Engineering Control of OCCUPATIONAL-DISEASE HAZARD

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It IS the purpose of this paper to outline a practical procedure which the engineer can employ in his own plant to assist in the control of occupational-disease hazards. The solution of the occupational-disease problem is by no means a one-man job; it requires the active cooperation of all concerned, the engineer playing a large part in its successful solution. He is more than an important cog in the wheel; he is a vital center in the mechanism for control of industrial health hazards.

The mechanism to be set in motion for provision and maintenance of healthful working environment is, within limits, much the same whether the engineer is associated with a large manufacturing organization or with a small unit.

The first step for the engineer to take is to ascertain just what hazardous materials, processes, and conditions exist in his plant. We all know generally that a variety of organic solvents are used in spray lacquers and thinners, that grinding wheels are made up of various types of abrasives. But such generalized information is not sufficient. It is essential that the engineer know specifically every potentially hazardous material used in his plant.

LIST THE MATERIALS THAT ARE HAZARDOUS

This then is the first item of the practical procedure to follow: Go through the plant, department by department, and list the materials used in or given off by each operation. You may be of the opinion that you know all these items as part of your intimate knowledge of the plant. But it has been our experience when making plant surveys that there are usually a number of gaps in the engineer's knowledge of these materials.

Do you know, for example, whether the thinner used in your plant contains benzol as a constituent, whether gasoline for nonfuel purposes is free from lead, whether sandstone grinding wheels are employed, and what abrasives are used on made-up wheels or disk grinders? A complete survey of plant conditions will disclose such information and provide information on the potentially hazardous materials with which you have to contend.

Since new materials are constantly being introduced, have a standing arrangement with the purchasing department to keep you informed of any such materials ordered. If it is decided to substitute methanol for denatured alcohol, it may not be necessary to make any mechanical changes in a process and you may not be notified of the substitution. But you should know that this more hazardous solvent has been introduced, as additional control measures may be required. One of the surest methods of keeping your permanent record up to date is to have the purchasing department transmit this information to you.

Of assistance in compiling the list of injurious materials used in the plant is the bulletin, "Occupation Hazards and Diagnostic Signs," prepared by Dublin and Vane.[1] This bulletin presents a list of hazardous occupations and the injurious materials and conditions which may be associated with them. The potentially hazardous materials to which workers were exposed in a group of plants in a typical industrial area are listed in the report[2] of a survey recently conducted by the United States Public Health Service. This report includes the number and percentage of workers exposed. It may also assist in compiling the list of such materials used at your plant.

The permanent record of the potentially hazardous materials and the operations with which they are associated may well be compiled in the form of the potential-health-hazard chart prepared by our bureau, in which the injurious materials are listed along the abscissas and the industrial classifications along the ordinates of cross-section paper. In the chart which you make up for your plant, the individual departments and operations will be substituted for the industrial classifications. The information given by this chart may be made more complete by inserting, instead of the *X* used in our chart, the number of workers exposed together with a symbol to indicate the relative severity of the hazard.

LEARN WHAT PROPERTIES OF HAZARDOUS MATERIALS AFFECT HEALTH

Having made a complete permanent record of the materials used, including their constituents, and of the departments and occupations where they occur, be sure that you are informed on the properties of these materials which affect health. You should know relatively how much of the material is required to cause injury and, generally, how the material affects the body. You should be sure that your information is reliable and that it is in accordance with up-to-date knowledge and opinion. Research on this subject is continually being conducted and our knowledge of the injurious action of these materials extended. Occasionally, erroneous impressions of the hazards presented by various materials gain credence and must be corrected.

Some years ago the textbooks stated that pneumoconiosis was caused by sharp-edged dust particles such as those of granite and aluminum oxide. It has since been shown that the sharpness or hardness of the dust particles is not the criterion of their pneumoconiosis-producing properties and that workers exposed to sufficient concentrations of quartz dust to cause pneumoconiosis do not develop this condition when exposed to similar concentrations of equally hard and sharp-edged aluminum-oxide dust. Many engineers have a good conception of the types of dust which are most injurious, but erroneous impressions come to light when industrial health hazards are discussed. For example, we often find that the engineer fails to recognize that carbon tetrachloride is injurious on its own account but has the misconception that only its products of hydrolysis when used in extinguishing fires are hazardous; and again that toluol is noninjurious since it was recommended

[1] U. S. Bureau of Labor Statistics Bulletin No. 582, 1933.

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[2] "The Potential Problems of Industrial Hygiene in a Typical Industrial Area in the United States," by Bloomfield, Scott, and Sayers, Public Health Bulletin No. 216, December, 1934.

is a substitute for the more toxic benzol The facts are that all the organic solvents are toxic, though to varying degrees So although you cannot expect to know the whole subject of industrial toxicology, it is important that you be reliably informed on the injurious properties of the materials used in your plant Such information can be obtained from some of the recent general references on the subject, or, even better, from such sources as your plant physician, federal and state bureaus of industrial hygiene or occupational diseases, insurance engineering departments, universities, and private consultants.

DETERMINE WHICH POTENTIALLY HAZARDOUS MATERIALS, PROCESSES, AND CONDITIONS ARE ACTUALLY CAUSING INJURY TO HEALTH OF THOSE EXPOSED

The third step in the procedure of controlling occupational-disease hazards is to decide which of the potentially hazardous materials, processes, and conditions are actually causing injury to the health of those exposed These potentially hazardous conditions will fall into three categories. Those obviously requiring control measures, those which may be considered negligible, and those which require determination of the exposure to show whether or not the potential hazard may actually be affecting health.

The use of determinations of atmospheric contaminants has been emphasized in the Connecticut Bureau of Occupational Diseases as an exceedingly satisfactory basis on which to proceed. Engineers are trained to work from facts; the results of determinations of injurious materials in the air are the fundamental facts in occupational-disease control.

The following experience shows what can happen when information is lacking concerning the exposure of workers to potentially hazardous conditions. Eighty men were connected with a department in which two machines involved the use of one of the newer organic solvents that had been shown to be only moderately toxic. Eleven of these men were directly engaged in the operation of the machines. The process had been in use for some time when an alteration was made which increased the concentration of the vapor and duration of exposure of the workers. Even with the increased concentration of the vapor, the odor was not unpleasant nor, as far as we know, did it cause the workers to complain.

Within a fortnight, one of these 11 workers, a normally healthy young man, 29 years of age, went home after the extra long Sunday shift of 12 hours feeling ill. He died six days later, the cause of his death being attributed to influenza and dilated heart. No cause-and-effect relation was linked at that time between his occupation and his death. On the Sunday following, a second man working at these machines was taken ill, and on the next day a third. Cases 2 and 3 were still ill when two more workers were transferred from workroom to hospital; and within 14 days from the death of the first victim, five workers had succumbed to fatal poisoning.

The point of this illustration is not that the organic solvent was extremely poisonous nor that it should necessarily be replaced by some less injurious material. There is no question but what the process, employing the very same solvent that caused the deaths, could have been conducted in such a manner as to cause no injury to health The point is that the engineer in charge of the operation did not recognize his responsibility to ascertain definitely whether the exposure to the solvent vapor was within safe limits Had vapor determinations been made at the time the process was changed, the hazard could have been controlled before the injury to health occurred.

Materials of equal or greater toxicity are being used in many plants today If any change is made in an operation or in the material used, ascertain that such change does not increase the hazard beyond safe limits. Only by knowing the hazards and determining that the exposure to them is within safe limits can you be assured that your plant will not be visited by any such lamentable occurrence.

Not only do determinations of these atmospheric contaminants show where control measures must be instituted but, in other instances, they may permit appreciable saving by showing that control measures involving expensive exhaust equipment may not in every case be necessary. Illustrative of such a situation is the potential hazard from the lead melting pot.

For years there has been a tendency to recommend exhaust ventilation over melting pots containing lead and its various low-melting alloys in slush casting and linotype-machine operation. To determine just how necessary it is to have hoods over the melting pots of type-setting machines, air analyses were made in connection with an investigation of health hazards resulting from the use of these machines.[3] The results of these analyses showed that the daily exposure where there were no exhaust hoods was less than 0 2 mg Studies made by our bureau where no local exhaust was applied to the linotype machines have also shown lead concentrations of this same order, well below the amount which causes poisoning. In studies conducted in lead-casting departments of four plants during the past year, we found the exposure of the casters to vary from 0.1 to 0.5 mg of lead per 10 cu m of air. The amount of lead collected in samples taken directly over the melting pots varied from less than 0.1 mg to less than 0.4 mg per 10 cu m.

Since it has been well established that except for prolonged exposures the limit of safety under most industrial conditions is an atmospheric concentration of lead dust or fumes of less than 1.5 mg per 10 cu m of air, the foregoing determinations indicate that there are more important control measures than the provision of exhaust ventilation for lead melting pots kept at moderate temperatures.

Of interest in this regard is a table of the calculated maximum lead-vapor content of air over surfaces of lead kept at various temperatures from 250 C to 1500 C which was published in the foregoing paper.[3] A portion of this table is reproduced in Table 1.

TABLE 1 CALCULATED MAXIMUM LEAD-VAPOR CONTENT OF AIR OVER SURFACES OF LEAD KEPT AT VARIOUS TEMPERATURES

Temperature C	Temperature F	Concentration of lead, mg per 10 cu m
300	572	0.00006
350	662	0.0016
400	752	0.02
450	842	0.2
500	932	2.0

From this table it will be noted that the temperature must exceed 900 F before injurious concentrations of lead vapor are given off from the melting pot. A warning should be given, however, that as the temperature exceeds this value the amount of lead vapor evolved from the surface of the molten lead increases rapidly; when the temperature doubles from 500 C to 1000 C the equilibrium concentration of the lead vapor above the surface of the molten lead increases 50,000 times.

Since things are not always what they seem, even when considering such a prosaic entity as occupational-disease hazards, the engineer should have information on the amount of the injurious substance to which the worker is exposed wherever there is a possibility of doubt. Determinations of atmospheric contaminants bring to light hazardous conditions before occu-

[3] "Hygiene in Setzmaschinenräumen," by Vaje and Weber, Schriften aus dem Gesamtgebiet der Gewerbehygiene, no. 44, 1935.

pational diseases develop. In former years the only criterion of the healthfulness of the industrial environment was whether or not clearly demonstrable injury to health occurred. And usually it was necessary for several cases of occupational disease to develop before the working conditions were accepted as the aetiological factor.

Utilize the methods available today to keep one step ahead of the occupational-disease specter. Determine whether the working conditions are safe or hazardous on the basis of the concentration of the hazardous material present. If the worker is exposed to more than the threshold dose, then act at once to correct the condition. It is not necessary for the engineer to delay, fearing that he may be overestimating the severity of the hazard and so letting his concern in for unessential and unproductive expenditures; he can stand behind his recommendations when they are based on facts which show the hazard to be excessive. It has been our experience that the engineer armed with such facts has received support from the management such as had previously been accorded him only on projects which offered an assured production profit.

APPLY ENGINEERING PRINCIPLES TO KEEP WORKER'S EXPOSURE WITHIN SAFE LIMITS

This leads to the fourth step in the procedure for the control of occupational-disease hazards: The application of engineering principles to keeping the worker's exposure to potentially hazardous conditions within safe limits. As stated by Clark and Drinker in their new book,[4] "Prevention of industrial disease is largely an engineering problem, as its basis is a separation of the toxic or irritating substance from contact with the worker."

This separation of the harmful material and the worker may require application of the most ingenious engineering skill or merely of simple engineering principles, but in either case there should be a generous portion of that most valuable quality, the ability to be practical. General methods of occupational-disease control measures can be divided into a number of groups, such as provision of enclosures, exhaust ventilation (both local and general), changes in process (dry to wet, for example), substitution of more toxic by less toxic materials, and wearing of special protective equipment.

Without going into examples of each of these general methods, consider from an industrial-hygiene point of view some simple operation, such as sandblasting. Assume that this operation is conducted in a modern, specially designed room, that the sandblaster is equipped with a positive-pressure helmet, that a steel abrasive is used, and that a cloth-filter type of dust collector is provided. It may perhaps be felt that the condition can be dismissed as completely satisfactory.

But is the sandlbaster adequately protected? Let us see just what should be taken into consideration to assure that an affirmative answer can truly be given.

The dust to which the sandblaster may be exposed comes from two sources, that in the sandblast room and that in the air line to his helmet. If there is an appreciable amount of molding sand on the castings being cleaned, the dust in the room will contain free silica, though the percentage will be considerably lower than if a sand abrasive were being used. The positive-pressure helmet may look good on paper, but examine it on the man to make sure it permits no easy access for the dust. With some types of helmets there is a strap or elastic which permits a tight fit around the neck. Does the sandblaster so adjust this that the dust cannot enter the breathing space? Or perhaps there is an opening at the front of the helmet when he leans over in the course of his work. The velocity of the dust is so great during sandblasting that it will find its way into the helmet if there are openings of appreciable size even against the stream of air escaping from it.

Having ascertained that the helmet fits properly and is so adjusted that the dust does not have access to its interior, turn your attention to the air supplied in the positive-pressure line. How much dust does it contain? Is the intake of the compressor so located that the air is clean? Even when an air washer is supplied we have occasionally found this to be ineffective if dust has been allowed to accumulate in it or if the water has evaporated or the glass cracked. And is a sufficient volume of air supplied? Does the valve on the air-supply line permit the sandblaster to reduce the volume of air below that necessary to make the helmet as effective as its manufacturer designed it to be? Possibly the air line contains some oil from the compressor and the blaster may shut off the air to avoid the discomfort at the expense of subjecting himself to a severe health hazard. Provide the man with a clean air supply and be sure he is getting the proper volume of it.

Having checked these items, make a dust determination of the blaster's exposure while conducting operations in the usual manner. A determination of the free-silica content of the dust will assist in the interpretation of the result. But a good helmet will keep the exposure well below five million particles per cubic foot of air which is considered good performance whatever the free-silica content.

After the actual sandblasting has been completed, are there other dusty operations which the blaster may include as a part of his duties? An approved filter-type respirator should be worn while performing incidental jobs involving moderately excessive dust exposures.

Perhaps one of these jobs is emptying the dust collector two or three times a day. In one case we made dust determinations of the blaster's average exposure while transferring the dust from the hopper of the collector into barrels and found it to be 324 million particles per cubic foot of air! Even this represented an improvement over a former condition since a canvas cover had been provided which extended the canvas discharge tube so that it fitted over the top of the barrel. At the plant where this determination was made, the blaster was exposed for ten minutes twice a day to this high dust concentration.

It is essential not only to keep the average exposure within safe limits, but also to avoid exposures to greatly excessive concentrations for even brief periods. The importance of avoiding such exposures is not limited to dusts but also applies to many other injurious materials found in industry, especially where the brief exposures are repeated day after day.

There are several methods for removing the dust from the collector without subjecting the worker to large amounts of it and some effective method should be utilized. In problems of this type the engineers of the equipment manufacturers are of much assistance.

A survey of the sandblast operation should include exposure of other workers in its vicinity. Is the sandlbast room itself tight? Where is the dust collector discharged? There has been much discussion concerning the discharge of cloth-filter dust collectors back into workrooms where free silica is one of the constituents of the dust. The final answer to this question depends upon the ability of the engineers of the equipment manufacturers to provide a collector which will clean the air sufficiently and with such certainty when all operating factors are considered that the worker is not exposed to an injurious atmosphere.

The difficulties of dust suppression, the limitations of dust collection, and certain other factors cause the preponderance of

[4] "Industrial Medicine," by Clarke and Drinker, National Medical Book Co., New York, N. Y., 1935.

opinion at the present time to favor the discharge at a point outside the plant of air from collectors handling a dust of high silica content. However, in a particular plant under certain circumstances, it may be especially desirable to return the air from the collector to the workroom. If this is done, then by all means ascertain by dust determination that those employed in the workroom are not exposed to excessive dust concentrations, and further, institute a rigid routine of maintenance and check dust determinations to assure yourself that the dust exposure is being kept within safe limits.

INSTITUTE ROUTINES OF MAINTENANCE AND CHECK-UP

The engineering control of any occupational-disease hazard cannot be attended to once and for all and then forgotten. Eternal vigilance, in the form of maintenance and check determinations of the atmospheric contaminants, is essential to the complete solution of the problem. This is the fifth step in the engineering control of occupational-disease hazards.

Maintenance is of such paramount importance in occupational-disease control that it should be made the subject of an entire paper. The following is an example of what can be done when such a piece of equipment as a dust collector is properly maintained under the direct supervision of the plant engineer. Dust collectors were connected to two sandblast-table rooms using sand abrasive. The collectors had been in continued use for six years. During this time they were thoroughly inspected and cleaned every month. Konimeter dust samples were taken at the discharge of the two collectors. These showed counts of 1.2 and 0.7 million particles per cubic foot of air for one of them, and, for the other, 3.1 and 2.8 million particles. A week later the second dust collector was checked with an impinger and a concentration of 2.35 million particles was found in the exhausted air. This collector had been cleaned and inspected about three and one-half weeks previously. Another impinger sample was taken within a few days after its next regular cleaning and the concentration at the discharge was found to be only 0.87 million particles per cubic foot of air. After another two weeks, opportunity was taken to collect still further Konimeter samples at these two dust collectors and average concentrations of 2.3 million particles and 1.5 million particles per cubic foot of air were found. The engineer who maintained these dust collectors in such excellent condition deserves much credit, which the engineers who originally designed the equipment would gladly accord him.

Other pieces of equipment than dust collectors also require adequate attention to maintenance to assure that a health hazard once controlled will continue to be controlled.

CONCLUSIONS

A procedure has been outlined for the engineer to utilize in his plant as his part in the control of occupational-disease hazards.

(1) He should make a permanent list of the materials used in his plant and keep the list up to date.

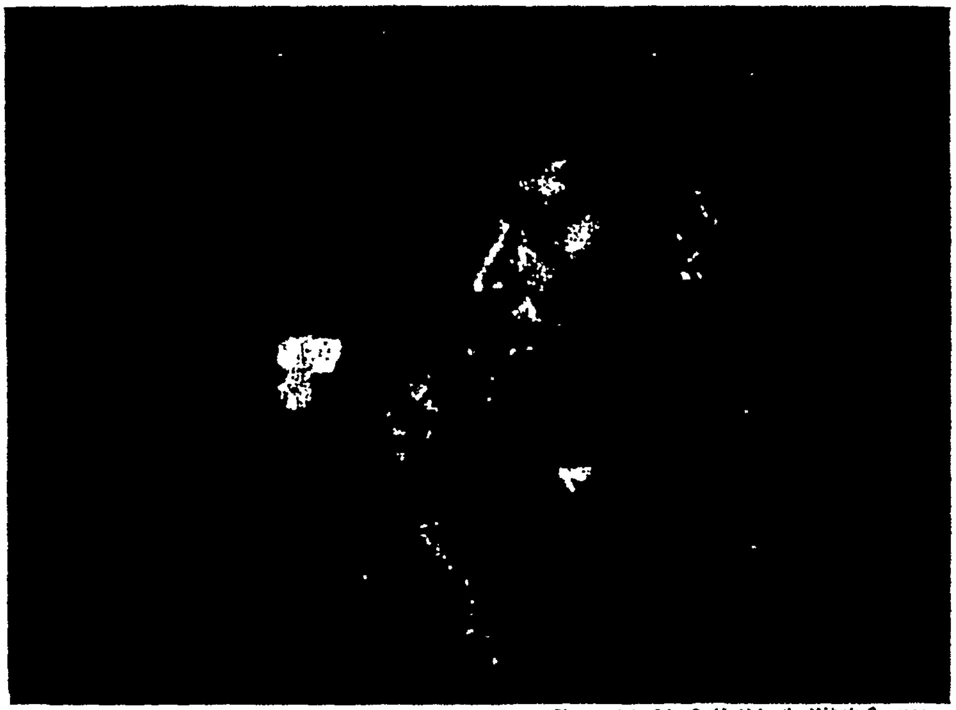
(2) He should be informed concerning the injurious properties of the hazardous materials used.

(3) He should determine which of the potentially hazardous conditions are actually causing injury to health and should be controlled.

(4) He should engineer the control measures, preferably checking the completeness of control by determinations of the injurious materials in the air breathed by the worker.

(5) He should institute routines of maintenance and check-up determinations.

The manner in which this procedure could be followed was outlined in connection with the simple operation of sandblasting. This same procedure can be utilized for the control of health hazards of similarly simple operations or of the most complex operations where a variety of hazardous materials are involved. Every available aid should be made use of in coping with the occupational-disease problem to the end that the hazardous condition may be controlled before it manifests itself in the form of cases of occupational disease.



Photograph by John P. Mudd for the Midvale Company