the occupational

diseases or intoxications but also serves to check the adequacy of preventive measures designed to prevent harmful substances from escaping into the breathing zone of workers. It is important for the physician to familiarize himself with every plant process and with the materials used in the plant so that he may appraise the workers' surroundings. A basic consideration in formulating a program of dust control must meet operational requirements as well as provide protection for the maximum number of workers.

The first thought in prevention should be given to the possibility of substituting harmless or less harmful substances for harmful ones where there will be no interference with the quality of the product. Typical instances of successful substitution include the adoption of nonsiliceous parting compounds in foundry practice, of steel shot or grit in place of sand in blast-cleaning operations, and of artificial abrasive grinding and polishing wheels for sandstone wheels.

Where substitution is not practical various engineering methods may be used. It is, of course, preferable for plant management to consult the engineer before the plant is built or remodeled so that control features can be engineered into the plant and machinery. Some machine manufacturers now include control equipment as an integral part of machines known to produce or disperse dusts.

Operational changes or a change in the process to eliminate specific hazardous aspects should be considered. Conversion of hand operations to partial or full mechanization may be possible. Mechanical handling and remote control of dust-creating operations frequently permit the use of more complete enclosure and ventilation application as well as the removal of the workers from zones of highest dust concentrations. Soldering processes may sometimes be changed to welding, thus eliminating lead fumes and dust.

Segregation of dusty processes may be used to advantage. Where plant layout and operational procedure is designed to permit separate housing or isolated locations for dust-producing operations, particularly those difficult to control, the exposure is limited to the least number of workers. This can sometimes be accomplished by arranging the working or production schedules to permit postponement of highly dusty processes until the end of the shift or principal working period. This latter procedure is commonly used in the case of rockblasting operations, shakeout and sand-conditioning work in foundry practice. This has the advantage of either simplifying required ventilation measures or limiting need for personal respiratory equipment as well as of reducing the exposed number of workers.

The enclosure or total encasement of dust-producing units, such as conveyor belts, screws and elevators, vibrating screens, grinding mills and bagging machines, is effective in greatly reducing dust dispersions. The application of mechanical exhaust to the enclosures will further decrease the escape of dust from these sources.

It is sometimes possible to abate dust dispersions sufficiently by wet methods, such as spray or stream of water or by the use of foams, colloidal and other wetting agents. Their value, however, is limited and should always be checked by dust counts in the adjacent breathing zones.

The most preferred single method of controlling dust dispersions is by effective ventilation. By effective, I mean a ventilation system that is designed to conform with established engineering principles and recognized good practice. It follows, also, that adequate care should be observed in its use and maintenance.

The basic criterion in the design of ventilation measures or mechanical exhaust systems is the production of air currents at the point of dust generation at a rate which will destroy the energy of the escaping dust and force it into

the exhaust system, thereby reducing dust concentrations to within safe limits. An efficient exhaust system produces adequate air velocities with minimum power consumption in the area of dust production and a minimum air flow from the dust free areas. An exhaust system should be equipped with a suitable hood to enclose as much as possible the sources of dust production and to provide air velocities sufficient to draw the particles into the exhaust system. Unless it is practicable to dispose of the dust into the outside atmosphere, the system should also be equipped with a dust collector or means of filtration. Where the outside atmosphere is used for disposal, precautionary measures should be taken to prevent possible recirculation or re-entry of the contaminated air through open windows or other means of access. Obviously, technical engineering knowledge and experience are necessary to design an exhaust system that will adequately control or eliminate dust dispersions of operations producing dust.

Good general ventilation or dilution ventilation of working spaces is often sufficient if the rate of dust production is not excessive. Where large volumes of air are employed care must be taken to avoid undesirable drafts. General ventilation by mechanical exhaust devices similarly requires a careful study of the problem in order to be fully effective. Principal factors include adequate air movement at the points of highest dust concentration and proper air flow to the sources of exhaust. Short circuiting of air flow is a common failing in this method of control.

Ventilation devices and exhaust systems, however efficient when first installed, are apt to deteriorate or be misused. All such equipment requires constant checking and maintenance. It is not uncommon to find expensive installations of dust control equipment rendered more or less useless by mechanical defects or by disconnecting on the part of the workers. The efficiency of dust exhaust systems

and other methods of forced ventilation should be checked by means of air samples taken by an approved technique. This should be done when the system is first installed and periodically thereafter.

Under particular circumstances respirators and other respiratory protective equipment worn by the individual worker may provide sufficient protection against dusts. The simplest type is the mechanical-filter respirator which removes a varying amount of a particulate contaminant from the air passing through it. The better the filter material the higher the percentage of dust removed. Only filters approved by the U.S. Bureau of Mines for different kinds of dusts should be used. They are intended for exposures of short duration and not for continuous use.

The supplied-air respirator with helmet is used largely in operations where the particles may injure the face and eyes, such as sandblasting, and metal grinding. It is essential that this type of respirator be provided with an adequate air supply drawn from a pure, dust-free source. The mistake is sometimes made of taking the air directly from a compressed air line without providing the air intake to compressors with a filter capable of removing the fine dust particles. Perhaps the air of the compressed air line may be wet and oily giving rise to odors and even in instances where hot compressors partially decompose the oil to carbon monoxide gas and other gases. Naturally, under these conditions, the air is unsuited for use in the respirator. It then becomes necessary to install a small rotary compressor or blower with a clean source of air. This latter method is also applicable in plants not equipped with compressed air. Unfortunately, when workers are engaged in operations requiring freedom to move about unencumbered by air hose, this type of respirator cannot be worn.

The effectiveness of personal protective equipment, including respirators, gloves, and special clothing, depends upon proper selection and maintenance. The education of the worker in their correct use is likewise important.

Orderliness and cleanliness, so far as practical for the type of work carried on, are important factors in dust control. For cleaning, safety, and efficiency, floors should be of concrete, wooden blocks, granite, or other impervious material. Where wet processes are used, adequate drainage should be maintained, and dusk boarding on other dry surfaces on which workers can stand should be provided. In the event this is not practical, rubber boots should be furnished. Walls, overhead structures, and equipment should be cleaned periodically, preferably by means of a good vacuum system. When possible, sweeping and cleaning should be done after working hours with ample protection afforded those so engaged.

All waste products should be disposed of in a safe manner as often as necessary. Under management supervision a responsible person or persons should be assigned the task of supervising housekeeping conditions. Elimination of bad shop practices is best accomplished by instructing workers regarding dangers incident to occupations. The employee who understands the reason for employing protective methods and devices will in most instances cooperate with management in obtaining results.

These general principles of dust control measures together with adequate medical supervision of the worker are our best solution to the control of the dust problems today.

THE MEDICAL SUPERVISION OF WORKERS EXPOSED TO DUST

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The hazard resulting from certain dusty processes in industry, always an important problem of industrial medicine, has been given undue publicity within recent years, and the conflicting testimony of those who specialize in the litigation field has led many industrialists to consider claims of alleged disease resulting from dust exposure among the common rackets of the day. Although many of these claims are admittedly vague and appear to be based more upon the universal desire to get something for nothing than actual injury, health impairment often follows exposure, usually after a period of years, to certain dusts or mixtures of dusts encountered in industry.

The harmfulness of dusts varies widely in accordance with the physical and chemical natures of each individual substance. Certain dusts are soluble or slightly soluble in the body fluids and their harmful effects are proportional to the toxicity of the compounds formed. Lead, mercury, and arsenic are examples of poisonous dusts. Other dusts exert their harmful effects locally on the skin and mucous membranes and through irritation to the respiratory passages. Chromic acid and alkalies are examples. Attention recently has been called to the probably harmful effect of dusts arising from radio-active ores. A fourth group of dusts which are insoluble or very difficultly soluble in the body fluids may initiate harmful pathological lung conditions. These may be subdivided into non-fibrosis and fibrosis producing dusts.

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(By fibrosis is merely meant the replacement of the normal elastic lung tissue by an unyielding scar tissue.) The organic dusts, mainly the vegetable fibers, such as cotton, jute, hemp, etc., are non-fibrosis producing dusts. The fibrosis producing dusts are limited, so far as we have evidence, to a few of the inorganic mineral dusts, such as free silica, crystalline silicon, quartz, and certain combined silicates. Of the fibrosis producing dusts, those having a high percentage of free silica are admittedly the most important because exposure over a period of years to such dusts distinctly predisposes the individual to tuberculosis.

It is seldom, however, that any one of these groups of dusts occurs singly in industry. Usually we are confronted with a variety of dusts in varying combinations, and until research investigation determines the effects of mixed dusts in measured combinations, it is difficult, if not impossible, to evaluate their degrees of harmfulness.

The diagnosis of a disease induced by exposure to dust is entirely a medical problem, and is based upon a correlation of the patient's occupation, his symptoms, and physical examination. Laboratory and X-ray examinations must be included when indicated. The elimination or control of a dust hazard requires the assistance of the engineer, the chemist, and specialists in other sciences whose training enables them to contribute additional information. It is essential to determine the source of origin of the harmful dust, its concentration within the breathing zone of workers, its chemical composition, and in most instances, the particle size measurements of the dust. With this information and a knowledge of the length of exposure, taking into consideration individual susceptibility and other physical defects of certain individuals which may favor the action of dusts on or in the body, the extent of the dust hazard

can be fairly well estimated.

Dust determinations indicate the locations where preventive measures must be applied. The effective method of prevention depends upon the circumstances giving rise to the hazard and may include the segregation of the dust-producing operations, the hooding or enclosing of the operations with the application of adequate exhaust ventilation, increased general ventilation, the use of protective clothing and respirators, good housekeeping, and, most important of all perhaps, the consistent maintenance of dust control equipment.

The methods by which dust may be collected and studied as to its chemical content, size of particles and amount per unit volume of air, have been the cause of much investigation and research. The general procedures followed have been so ably described by previous speakers before this group that any reference I may make would merely be a repetition and a digression from the subject of the paper.

The effectivness of dust control measures in preventing diseases produced by dusts can be determined only by careful physical examination of the workers so exposed under the guidance of competent medical supervision. The benefits which accrue to the employer and employee, alike, as a result of the physical examination of all applicants for employment, as well as periodical examinations of those already engaged, would indicate very careful consideration by industry of a program for control of sickness. Such a procedure protects the employer from engaging an applicant already physically or mentally impaired who later may claim disability for a condition either not associated with employment or contracted during a previous employment. The applicant's physical and mental condition is established and by keeping records of his subsequent illnesses and accidents, the question of responsibility for injuries and sicknesses

incurred during employment need never arise.

The applicant is protected from engaging in work for which he is physically ill adapted which, if undertaken, might easily bring about serious impairment of his health. For example, an applicant with an arrested tuberculosis who seeks work in certain dusty occupations, if allowed to engage in such work might readily convert an inactive tuberculosis into an active one; thereby, endangering life or at least seriously impairing the applicant's future efficiency and earning capacity. Whereas the same applicant, if assigned to a position that involved no such exposure, might be expected to continue for years as a useful and productive workman. The examination of applicants for employment likewise protects those that are already employed from the risks of communicable diseases such as tuberculosis and various acute respiratory and other infections being introduced into their midst by a new applicant.

Many of the younger individuals who seek employment have never before received a thorough physical examination and consequently are unaware of the defects from which they suffer. As a result of physical examinations, many defects are located which may be removed or corrected before they have caused irreparable damage, thereby increasing the efficiency of the worker and often averting definite and finally chronic diseases. Furthermore, incipient tuberculosis, unsuspected diseases of the heart, kidneys, and a host of other diseases of a similar nature are discovered and the applicant referred for proper medical care and treatment which otherwise might have been postponed until too late. As briefly stated by that great Italian investigator and father of industrial medicine, Bernardino Ramazzini, "A danger forseen is half avoided, a disease known is half cured."

Of even more importance than the initial physical examination of applicants is the periodic examination and care of old employees by an industry. Such a procedure serves to check the efficiency of preventive measures designed to prevent occupational diseases. It offers the most effective way of controlling the health of large groups of workers by discovering early not only occupational diseases, but many other conditions that go undiscovered until the worker is acutely ill or becomes disabled. If the various contagious conditions go unrecognized others become infected, thereby causing serious economic loss as well as endangering the health of a group of individuals.

The information obtained from physical examinations affords the medical supervisor the opportunity to make certain that employees are engaged in suitable work out of which they are getting maximum results, to correct the effects of undue exposure to harmful environmental conditions, and generally to lessen all occupational hazards. As a public health measure, it is impossible to over-estimate the value of such periodic examinations in establishing among employees interest in sickness prevention.

For a long time the importance of accident prevention has been well recognized by industry. The very earliest attempts at industrial medicine consisted largely in the prevention and treatment of accidents occurring in the course of employment. By systematic work along educational lines and establishment of safety departments supervised by trained personnel the occurrence of serious accidents, many of which were considered as unavoidable, has been enormously reduced. The problems today that confront all industries are how to bring about a like reduction in diseases, particularly those associated with or initiated by the so-called hazardous occupations.

Since actions for damages on account of diseases due to alleged negligence of the employer are being brought with increasing frequency in the civil courts, a great many bills have been introduced in state legislatures for the purpose of bringing certain occupational diseases under the compensation acts. At the present time considerable discussion as to the advisability of including the most important of the lung diseases caused by dusts, namely silicosis, under the compensation law is heard. Despite the fact that silicosis is always purely an occupational disease, none of the state workmen's compensation laws in the United States specify silicosis as a compensable occupational disease, with the exception of Kentucky which passed an amendment, effective June 14, 1934, permitting employers in certain industries subject to the silica dust hazard to voluntarily place themselves under the workmen's compensation act with respect to the disease silicosis.

Of the eleven states and three territories in which occupational disease is compensable, five have schedules of diseases which shall be covered, and none of these lists silicosis, so that it is definitely not compensable in those states, namely, Illinois, Minnesota, New Jersey, New York, and Ohio. In six states and two territories and in the District of Columbia, there is more or less general coverage for occupational diseases, and silicosis may be held compensable under the laws of California, Connecticut, District of Columbia, Kentucky, Massachusetts, by mutual consent of employer and employees in Missouri, and in North Dakota and Wisconsin.

The governors of a few states have appointed commissions to study the methods for bringing diseases caused by certain dusts under the compensation act and for promoting preventive measures. Very valuable and interest-

ing reports have been issued by such commissions in the states of Pennsylvania and Massachusetts, while New Jersey, Illinois and Wisconsin have studied the situation intensively.

The Massachusetts and Wisconsin commissions recommended regulations for the preventive measures, since the disease is already a compensable one in these states. The Massachusetts commission's recommendations included compulsory physical examinations on entrance to certain specified hazardous employments and periodic examinations throughout exposure, neither of which was carried through. The Industrial Commission of Wisconsin has developed and put into effect a code which attempts to define what constitutes a harmful concentration of various injurious dusts and establishes a "safe limit" below which the atmosphere of workrooms must be maintained. The Pennsylvania Commission recommended a scheduled list of diseases and special provisions for the compensation of disabled workers with strong emphasis on a medical board of control such as exists in the administration of occupational disease compensation and silicosis acts in operation throughout the British Empire.

These references serve to indicate the trend of present-day thought with respect to control and diagnostic measures. Control measures cover a wide scope of conditions to be standardized, which, beside physical examinations, include methods of determining the extent of hazards; equipment designed to protect the workers; and the elimination or control of contributing factors. These problems can be solved only by the combined experience of trained men in the various sciences. The diagnosis of the diseases resulting from exposure to industrial hazards and the extent of disability incurred obviously should be entrusted to medical men specially qualified for this work with facilities for

adequate radiological examinations. Disputed cases should be referred to a board composed of trained personnel capable of coordinating the medical, radiological, and pathological examinations as well as the results of scientific investigations. The action of such a board of specialists should be final.

The set up of a proper program for medical control of workers exposed to dust depends upon the number of employees involved and individual plant conditions. A series of articles under the title of "The Medical Department Manual" by Dr. Hart E. Fisher, being published at present in the current numbers of "Industrial Medicine", gives a very comprehensive account of the organization, operation, and routines of a medical department. These articles no doubt will be available later in book form and should be read by everybody concerned in the control of industrial health hazards. Any number of instances of adequate medical supervision of workers might be listed, differing from one another in certain respects, but all retaining the essential features of control measures. Briefly, these include:

1. The establishment of a medical department with adequate facilities and medical personnel which has qualified in the field of industrial medicine. A process analysis of all operations in the plant should be made and the medical supervisor should list all possible health hazards and familiarize himself with their physiological effects. If necessary, he should conduct research studies to determine the harmful effects of new substances introduced into plant processes about which little is known. In cooperation with other departments, he should investigate the extent of the hazards and devise measures of control.

2. The routine examination of all applicants for employment. The procedure should include a detailed history of the applicant's previous illness-

es and accidents classified under (a) diseases of childhood, (b) general infectious diseases, (c) respiratory diseases, (d) venereal diseases, and (e) accidents and resulting physical defects. A detailed history of previous occupations engaged in is very important. The mere statement of the type of industry in which the applicant was engaged has slight value, if any. The exact duties performed in each occupation should be noted and information ascertained as to the probable length of exposure to hazardous substances. After the history has been taken and a photograph for identification purposes made (if part of routine), the applicant should be directed to the examining room where he is instructed to remove his clothing for physical examination. This examination should be made as complete as is considered necessary to determine the applicant's physical condition.

If the applicant has been or will be exposed to dusts which induce lung diseases, an X-ray picture of the chest is an important part of the examination. This part of the examination may be referred to an experienced roentgenologist, as the value of this method of diagnosis depends upon the type of pictures taken and the experience of the reader who interprets them. The examining physician also may need additional information obtained by laboratory analyses of the blood, sputum, and urine. These aids to diagnosis should be provided or made available when desirable.

3. The rating and placement of applicants. In cooperation with the personnel department, the applicant should be rated and placed, not only on his training and past experiences, but also on his physical and mental abilities to fill vacancies occurring from time to time. The record of his physical and mental examination should be the confidential property of the medical department.

4. Periodical physical examinations. The frequency of periodical examinations necessarily must depend upon individual circumstances according to the need for such examinations as determined by the supervising physician. Where physical examinations are made for the first time, the employees of long standing should be given ample explanation of the benefits of such examinations and be given assurances that their jobs are secure.

5. Provision for the disabled. Employees who develop disabilities during the course of employment should be re-assigned to occupations which will not interfere with or aggravate the disability, or they should be provided for in other ways.

No program of supervision can be effective or even endure which does not include these essential features conducted with fairness and in good faith toward all concerned. Employees want, above all else, security of employment and any attempt to use the periodical physical examinations as a means for eliminating those who contract disabilities incident to occupation without providing for their needs, will meet with determined opposition. Physical disabilities need not disqualify a man for work, but, rather, indicate the types of work he can do and not endanger himself or others, thereby prolonging his years of usefulness and adding to his enjoyment of life.

Many concrete examples might be cited of results obtained through dust control measures and competent supervision of workers. One which strikingly illustrates the value of such measures is the experience of the South African gold mines. During the years 1918-20 the production rate for silicosis for those who had 10 years underground service amounted to about 10 per cent. The highest rate for those having 16 years service amounted to 14.5 per cent. During the years 1920-23 the production rate for those who had 10 years of service

dropped to 5 per cent and during the year 1931-32 the rate dropped to a fraction over 1 per cent. The highest rate during the 1920-23 period amounted to a little over 7 per cent with 16 years' service and in the period 1931-32 the highest rate was about 4½ per cent after 18 years of service. This experience can be duplicated wherever preventive measures are effectively applied.