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HYGIENE AND SANITATION BULLETIN

OUTLINE

OF

OCCUPATIONAL DISEASE PREVENTION

Bureau of Engineering and Safety
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FOREWARD

This bulletin is issued as part of an informative series relating to Industrial Hygiene and Sanitation and a program for providing authoritative information concerning industrial safety and health to labor, management, engineers and the interested public of New Jersey.

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OUTLINE OF OCCUPATIONAL DISEASE PREVENTION

INTRODUCTION

1. It is difficult to estimate the total number of occupational health injuries that American workmen suffer each year. The major reasons for this appear to be--

   (a) Incomplete reporting due to limited occupational disease coverage of many Workmen's Compensation Acts and to the lack of any coverage in many States.

   (b) The fact that most of the compensation acts having complete occupational disease coverage are so recent that the experience under them does not yet furnish a dependable gauge.

   (c) Many damaging exposures either do not produce disablement or escape detection as the source of disability, hence go unreported.

   (d) Some physicians are unwilling to report cases as possible or probably occupational for fear of involving the employer in litigation.

   (e) Many physicians are not sufficiently informed on occupational diseases to be able to recognize them as such.

2. Compensation data from such States as Wisconsin, Massachusetts, Ohio, and New York where occupational diseases have been compensable for many years, do not show occupational health disabilities for industry to be over three percent of total occupational disabilities. Data to permit a reasonably accurate estimate of the number of less than disabling health injuries is not available.

3. This numerical relationship between health injuries and accidental injuries should not, however, be taken as an indication that occupational health hazards are of little importance. The contrary is true, because

   (a) Every three percent of the national occupational injury tool sums up to a large total of human misery, productive time loss and cost. Three percent of the 1943 occupational injury total would be some 70,000 cases of disablement of one day or more each.

   (b) A substantial proportion of health disablements persist over long periods or may recur at any time throughout life.

   (c) The occupational connection of many escapes detection.

   (d) Some substances, for example lead, may "set the stage" for future illnesses or they may injure health, but not to a degree that yields disablement.

   (e) New hazards are continually coming into being through the use of new substances, new uses for old substances, new combinations of substances, process changes and the like.

4. It should be pointed out here that the more serious health hazards are not, in general, common to all industry. In certain types of industry, however, health hazards are much more serious than accident hazards. That is, while potential health hazards are found throughout industry, the more serious exposures come from work with toxic substances whose use is for the most part concentrated in a limited number of industries.

5. The human body is not only an exceedingly complex and delicate mechanism, but healthy life depends upon the continuous orderly operation of incompletely understood but highly intricate chemical and physical processes. Anything that interferes with these processes or damages any part of the body is injurious in some degree. The human system has many defenses against the health hazards that ordinary living presents, but it has less defense against the toxic substances used in industry. Also, industrial processes often intensify familiar exposures, such as heat, radiant energy, non-toxic dusts, and the like to such a degree that the bodily defenses adequate to combat ordinary exposures of this nature are overcome and injury results. We may therefore classify health hazards as--

   (a) Chemical. For the most part these are substances that directly attack the body or certain parts of it, such as poisons and corrosives. They may be gases, vapors, liquids, solids or dusts or combinations of these.

   (b) Biological. These include a long list of infections such as anthrax, tuberculosis, pneumonia and typhoid fever, such fungi as those causing athlete's foot, and parasites such as that causing trichinosis.

   (c) Harmful environmental conditions or exposures, such as excessive noise, radiant energy, excessive vibration, extreme temperatures, and rapid temperature change.

MANNER OF ATTACK

6. Injurious substances reach the body and cause damage by -

   (a) Inhalation - breathing.
   (b) Skin contact - absorption through the skin; direct attack on the skin.
   (c) Ingestion - swallowing.

Inhalation

7. Inhalation is by far the most important of these means of entry by which injurious substances affect the human system. The great majority of occupational poisonings result from breathing air that contains toxic substances in the form of gases, vapors, mists, dusts, fumes or combinations of these. The lungs are remarkably efficient devices whereby the red blood cells (red corpuscles) are enabled to absorb oxygen from the air and carry it to all parts of the body. But this same mechanism will also draw into the lungs the percentage of any gas or vapor contained in the air breathed. Some of these gases are more readily absorbed by the red blood cells than oxygen. Carbon monoxide, for instance, is taken up by the red blood cells some 300 times as readily as oxygen.

8. The lungs are made up of countless millions of air cells (alveoli saccules) microscopic in size into and out of which air is circulated at each breath by the rhythmical expansion and contraction of the lungs. The sum of the absorbing surfaces of these saccules is very large, some 2,000 square feet for a man of average size or roughly 200 times the area of his outer skin.

9. Soluble dusts may be partly or wholly dissolved by lung moisture and then absorbed. Corrosive dusts will attack the linings of the respiratory passages. Dusts and fumes that will not dissolve or be absorbed may cause injury through irritation of the delicate linings of the air passages, or by clogging the minute air cells and the still smaller passages to them. They may even carry harmful bacteria into the lungs or create a condition favorable to bacterial attack. It is essential, therefore, to conclude that no dust can be regarded as entirely harmless if its concentration is high.

10. In view of the facts, it is obvious that the prevention of air-contamination is the first principle in safeguarding work with substances that may, at any stage of the operations, become air-borne. This principle should always be applied to the maximum practical degree. Wholesome air is essential to health.

11. Substances that can be air-borne are classified as -

    Gases - Substances (as air) that at ordinary temperatures can exist at atmospheric pressure only as gases, for example carbon monoxide, hydrogen sulphide, and ordinary city gas (itself a mixture of gases.)

    Vapors - The gaseous form of substances able to exist in the open air at ordinary temperatures both as a gas and as a liquid or a solid. All liquids and some solids (for example naphthalene-"moth balls") evaporate, vaporize, (that is change to gas) more or less rapidly in contact with air. The higher the temperature the more rapid the vaporization. The distinction between gas and vapor is largely a matter of usage. For example gasolene in the gaseous form above the surface of liquid gasolene in a bucket is spoken of as gasolene vapor though it is truly a gas.

    Mist - Very fine droplets of liquid suspended in the air are termed mists. They may be produced by condensation from the gaseous form (example-fog above a pond on a cold morning) or through escaping gas carrying droplets of liquid into the air (example-mist above a tank in which an electrolytic plating operation is being carried on) or by breaking a liquid up into a mist (example-paint spraying).

    Dusts - particles of solid matter fine enough to float in the air. In industry dusts come mostly from crushing, grinding, and handling operations.

    Fumes and Smoke - solid particles formed by the cooling or chemical combination of substances in the gaseous form. Examples-lead when sufficiently heated gives off vapor (gaseous lead) which is quickly oxidized (to lead oxides) in the heated air above the molten lead and appears as a fume. If an open vessel of muriatic (hydrochloric) acid is brought close to one containing ordinary ammonia, a cloud of white fumes of ammonium chloride will appear.

12. The significant distinction between fumes and dusts is that of particle size. Fumes when formed consist of exceedingly fine particles (in theory, individual molecules) though these tend to unite (coalesce, agglomerate) to form larger particles. Dusts are formed by the mechanical crushing or abrading of solids, hence their size will depend upon the nature of the material and of the treatment to which it is subjected. As compared to fumes, however, even the finest dust particles are relatively large. The importance of size lies in the fact that the finer the particle, the more easily and lastingly air borne it is, the more difficult its removal from the air and the more readily it is taken into and absorbed by the lungs.

Skin Contacts

13. The outer skin is surprisingly effective in protecting the tender tissues beneath it from dirt, bacteria and other exposures of ordinary living. But science has developed a large number of substances and types of exposures whose power to damage or destroy is far beyond that which the unaided skin can resist. Where such substances are involved, skin contact should be eliminated as far as possible by positive means, such as mechanical handling, arrangement of process, and good housekeeping. Where this cannot be adequately accomplished, additional protection such as protective clothing and protective creams is necessary. The type of protection that will prove effective in each instance will depend upon the nature of the substance or substances involved and the conditions surrounding the exposure.

14. Relatively few toxic substances are readily absorbed through the skin in dangerous amounts; but it is always wise to treat all liquids, sludges, etc., as though they were dangerous unless they are definitely known to be harmless under the conditions involved. Fatal poisoning can occur from short exposure of large skin areas to strong concentrations of a few substances as for example, aniline, tetraethyl lead, and hydrocyanic acid. Chronic poisoning can occur from or be aggravated by continued slight exposure of the skin to such substances.

15. A very large number of substances are corrosive, i. e., will attack the skin directly. Chief among these are the commonly used strong acids (sulphuric, hydrochloric, muriatic, nitric, and hydroflueric,) familiar alkalies, (caustic soda, caustic potash and lime), the halogens (chlorine, bromine, fluorine), phenol (carbolic acid), and various compounds or derivatives of these basic substances.

16. A great many substances used in industry can cause or promote skin disease (dermatosis). Corrosives too weak or too dilute to destroy the outer skin directly, can often, through continued contact, reduce the normal resistance of the skin against the attack of ever-present bacteria. Such solvents as gasoline dissolve the fatty protective substance from the skin and thus promote drying and cracking and open the way for bacterial attack. Many vegetable and animal products furnish conditions particularly favorable to bacteria and thus increase the hazard. Available data from the reports of state compensation authorities indicate that at least half of the total of disabling occupational health injuries are due to various forms of dermatoses.

Ingestion

17. Ingestion as a factor in occupational disease is important chiefly in that even minute amounts of the more toxic substances swallowed daily in addition to the amounts breathed in, may add up to chronic poisoning. When dealing with such highly toxic substances as many of the compounds of lead, arsenic or mercury, every means must be taken to keep the poison out of the human system. Every possibility of swallowing any of the substances in question must be guarded against in every practicable way.

18. Some portion of practically every air contaminant breathed in through the mouth may become mixed with the saliva and swallowed. Therefore, control of air contamination eliminates or greatly reduces ingestion from this source. It is also necessary to guard against the possibility that toxic substances may reach the mouth through contaminted food, drinks, smoking and chewing tobacco, and chewing gum. Food should neither be kept nor eaten in toxic surroundings. Drinking water should be furnished by the angle jet type of sanitary fountain only. Soft drink, candy, gum, cigarette dispensers, etc., offer a hazard if there is any chance of toxic dust settling on them or their contents. Smoking on the job offers the extra hazard that the cigarette or tobacco carried by the worker may become contaminated. Chewing tobacco is particularly likely to become dangerously contaminated. Washing the hands thoroughly before eating is obviously essential. Before leaving, workers should take a bath and change to street clothing, leaving their working clothes on the premises. These should be laundered frequently.

Harmful Environmental Exposures

19. While the great majority of the serious health disabilities in industry are due to the use of poisons or otherwise injurious substances, a substantial total of health impairment is due to adverse environmental conditions. For the most part, these are cumulatively damaging rather than disabling. Some, however, can bring lingering disability or death; for example, X-rays may cause cancer or sterility, excessive heat may cause "heat stroke"; excessive exposure to ultra-violet light can cause visual impairment.

20. The environmental conditions that-when sufficiently unfavorable, can cause physical injury-include

Excessive fatigue
Excessive noise
Sustained vibration
Defective lighting
Excessive temperature
Dampness inducing chill
Uncontrolled radiant energy
Abnormal air pressure (work in compressed air)

21. *Fatigue.* While overfatigue can seriously injure health, it cannot be accurately measured. General limits of performance which it is not safe to exceed, cannot be set. However, unless a proper and fairly definite relationship is maintained between sustained activity and rest, overfatigue will occur. If fatigue is continued long enough, it will injure the most rugged constitution. Fatigue can be both mental (or nervous) and physical (or of the body). Other things being equal, disagreeable activities either mental or physical are more rapidly tiring than are enjoyable ones. Every one should seek, as far as possible, to maintain a relationship between his activity and his rest that brings him refreshed to each new day. Employers should seek to arrange the work load on each employee at a level such that there is no appreciable carryover of fatigue from one day to the next. Work so exhausting that a reasonable night's rest is not sufficient to restore well being, will, if continued long enough, cause health injury. The hours may be too long, the pace too swift, operative procedure too tedious, the intensity of effort too great, etc., but whatever the details, once persistent over-fatigue has been demonstrated, some corrective action should be taken. Of course, the employee must cooperate reasonably by so governing his non-work activities as to maintain reasonably adequate rest periods and avoid harmful excesses.

22. *Vibration and Physical Shock.* Long continued intense vibration and physical shocks can cause nerve injury with more or less loss of muscle function. Long exposure to the condition is required and the disability usually yields to rest or change of work. *Example - finger or arm stiffness from air hammer operation.*

23. *Noise.* Repeated loud or sharp noises or intense sustained noise can affect the nervous system unfavorably, producing a nervous condition that in some cases amounts to hysteria. Noise exposure also contributes to fatigue. Sufficiently intense noise can in time produce deafness. Old boiler shop workers are likely to be partially deaf. The same is true of aviators. Fortunately, sound intensity is measurable and enough is known about safe levels of sound to enable competent technicians to advise corrective measures in specific cases.

24. *Lighting.* The correct functioning of one's eyes is so important, and their connection with the central nervous system is so intimate, that anything that affects the eyes adversely affects one's whole system. Lighting should furnish a level of illumination adequate to allow the seeing task in question-provided vision is normal-to be performed efficiently without any sense of eye strain. There should be no glare, no shadows nor sharp differences in light intensities, no continuous or unduly frequent flickering or flashing. An American standard lighting code* has been developed by a committee of highly qualified technicians. It has received wide acceptance in industry.

25. *Temperature, humidity and air motion.* The human system functions best with comfort within a rather narrow range of temperature and humidity**. For ordinary light work this range is from about 55° F with humidity 55% to 70° F with humidity 30%. This is called the comfort zone. As temperature increases above this zone the factor of humidity becomes increasingly important. Heat stroke can probably occur with the temperature as low as 80° if the humidity is high enough. The higher the humidity the slower the rate of evaporation of perspiration. Evaporation uses up heat and that is why "sweating cools one" if the sweat can evaporate quickly. Perspiration is the device by which the body keeps its own temperature down. Air motion helps by increasing evaporation. Some air motion is necessary for comfort even in the comfort zone. Too much air motion (drafts) can chill the body; a condition favorable to colds and pneumonia. The same applies to too low working temperature and too rapid temperature drops. Men exposed to high temperature or on work on which they sweat heavily should bathe and change to dry clothing before being exposed to cold as on leaving work in winter. Discomfort experienced by workers on hot work is a useful but not an infallible guide as to hazardous exposure. However, maintaining a reasonably comfortable condition is always on the side of efficiency.

26. *Dampness.* Continued exposure to wetness underfoot and the wearing of wet clothing lowers resistance to colds, and respiratory diseases, and may promote certain types of dermatoses. There are few locations in industry in which these conditions cannot be effectively controlled by such measures as the prevention of spillage, floor drainage, floor racks or the provision of water resistant clothing.

27. *Radiant Energy.* Various types of radiant energy can be harmful. For example, the X-ray can produce cancer, sterility or destruction of tissue (burns). The safe limits for the more serious of these exposures have been fairly well established, however, and should not be exceeded. Each X-ray installation should be checked by a technician competent in this field. Radium exposures are similarly hazardous. Ultra violet light, the cause of sunburn, if intense enough, will burn the skin and is particularly injurious to the eyes.

**Available from American Standards Association, 70 E. 45th St., New York City.*

***By humidity is meant relative humidity that is the percent of air saturation; for example 55% humidity means that the air has 55% of the moisture it could hold at the given temperature.*

ultra violet rays from an electric arc will cause eye inflammation in a single intense flash. That is why protective filter lenses must be worn in all electric welding. The ultra violet rays must be cut off and the intensity of the light as a whole reduced. Gas (or flame) welding produces little ultra violet but the welder must wear eye protection that will reduce the intensity of the light.

28. *Air pressure.* Work under air pressure, such as in caissons or diving apparatus, puts the human system under such a strain that only persons in excellent physical condition should work in compressed air. Some nitrogen is always absorbed into the blood through the lungs together with the oxygen. As the air pressure increases, the ability of the blood to absorb nitrogen increases. If, after being under pressure a while the pressure is reduced too quickly, some of the extra nitrogen which has been absorbed will form bubbles which are likely to obstruct the blood flow and cause cramps, "the bends". In severe cases, paralysis, or even death, may result. Therefore, in all work in compressed air the pressure must be reduced gradually enough to keep the bubbles from forming. Definite schedules of decompression have been worked out for various pressures and should always be followed.

THE APPRAISAL OF HEALTH HAZARDS

29. The factors that determine whether or not injury will probably result from any given exposure can be stated quite simply, but the making of an analysis adequate to guide proper corrective action usually requires the services of an experienced industrial hygienist engineer. However, any person reasonably familiar with industrial processes can readily learn to recognize conditions likely to spell danger. He can improve or correct many of these conditions by application of well-established procedures or by the use of devices of proved effectiveness or both. He can learn when it is advisable to call upon the specialist and can also learn to maintain the effectiveness of the control measures prescribed by the latter. The purpose of this part of this discussion is to present the briefest form the principles on which health hazards appraisals are based and indicate the methods used in making them.

Whether or not injury results and its nature and degree will be determined by—

(a) The nature of the substance or injurious influence involved.
(b) The intensity of the exposure.
(c) The length of the exposure.
(d) The susceptibility of the person exposed.

Nature of Substance or Exposure.

30. Obviously, the nature of the substance or substances involved is of first importance. A very large and steadily increasing variety of substances capable of causing injury is being used in industry. The degrees of hazard these offer vary from the mildest to the most acute, but adequate safeguards can be thrown about the use of any or all of them. To do this, however, it is necessary to know the properties of the substance in question, and the manner of its attack on the human system. This brings up the next point, i.e., that before any new substance is brought into use, its properties should be determined so that all necessary safeguards can be applied. The responsibility here is twofold; namely:

(a) The employer making use of a possibly hazardous substance new to him should secure full information as to its properties and set up all needed safeguards about its use by his employees.
(b) The producer of a new product should obtain and supply to every purchaser the information necessary to guide its safe use.

31. If the possibly harmful exposure in question is environmental (not due to a specific substance), the appraiser must still consider the nature of the exposure. While there is no novelty in excessive noise or heat or light, etc., our continually changing and developing industry occasionally introduces such influences in new ways, thereby necessitating new or improved methods of control. More important is the fact that recognition of their adverse influence on health has been slow to develop. This is undoubtedly due to the further fact that the injury produced is seldom distinguishable from health damage of non-occupational origin. For example, excessive noise tends to injure hearing, but it will not always do so. Furthermore the level at which it is likely to do damage has not, been definitely determined. The proper procedure for such environmental exposures is to establish standards that will assure comfortable, healthful conditions and avoid or correct considerable variations therefrom.

Severity of Exposure

32. The more intense the exposure, the shorter the time needed for injury to result. This applies particularly to air contamination. Practically every toxic substance can, and does, become air borne to some degree in

the form of dust, vapor, fume or gas. Therefore it is vitally important in working with the more toxic substances at least, to maintain a close watch of their concentration (in the air of the work place) and keep it at all times within limits that are known to be safe. The factor of severity of exposure applies to the strength of many substances, particularly those in liquid form. In a very real sense also, it applies to such environmental influences as sound, heat, humidity, etc.

Length of Exposure

33. The third governing factor, length of exposure, is significant in two ways, that is, for a single exposure and for repeated exposures. Some substances (for example, carbon monoxide in non-lethal concentrations) produce little or no continuing injury; with such substances, therefore, the shortest exposure that may injure for any given concentration, furnishes a fairly satisfactory guidepost for safety. This, of course, assumes in addition a reasonable allowance on the side of safety to guard against errors of measurement. The majority of toxic substances are more or less cumulative in their action; that is, part at least of the substance taken into the body will remain for a time and successive daily or frequent exposures may ultimately result in definite injury, usually permanent. Therefore, with substances of this type both the single exposure and the sum of a series of exposures must be considered in appraising the hazard.

Personal Susceptibility

34. The resistance that the body offers to specific substances or harmful influences varies as among individuals. Also, for any given individual, resistance may vary from time to time. This variation is spoken of as personal susceptibility and is of particular importance in the field of dermatoses. Some few individuals are particularly susceptible to certain substances or to extended exposure. Sometimes a single severe exposure may produce sensitivity in persons previously showing normal resistance.

Measuring Air Contamination

35. It is obvious that the damage done by a given toxic substance will depend chiefly upon the amount taken into the system. Therefore, the amount (weight) of it in a given volume (cubic feet) of air will give a measure of the hazard involved in breathing air containing it. But for some substances--notably silica and asbestos--the hazard may best be judged by determining the number of particles that can get into the tiny air cells in the lungs. For that reason, the hazard of such dusts is measured by counting the number of particles smaller than 10 microns (1/2500 in.) in size, because particles larger than this are relatively few; they settle quickly and if breathed in are for the most part caught by the tiny hairs (cilia) that line the lung passages and are finally coughed out. Dust determination by either the weight or counting method requires the use of special equipment and highly specialized knowledge and skill. In most of the States, industrial hygiene units in the health or labor departments offer this service. Some commercial research laboratories render such services for a fee. A few large industrial firms are staffed and equipped for this work in their own plants.

36. Dust counts are given in terms of millions of particles per cubic foot of air. Large numbers of dust particle are present in even the purest air. Counts of one-half million or more are normally found in homes and in buildings of ordinary occupancy; 100 millions and more are not uncommon in industry. Anything above 50 million particles per cubic foot of air has become generally accepted as unsafe for even the most innocuous dusts. Some authorities would set this limiting figure substantially lower. Five million particles per cubic foot is considered the maximum allowable for continuous exposure to dust containing over 40% of free silica. Some authorities prefer a figure of three million particles of free silica as the maximum.

37. Dust that is visible in the absence of a beam of sunlight (or similarly intense light ray) usually indicates a high dust concentration, hence the common saying "If you can see the dust, there is too much of it." This is not an infallible guide, but safety is definitely on the side of eliminating visible dust.

38. Gas and vapor concentrations are measured by means suited to the nature of the substance in question. In some cases, satisfactory methods have not yet been worked out, but the substances of common occurrence can be adequately measured. Instruments are available that measure the concentration of combustible gases and give direct readings--these depend upon the heat produced by the combustion of the gas in question and, therefore, must be calibrated for any given gas. They will measure exceedingly small concentrations and can be made to ring an alarm, start exhaust fans, operate furnace controls, etc. Example--carbon monoxide control systems in garages and highway tunnels which cause the carbon monoxide to announce its presence at a given concentration and to keep itself under control by operating the fans as they are needed.

The Health Hazard Survey

39. The first step in appraising health hazards is to find the hazards. The survey should be made by technically qualified persons and normally involves the following steps:

    (a) *Securing a complete list of the materials used.*
    (b) *Making a study of the processes involved to find hazard points.*
    (c) *Determination of the nature of the products, byproducts and wastes produced.*
    (d) *Analysis of the possibilities of explosion, fire breakout, or other untoward occurrences.*

    Purchasing department and stock room lists will, in the well-managed plant, include all materials and products brought in from outside. Sometimes, however, such lists are not complete due to the retail buying of certain supplies. Such purchases are likely to include paints, cleaners, solvents, and the like for occasional use. The hazard possibilities involved may be considerable and should not be overlooked.

40. The content of products sold under trade names often offers a problem. Frequently the list of ingredients is obtainable only from the manufacturer. It is important to secure this information, however, especially in the case of such substances as paints, solvents, cleaners, inks, and pigments, whose use may expose workers, to toxic, corrosive or irritating substances.

41. Full knowledge of the materials used having been obtained, the next step is to examine the processes and procedures for possible harmful exposures. Wherever dusts, gases, vapors, mists or fumes are produced, injury is always possible if air contamination is not kept within safe limits for the substances involved. The handling and production of liquids involves the danger of spills, splashing, fuming, and vaporizing. Manual handling of toxic, corrosive, or irritating substances offers specific hazards. The investigator should set down in suitable detail each hazardpoint found. With these located, the means of appraisal of the extent of the hazard and determination of the need for correction will depend upon the nature of the substance or type of detrimental exposure.

42. No analysis would be complete without consideration of all the byproducts and wastes involved. Particularly in the chemical industries, these may introduce hazards other than those connected with the source materials; or their toxicity may be greater.

43. The possibilities of failure to maintain good control of processes and operations should always be considered This will include overheating, explosions, fire breakouts, failure of control devices, failure or reduced effectiveness of exhaust equipment, interrupted power supply, contamination of water supply, and any other factor which might unexpectedly render a normally safe situation hazardous.

METHODS OF PREVENTION

44. There are eight principal methods used for the elimination or control of industrial health hazards, namely:

    (a) *Substitution of less toxic material.*
    (b) *Enclosure of the harmful process (with automatic operation)*
    (c) *Isolation of the harmful process from the remainder of the plant with special protection for workers necessarily included in the area isolated.*
    (d) *Local exhaust ventilation.*
    (e) *General ventilation.*
    (f) *The use of wet methods.*
    (g) *The use of personal protective devices, particularly respiratory protection.*
    (h) *Decreasing the daily exposure through short work periods.*

45. It is usually unwise to rely wholly on any one of these methods. Several should usually be used in combination. The specific measures used in each case should be determined by an industrial hygienist, he should supervise their installation and make periodical check ups to insure their continued effectiveness.

Substitution

46. The plant materials survey should have yielded a complete list of the toxic materials used. In each case, the possibility of substitution of a less hazardous substance should be considerered Many examples could be cited, such as the elimination of toxic white phosphorus in match heads, the substitution of titanium oxide or zinc oxide and sulfide for lead in white paints, or the use of solvents of relatively low toxicity in place of benzene (benzol).

47. The reverse possibility should always be guarded against, namely, the substitution of a more toxic substance. This is especially likely to come about through an effort to save money or processing time without adequate consideration of the hazards possibly involved. A notable example was furnished by the death of several employees of a daily newspaper due to the substitution (in part)of benzol for a less toxic solvent in order to speed up the drying time of the printing ink used. The exhaust system, adequate for the former ink, was inadequate for an ink containing a substantial amount of benzol.

48. Sometimes a substitution of process or change in the process can be made to lessen the expense. Examples--the use of ready mixed lead paints instead of mixing the paint on the job; the application of paint or other protective coating by dipping instead of spraying.

Enclosure

49. Many processes involving the use of toxic substances can be completely enclosed during all or part of the operation to prevent the escape of atmospheric contaminants. A slight negative pressure within the enclosure (by means of a suitable exhaust) will give protection against leaks during the operation. Loading and removing the contents should be mechanical or automatic wherever possible. When this is impracticable one or more of the other methods listed should be so applied. The means chosen should be as positive as possible, thereby eliminating the hazard itself rather than depending upon personal protective devices essentially defensive in nature. Examples--the modern fully enclosed and exhausted tumbler for cleaning small castings; the modern dry cleaning machine for garments.

50. Many processes require enclosure for efficient operation. With these, the problem is one of preventing leakage by proper design and construction supplemented by a high standard of maintenance. Examples--lines carrying hazardous gases or liquids must be designed and constructed to allow for expansion, and all joints, fittings and valves must be excellently maintained. Sand blast booths must be so designed and constructed as to eliminate air leakage and they must also be carefully maintained. In addition, they should be so exhausted under negative pressure as to keep air leakage inward; otherwise leakage will carry dust out into the workroom.

51. Many processes, whose enclosure is not necessary for productive purposes should be enclosed, nevertheless where practicable. In this class are many mixing, screening, and grinding operations, heat treating, cleaning and the like. The test in each instance is--does the process at any stage give off any substance that may contaminate the air? If so, can it be completely enclosed? If not, can a partial enclosure combined with exhaust be applied? Examples--dry grinding mills, rubber compounding mills, cyaniding kettles, lead pots, plating tanks, degreasers.

ISOLATION OF THE PROCESS

52. Some types of hazardous processes may endanger workers other than those directly concerned with the process. Such processes can be isolated in a separate building or carefully sealed off area with suitable specialized protection provided for the workers required for the process. The sand blast booth with the operator inside (wearing his supplied air helmet, etc.) furnishes an example of the application of this method to a single job.

LOCAL EXHAUST VENTILATION

53. Air pure enough to breathe continuously with safety is an obvious *"must"* if workmen are to retain their health. That it also be not unpleasant to breathe is important in the interest of efficiency and employee morale.

54. The survey should have located the sources of air contamination and the nature of the contaminants. The first effort should be to prevent the contaminating substance from getting into the air. This is, of course, the purpose of enclosure, but wherever this is not practicable or not fully effective, the harmful substances should be trapped at their points of origin and removed by means of local exhaust.

55. The most difficult processes to make safe are ordinarily those which yield toxic dusts, vapors, fumes, or gases, and which must be hand operated. Examples--granite cutting, spray painting, electric and gas welding and cutting; pneumatic drilling in rock. Each of these requires specialized equipment.

56. The manufacturers of exhaust equipment have made great progress in developing devices to meet the commoner situations and they maintain technicians to aid in the solution of special problems. For instance, highly effective spray booths are available. Specialized exhaust devices have been developed which will, if properly applied and maintained, eliminate most of the hazard from granite cutting and rock drilling. The safeguarding of welding is a current problem whose fully satisfactory solution will require further research into the nature and extent of the air contaminants produced. However, it is now certain that existing exhaust devices and existing knowledge if properly applied will eliminate most of the hazard here also.*

57. While the design of exhaust equipment requires a high degree of technical competence, and should be handled only by qualified engineers, certain principles are so generally applicable as to justify their mention here:

(a) *To be effective, the air flow to the exhaust duct must include the entire area liberating the contaminating substance.*

(b) *The shape and size of the hood (and baffles), its position in relation to the work and the air velocity used, should be such as to trap all the contaminants produced and carry them into the exhaust duct and away.*

(c) *The air velocity over the area where the contaminant must be picked up is the significant velocity. In the case of dusts or other solids, the minimum velocity in the ducts must be sufficient to prevent settling-out. Sharp corners, irregularities or other conditions that cause air turbulence reduce efficiency and should be avoided.*

(d) *The air flow should always be away from the breathing zone of the operator. For example, plating tanks should, in general, be exhausted at the back, the air pulled past the operator over the surface of the plating solution and thence to the duct at the back.*

(e) *Advantage should be taken of gravity, where practicable. That is, heavy dusts, fumes, and vapors should be exhausted downward. When heated air is produced as in cyanide pots, furnaces, etc., it should usually be exhausted upward and backward in order to get the benefit of the heat-induced draft. It should not be drawn directly upward unless the operator's station is safely away so that the fumes will not be drawn through any part of his breathing zone.*

(f) *Stack (chimney) suction unaided by forced draft, because of its unreliability, is seldom if ever adequate when toxic contaminants are involved. In any given installation, the amount of suction produced will be affected by the velocity and direction of the wind, the barometric pressure, and the amount and temperature of the heated air produced. Every exhaust system should have at all times a margin of capacity safely above the minimum necessary to remove the maximum yield of contaminating substances. Only forced draft can assure this.*

58. The disposal of the air exhausted from productive processes presents a problem in the case of toxic substances or substances that may create a nuisance such as dust, odors, shavings or lint. Merely discharging the exhausted air outside the building may poison or damage neighbors. Air currents may also carry the contaminant back into the plant through window or other openings. This hazard may be lessened by discharging from stacks carried well above the building roofs, but the unsoundness of thus contaminating the general atmosphere is building up a widespread sentiment against such a practice. In some cases, the contaminant may have considerable value. The general desirability of collecting substances exhausted has led to the development of various types of collecting equipment whose purpose is to separate the contaminant from the air exhausted and enable its recovery or harmless disposal. These are commonly of four types: the cyclone, cloth filters, air washers, and electric precipitators.**

59. Cyclones depend upon the fact that solids carried by air tend to settle out if the air speed is reduced or its direction of flow changed. Therefore, by carrying the main exhaust duct into a large chamber designed to slow the air down as much as possible and at the same time give it a whirling motion, the heavier particles settle out into a collection space at the bottom which can be emptied from time to time. Cyclone collectors, however, are not effective for very fine particles and, therefore, are not adequate for toxic dusts. They are widely used in the wood and textile industries.

60. The cloth filter is what its name implies. The air is passed through filter bags much like those in the ordinary household vacuum cleaner. The bags hang with open end downward so that when the dust builds up sufficiently it can fall into a clean-out space below. The framework supporting the bags can be shaken or jarred from time to time to loosen the collected dust. Frequent inspection and good maintenance are necessary as even a few small holes in the fabric reduce the effectiveness considerably.

* *See American War Standard, "Safety in Electric and Gas Welding and Cutting Operations."*

** *Details are obtainable from the manufacturers of the various types of equipment.*

61. Air washers remove dust by thoroughly wetting it. The air is passed through a series of passages continuously drenched by a fine spray or a mist of water. The dust is carried off in the stream of water or collected in catch basins as a sludge. This method is most effective with dusts that dissolve or with heavy dusts. Some dusts such as coal dust or flue dust are very difficult to wet and hard to deal with by this means.

62. Electric precipitators depend upon the fact that dust particles that can be made to pick up a charge of electricity will thus be attracted to an oppositely charged object or surface. However, the first cost and the expense of operation are high; hence this method is practically limited to cases in which the dust has considerable value.

63. Collectors should always be located upstream from the fan or blower in order to prevent abrasion or corrosion of the blower and to reduce the hazard of explosion--an ever present possibility in exhausting combustible dusts, gases, vapors, or fumes.

64. The technical problems involved in the design and installation of exhaust and ventilating systems and equipment are such that the advice of competent technical specialists should always be secured. This is particularly important when the system installed includes reconditioning and recirculation of the air exhausted, which in our northern climates is quite a saver of heat. In such a system, any failure to remove the contaminant effectively would obviously be most serious. For this reason, many authorities believe that recirculation should not be used at all when toxic contaminants are involved. Others would permit recirculation where highly reliable means of prompt discovery of any drop in effectiveness of the air-purifying equipment is provided and maintained. Indicators of the type mentioned in pp. 38 controlling the mechanical ventilation, can be made to furnish the needed protection against combustible contaminants, such as carbon monoxide (CO) or the petroleum solvents. But for contaminants for which no such devices are available, for example, lead fumes, silica dust, or chlorinated hydrocarbons, recirculation would necessitate practically continuous air analysis to insure safety. The cost of this would in most cases at least, overbalance the value of the heat saving.

GENERAL VENTILATION

65. Operations may be such as to make the use of local exhaust impracticable as, for example, on the casting floor in the ordinary type of foundry. Furthermore, some contaminant may escape even the best local exhaust. Occasional operations such as painting, welding, cleaning, brushing, and grinding may produce a considerable degree of air contamination. Heat, humidity, or odors or a combination of these, may produce an unpleasant or debilitating atmosphere. Therefore, general forced ventilation to provide a continual influx of fresh air is often necessary - or at least desirable.

66. Where the workers themselves constitute the only source of air contamination, an air change of 2 to 4 times per hour is ordinarily adequate. If the air space is over about 400 cubic feet per person, this rate of air change can usually be obtained by natural ventilation. Where construction, location, or arrangement hinders natural ventilation, special means such as siphon type roof ventilators may be necessary to reach this minimum of ventilation.

67. Few workrooms are entirely devoid of sources of air contamination (other than human) and, therefore, the tendency is to raise substantially the limits mentioned above. Experience strongly supports the view that for the average workroom having only moderate sources of air contamination from the limited use of low hazard substances, natural ventilation should be relied on only if the gross cubical contents of the workroom is 2000 cubic feet or more per person. The American Foundryman's Association, in its code of Recommended Practices in Industrial Housekeeping and Sanitation, makes this specific recommendation. The City of Chicago code makes it mandatory. State and city regulatory agencies, either through laws and codes or by corrective orders, frequently accept lower figures but now show a tendency to raise them. They generally require ventilation rates of from 20 to 70 cubic feet per minute per person or from 6 to 40 air changes per hour,. depending upon the exposure or occupation.

WET METHODS

68. The use of a suitable liquid, usually water, is often practicable to keep dust down. It is also helpful in some cases in removing soluble vapors such as those of alcohol. However, fine dust particles and fumes are difficult to wet. Also, the wetted particles may be redispersed if the liquid dries up. It is often difficult to wet all the material and keep it wet without using too much liquid and thus creating a sloppy,

and, therefore unsatisfactory or unsafe condition. In spite of such limitations, the reasonable use of moisture in such operations as grinding, drilling, loading or handling dusty materials and sweeping will, often at least, reduce dustiness. For example, wet drilling substituted for dry drilling in typical quarrying operations has been shown to reduce dust concentrations, from some 560 million* particles per cubic foot of air to 30 million particles. Wet methods are particularly helpful in foundry operations.**

PERSONAL PROTECTIVE DEVICES

69. Personal protective devices have one serious weakness, that is, they do nothing to reduce or eliminate the hazard. They merely set up a defense against it and any failure of this defense means immediate exposure to the hazard. The fact that many protective devices can be or can become ineffective without the knowledge of the wearer is particularly serious. All of which justifies the dictum that personal protective devices must be regarded as of an emergency or temporary nature only, supplementary to suitable preventive measures, but never in preference to them.

70. Personal protective devices to protect against harmful substance may be classified as

Respiratory protective devices
Protective wearing apparel
Protective creams, lotions, etc.

Respiratory Protective Devices

71. To insure the effectiveness of respiratory protective devices, the U. S. Bureau of Mines tests and approves such equipment. By January 1944 approvals had been issued for various types of devices in all the classifications discussed below. Only those approved by the Bureau of Mines should be used, as such approval constitutes the only authoritative proof of their effectiveness. Lists of approved devices may be obtained from the U. S. Bureau of Mines, Washington, D. C. upon request.

72. All these devices have two things in common; they are more or less uncomfortable to wear and they reduce efficiency. It is difficult to secure and maintain faithful performance in their use. If the lessened efficiency (plus absenteeism and turnover due to such a situation) could be measured in terms of cost, it would probably, in most cases, show very clearly that substantial expenditures to eliminate the hazard are justified.

73. Respiratory protective devices are of two types--

(a) Air purifying - which removes the contaminant from the air as it is inhaled by filtering or by chemical absorption.
(b) Air supplying - which supplies clean air from an outside source or oxygen from a tank carried by the wearer.

74. It is important that the type of respirator used be correct for the hazard involved. Approvals and manufacturers' directions (for the use of approved devices) always describe the protection afforded and these should be heeded. For example, the ordinary dust respirator is not effective against lead fumes or gases; the gas mask designed to protect against ammonia alone does not protect against carbon monoxide; only the supplied air types protect against an atmosphere deficient in oxygen or one in which the content of toxic gases is too high for the capacity of the air-purifying type of respirator.

75. The safe and correct use of all types of respiratory protection requires careful attention to many details and the unfailing observance of rules for safe procedure. Full details of types approved by the Bureau of Mines should be obtained from the manufacturers, thoroughly mastered and fully complied with.

76. Air Purifying Types. These are classified as--

Dust Respirators
Chemical cartridge respirators
Canister gas masks

* *Bloomfield, J. J., Industrial Safety, Prentice-Hall, New York City.*

** *"Dust Control in Foundries" Division of Labor Standards, U. S. Department of Labor, 1940*

77. The dust respirators filter dust particles out of the air by means of a filter, usually of treated paper or felt. The filter is mounted on a face piece, or half mask, covering nose and mouth and fitting closely to the face to avoid air leakage. The better types include a valve which opens to release the exhaled air. The construction of the facepiece must permit of sufficient adjustment to fit the contour of the face, and it must be faced with resilient material to provide a seal with comfort. Soft cotton facepiece coverings called *"facelets"* are helpful to prevent skin irritation, especially for irritating dusts such as lime.

78. The particles strained out by the filter, gradually clog up its pores and thus increase breathing resistance. When breathing resistance becomes so high as to be uncomfortable, the filter should be changed.

79. *Chemical Cartridge Respirators.* These are quite similar in design to dust respirators. A cartridge (or twin cartridges) containing a suitable chemical (or chemicals) is substituted for the filter. The chemical used will depend upon the gas or group of gases against which it is designed to give protection.

80. It is important to remember that cartridge respirators can carry but small amounts of chemical and, therefore, are effective for light concentrations of gases only and for limited periods of time. It is unsafe to depend upon them in concentrations of acid gases higher than five hundredths percent and for organic vapors higher than one-tenth percent. This makes them entirely unsuitable for any use, where high concentrations may exist.

81. *Canister Gas Masks.* These carry larger amounts of chemical and afford protection against higher concentration and for longer periods of time. They consist of a facepiece, corrugated connecting tube, canister and harness. The large canister permits a larger combination of chemicals thereby affording protection against a wider range of gases. The all-service type is designed to protect against low concentrations of all types of industrial gases, smoke and fumes.

82. Canisters are approved for use in concentrations of not over two percent of most gases, for ammonia not over three percent. Only the supplied air type of respirator should be used for higher concentrations. Each canister will give protection for a period of time dependent chiefly upon the concentration of the gas, the rate of breathing, and the age of the canister. As it nears exhaustion, a trace of gas will leak through, which, if the gas has a distinctive taste or odor or is irritating, will give at least some warning of impending failure to protect. The all-service mask includes a timer which records cumulatively the time of use and thus give the careful wearer warning against its exhaustion even in the case of carbon monoxide which is odorless, tasteless, and non-irritating.

83. *Supplied Air Respirators.* These consist essentially of a facepiece or helmet to which air from a suitable outside source is supplied through a hose, or combination of hose and pipe line. The types used are hose masks, air line respirators and oxygen breathing apparatus.

84. *Hose Mask.* This consists of a full mask facepiece with large diameter hose to which air is supplied by a hand operated blower or a small power driven blower. A sturdy harness furnishes an anchor for the hose line and for a life line by means of which the wearer can, if necessary, be drawn back to safety.

85. Hose masks are the simplest and safest form of protector for many situations in small areas (150' is the maximum permissible length of hose line). They are particularly useful for work in tanks, bins, pits, wells, the holds of vessels, etc. They should not be used where the wearer could not reach safety if the air supply was cut off. It is emphasized also that for substances (as HCN) that can be absorbed through the skin or those that attack the skin directly as acid fumes suitable additional protection is necessary.

86. *Air-Line Respirators.* These are for use with compressed air. A valve to control the air flow is therefore added and the air line is of relatively small diameter. They are unsafe for an atmosphere from which the wearer could not escape in event of failure of the air supply. They are satisfactory for exposures of the type for which chemical cartridge or mechanical filter protection may be used.

87. In sand blasting, metal spraying, or other operations for which complete head and neck protection is required suitable protective helmets are used. The fit should be tight enough in relation to the volume of air flow to prevent any leakage of contaminated air into the helmet.

88. *Air Supply.* Great care must be taken to insure a pure air supply. The area around the air-hose intake should be looked over carefully for possible sources of contamination such as gasoline or diesel engine exhausts (including automobiles and trucks), smoke or gases from furnace stacks, dusts, chemical fumes, etc.

When compressed air is used, this applies to the intake of the air compressor. Compressed air is likely to contain the fumes of the oil used to lubricate the compressor valves; it may also contain dust, moisture and odors and under some condition, carbon monoxide. Therefore, an air purifier which will safely remove all of these substances is necessary. Very careful and adequate maintenance and operation of both compressor and purifier are vitally important. For these reasons the provision of a separate motor driven blower is definitely preferable.

89. *Oxygen-breathing Apparatus.* The wearer breathes oxygen from a high pressure tank which he carries and is thus entirely independent of the outside air and limited as to scope of action only by the supply of oxygen he can carry. Both 1-hour and 2-hour sizes are used. Their chief use if for rescue and emergency repair work in mines, fighting fires in tunnels, ships, etc., entering storage tanks containing volatiles, entering sewers, gas holders, etc. and similarly high hazard situations. Special training is necessary for their safe use.

90. *Maintenance.* No matter how well a respiratory protective device is designed and made, unless it is properly cared for and maintained in good condition it will fail to give protection or be otherwise unsatisfactory. Therefore, when the need for such devices is determined upon, the planning should include full provisions for their careful and unfailing maintenance. This should include inspection, repairs, replacement of used filters, cartridges, and canisters, cleaning and sterilization, etc.

91. *Acceptance by Workmen.* At best, a respirator of any type is more or less uncomfortable to wear and a nuisance. Unless workmen realize fully the need of the protection, they will not wear them faithfully. Important factors in getting full employee cooperation in this respect are--

(a) *Recourse to respiratory protection only as an emergency, a temporary, or a final method after every effort has been made to eliminate the hazard.*
(b) *Explaining the situation fully to the workmen involved.*
(c) *Careful fitting of respirators, etc.*
(d) *Adequate provisions for maintenance and cleanliness.*
(e) *Careful instruction as to use.*
(f) *Intelligent fully informed supervision.*
(g) *A respirator once issued to a workmen should be reissued only to him as long as he has use for it. Those released through labor turnover or transfers should be fully reconditioned, sterilized and returned to stock.*

Protective Wearing Apparel.

92. In all work with substances that attack through the skin or attack the skin itself, protective clothing may be used to advantage to lessen skin contact. It must be suited to the nature of the substance, the exposure involved and the kind of work done. The material of which the garment or protective article is made must be resistive to attack by the substance in question, must not absorb it to any extent or be easily penetrated by it, must be cleanable and should have reasonable wearing qualities. The garment or article must be as comfortable as possible. For women workers, the factor of appearance is important.

93. The names of manufacturers of protective wearing apparel may be obtained from the advertisers' lists of current safety journals or from the directories of manufacturers. Garments and articles of common use include head coverings, coats and jackets, aprons, coveralls, trousers, gauntlets, hand and finger protectors, leggings, boots and shoes.*

Protective Creams and Lotions

94. There are a number of preparations on the market designed to protect the skin against attack. Their effectiveness varies, but properly selected and correctly used, they may be very helpful. They should never be relied on in lieu of positive means of preventing or reducing skin contact; but since in work with any substance some contact with at least the hands and arms in inevitable, this type of protection may constitute a worthwhile aid to prevention.

95. In each instance it is essential that—

(a) *A cream or lotion effective against the substance or substances involved be selected upon competent medical advice.*
(b) *The employees involved be carefully instructed as to the value of the protection and in its proper application.*

* *Also see American Standard Safety Code for Protective Occupational Clothing L-18-1944.*

(c) Adequate facilities be provided for washing and for change of clothes necessary to eliminate all contact with the substance in question during offtime.

(d) The worker cooperate by careful personal hygiene; at the very least washing thoroughly before eating and at the end of each shift.

LIMITING THE PERIOD OF EXPOSURE

96. As a last resort where other methods do not reduce or control the hazard sufficiently for safety, the daily period of exposure can be limited. Work under compressed air furnishes an excellent example of this. Schedules of maximum length of shift and length of decompression period for all workmen under air pressure have been worked out. The higher the pressure the shorter the shift and the longer the decompression period. These are coupled with adequate medical supervision and careful selection of personnel.

97. The same principle is applied to work with lead and some other highly toxic substances both by limiting daily exposure and by rotation of the workmen between hazardous and hazard-free jobs on a schedule suited to the needs of the work and the nature of the substance involved.

98. This method is often so easy and inexpensive (in first cost) to apply that it is apt to be resorted to in lieu of measures to remove or reduce the hazard. Such a course is likely to prove very unsound in the long run. For instance, a manufacturer of lead storage batteries who used this method for a longtime was finally forced to rebuild his plant to reduce the hazard because of suits brought by former employees who suffered permanent but not immediately disabling injury in his employ.

MEDICAL SUPERVISION

99. Medical supervision is an essential part of any adequate program of prevention when such relatively high hazard substances as lead, benzol, or silica are involved. As experience grows, it becomes more and more clear that a good degree of medical supervision of worker health would be of benefit to both employees and employer in at least the great majority of plants. While serious health hazards are limited to relatively few plants, milder hazards are quite widespread throughout industry and constitute a drain on the health of large numbers of workers. While in most cases these are in general non-disabling, both employees and employers would gain greatly by their elimination.

COMMON INJURY-PRODUCING SUBSTANCES

100. Potentially hazardous substances used in industry are numbered in the thousands and the total is constantly increasing. Only a moderate number are widely used however. This discussion deals with only those deemed to be of major importance.

The Metals and Metalloids

101. *Lead.* Lead is so widely used and so widely distributed throughout the earth's surface that there are minute traces of it in most drinking water and in many foods. Therefore, we are all continually getting very small doses of lead without harm because the system can eliminate these small quantities. Poisoning can occur only if the lead intake becomes greater than the capacity of the body to eliminate it. When the physiologic tolerance each person possesses is exceeded, the symptoms of lead poisoning appear.

102. The majority of lead poisoning cases result from breathing dust or fumes. Lead may also be swallowed through contamination of anything taken into the mouth. Some organic lead compounds, for example, tetraethyl lead, may be absorbed directly through the skin.

103. The fact that unless a massive dosage is received, lead poisoning develops gradually makes it particularly important to maintain close medical supervision over all persons exposed to lead or its compounds in any form. Such supervision should be additional to all practicable preventive precedures, never a substitute for them. The earlier the detection and treatment, the better the chance of cure.

104. Lead usually attacks the blood-forming organs though it may also affect practically any part of the body. Early injury can usually be detected by blood and urine analysis. Persons working with lead in any form and not under medical supervision should promptly consult a physician upon any of the following warning signs—*gradually increasing weakness, frequent headaches, dizziness, constipation, loss of appetite and weight, pallor, diffuse abdominal cramps (colic), joint pains.*

105. Preventive methods include primarily—

(a) Removal of lead dust or fumes at their points of origin by exhaust ventilation.

(b) Detailed care in designing equipment, arranging processes and methods of work to eliminate spillage, hold handling to a minimum and avoid conditions and practices that might carry or throw lead dust or fumes into the air.

(c) Maintenance of a high standard of cleanliness by good housekeeping, vacuum cleaning and wet sweeping, preferably done after working hours.

(d) The use of non-absorbent smooth surfaced material for floors, walls, benches and all other structural surfaces.

(e) The provision and faithful use of facilities for personal cleanliness; shower baths with hot and cold water, individual towels, separate lockers for work and street clothing.

(f) Lunchroom facilities separate from workrooms with provision to keep all food and drink free of lead contamination. Eating in workrooms should be prohibited.

(g) Maintenance of frequent testing of the air of workrooms for lead. Concentration of lead should be kept below 1.5 milligrams per 10 cubic meters (353 cubic feet) of air.

(h) Maintenance of close medical supervision to detect signs of incipient poisoning, together with medical reexamination at least every 6 months, of all workers exposed to lead.

(i) Maintenance of complete detailed records of all medical findings on each worker.

(j) Full instruction of each employee as to the procedures he should follow and the precautions he should take.

(k) Maintenance of a definite system of safeguarding workers who, dispite all preventive precautions, show too great a lead intake. Measures used include transfer to work involving lesser exposure, reduction in hours of lead exposure, special diets, assistance in securing other employment.

(l) PROVISION OF APPROVED RESPIRATORY PROTECTIVE EQUIPMENT FOR EMERGENCY EXPOSURES FOR WHICH OTHER MEASURES ARE NOT ADEQUATE. MAINTENANCE OF SUCH EQUIPMENT IS A CLEAN AND EFFECTIVE CONDITION AT ALL TIMES.

106. *Arsenic, Antimony, Cadmium, Manganese, Mercury*--These and other less commonly used metals or metalloids require precautions similar to those for lead. All of these substances poison the worker chiefly through inhalation in the form of dust or fumes. Like lead, all may affect practically any part of the body or bodily function and the injury once acquired tends to be chronic. Manganese is primarily a nerve poison usually evidenced by peculiar gait and tremors. Arsenic poisoning is ordinarily characterized by skin eruptions or a bronzy skin discoloration and loss of hair. Mercury poisoning is usually very gradual. Its early signs are sore mouth with excessive watering, loosening of the teeth, tiredness, lessening appetite and tremors. Metallic mercury is particularly hazardous, because it vaporizes to some extent at room temperature and fumes quickly on heating and because of the ability of liquid mercury to combine with or adhere to other metals or be absorbed by other substances. Only the most through-going preventive measures carefully followed will prevent poisoning. The compounds of mercury or arsenic are as a rule highly toxic and special precautions are necessary to their safe handling. Close medical control is important for all exposed workmen. Air analysis is similarly important.

107. *Chromium.* Certain of its compounds have a caustic action. They attack particularly through cracks or abrasions in the skin, to cause ulcers (commonly called "chrome holes") on hands and arms, and perforate the septum of the nose. Preventive methods of chief applicability are—

(a) The design of processes and equipment to eliminate as far as possible splashing, drippage, spillage, spattering and fuming.

(b) Removal of fumes or dust at their points of origin.

(c) Elimination of skin contact as far as possible.

(d) Provision of protective clothing, particularly boots, gloves aprons for those working with chromium solutions.

(e) Provision of protective ointments for the use of workers exposed.

108. Cadmium, once rarely used, is becoming more common as an anti-rust plating. It is highly toxic. Its fumes or dust attack the lungs chiefly. It melts and fumes at a slightly lower temperature than does lead. Operations in which its fumes or dust may be produced must be effectively exhausted or other effective means of preventing air contamination from it must be provided.

109. *Metal Fume Fever.* When considerable amounts of the fumes given off by highly heated metals are breathed, they are likely to produce metal fume fever commonly known as "zinc chills," "brass founders ague," or "zinc oxide chills." The symptoms, setting in several hours after exposure, are a dryness in the throat and a feeling of weakness and nausea followed by chills and fever, profuse sweating and increasing weakness. If toxic metals such as arsenic or lead are involved, the types of poisoning characteristics of these substances will follow the chills. If the metal in question is non-toxic (as zinc) full recovery usually follows within a day or two. Continued exposure to such non-toxic fumes builds up an immunity to them which, however, lasts for only about 5 days after exposure ceases.

110. *Industrial Skin Diseases (Dermatoses.)* Skin diseases resulting from industrial exposure may occur in almost any field of work. Any foreign substance can be irritating if it is in continuous contact with the skin. Skin irritations most frequently result from contact with poisonous or irritating chemicals, oils, greases and the resins or juices of certain plants and from many varieties of bacteria. The majority of dermatoses are due to chemical agents. These may be classed as primary irritants or substances that will burn, corrode or otherwise attack the normal skin directly; as specific irritants* or substances that will cause dermatoses in hypersensitive persons only; as sensitizers or substances that render the skin more sensitive to attack, that is, the dermatoses develops only after extended exposure, reexposure brings prompt return of the dermatosis. Definite ways in which dermatoses are caused may be classified as—

(a) Chemical irritants or caustic agents may harm the skin directly.

(b) Substances, such as naphtha, petroleum, or benzol, that dissolve and remove the natural oil of the skin cause irritation and create a condition favorable to infection.

(c) Oil and grease may injure the skin by blocking the pores and hair follicles thereby introducing infection.

(d) Scratching, brushing, or constant rubbing of the skin injures it and opens the way for infection.

111. There are great differences among people; in some individuals the skin is easily irritated by contacts quite harmless to others. The warning signs are so varied that it is impractical to list them all here. Early irritations are usually shown by a slight reddening of the skin with itching and burning. Blisters, swellings, and frequent boils may be the first signs of industrial dermatosis. These signs are usually limited to exposed parts of the skin.

112. Preventive measures include the—

(a) Reduction of skin contact with irritating or otherwise harmful substances to the minimum by suitable handling methods, adequate equipment, process layout and arrangement, the elimination of spillage, drippage, spattering, etc., good housekeeping and close control of operations.

(b) Elimination of dust and fumes by effective exhaust ventilation at all points of origin.

(c) Provision of suitable protective clothing and protective equipment as boots, gloves, aprons, shields, et

(d) Provision of adequate washing, bathing, and locker facilities and the use of protective creams, lotions or ointments suited to the nature of the exposures involved.

(e) Instruction of workers as to the hazards involved, the precautions they should take, and the practices they should follow.

(f) Maintenance of medical supervision adequate to the exposures involved.

113. *Corrosive Chemicals.* A large number of substances attack the skin directly, causing chemical burns. Chief among these are the commonly used acids and alkalies. The corrosiveness varies with the concentration or condition of the substance. For instance, a strong solution of hydrofluoric acid will burn deeply almost instantly upon contact. Some grades of certain acids "fumes" particularly nitric acid. These fumes are highly corrosive. Nitrous fumes are especially hazardous. Breathed to any considerable extent, they may cause lung damage that can be fatal in a matter of hours. Even the milder corrosives and the most dilute solutions of the acids and caustics may cause chronic skin irritation if the exposure is continuous enough. Example—the chapped sore hands frequent among cleaning women and laundresses.

114. Chemical burns of the eyes are especially serious. Not only do the eye tissues "burn" easily, but injuries that would be relatively inconsequential elsewhere are likely—especially if neglected—to result in serious or even total loss of vision.

115. Prevented measures are similar to those listed for dermatoses with especial emphasis on—

* *Occupational diseases of the skin - Schwartz and Tulipan.*

(a) Prevention of spillage and spatterings:

(b) Safe methods of handling:

(c) Adequate personal protective equipment and clothing:

(d) Emergency provisions such as--

(1) QUICK OPERATION DE[illegible]-SHOWERS, FOOT TREADLE TYPE

(2) EYE [illegible]S. BUBBLE FOUNTAIN FOOT TREADLE TYPE

(3) RESPIRATORY PROTECTIVE EQUIPMENT FOR USE IN ACID CHAMBERS, TANKS, ETC., OR IN CASE OF MAJOR BREAKOUT,

116. *Volatile Solvents.* All the commonly used volatile solvents are toxic in some degree. Benzol (benzene) is highly toxic. Its kindred substances, toluol (toluene) and xylol (xylene) are less volatile and less toxic, hence considerable less hazardous to use. Wood (methyl) alcohol or methanol is a strong poison. Other alcohols vary widely but in general are less toxic. The petroleum solvents (the naphthas, gasoline and the trade name compounds such as Stoddards solvent) are relatively non-toxic. However, caution should always be exercised with solvents whose complete make-up is not given, since trade name compounds may contain percentages of benzol or other highly toxic substance. Also "commercial" grades of any of the relatively non-toxic solvents whose purity is not guaranteed, may contain a considerable amount of some highly toxic substance as an impurity.

117. Practically all volatile solvents are anaesthetics in greater or less degree. Relatively short exposure to high concentrations may therefore, cause loss of consciousness with probable death unless rescue is prompt.

118. The volatile solvents may be placed in two classes, namely: those that will burn and those that will not. Of the latter those most frequently used are made from such hydrocarbons as methane, ethane and ethylene by replacing all or part of the hydrogen in them with chlorine. They are known collectively as chlorinated hydrocarbons.

119. *Chlorinated Solvents (Non-flammable).* The effectiveness of these substances in dissolving fats, greases and oils and the fact that they will not burn, has led to their wide use in cleaning metal parts preparatory to plating or other finishing. They are similarly useful in dry cleaning clothing and textiles. Carbon tetrachloride is used as a fire extinguishing agent in portable fire extinguishers.

120. Many of the chlorinated solvents are toxic. Continued breathing of the vapors of these in concentrations above the established safe limits may result in permanent injury to the liver and other vital organs. Their ability to dissolve the natural oil and fat of the skin may result in dermatoses upon continued skin contact. Their vapors will also cause irritation of eyes, nose, throat, and lungs. However, the concentrations necessary to cause such irritation are frequently higher than those that are safe for continuous exposure so that irritation cannot be relied upon as a safe warning sign.

121. The chief preventive methods are--

(a) Enclosed automatic processes. (Machinery of this type has come into fairly general use in the dry cleaning industry.)

(b) When a fully automatic process is not practicable, enclosure of as much of the operation as is practicable with local exhaust to capture all vapors that might otherwise escape. When heat is used in the process, accurate heat control is essential. For example, the small common degreaser commonly used for cleaning of all metal parts if properly operated is quite safe, but heat control must be accurate and the operator must follow correct procedure.

(c) Maintenance of medical supervision of workers exposed to chlorinated solvents.

(d) Maintenance of a system of air analysis to insure prompt discovery of hazardous air contamination in the workplace.

122. *Flammable Solvents.* Benzene injures the blood-forming organs and structures. Chronic poisoning may occur from continued exposure to very small concentrations. Quickly fatal poisoning may occur from a short exposure to high concentrations. Toluene and xylene are regarded as less toxic than benzene and since they evaporate less readily they present considerably less hazard at room temperature than does benzene.

123. Wood alcohol (methanol, methyl alcohol) injures both nerve tissue and the liver. Acute poisoning from breathing large amounts of the vapors or drinking the liquid is likely to destroy the optic nerve and produce blindness. Wood alcohol was the usual cause of deaths and blindness that so commonly followed the drinking of bootleg liquor during prohibition.

124. Carbon bisulphide is also a nerve poison. Continued exposure to small concentrations can cause permanent nerve injury with symptoms that range from loss of muscle function to serious neurosis. Exposure to high concentrations can quickly cause death. It evaporates with extreme rapidity and is highly flammable.

125. The hazard of fire and explosion from the vapors of these solvents is always present when they are used. Preventive methods against fire are largely based on the idea of keeping the concentration of the vapors well under the lower limit at which they will burn. However, in most cases, this is many times too high for safety as regards health, and should not be used as a safe guide even with the least toxic of the flammable solvents.

126. Preventive methods are essentially the same as for the chlorinated hydrocarbons. The wide range in toxicity, however, emphasizes the importance of, in each instance, suiting the specific methods used to the nature of the substance in question and to the conditions surrounding its use.

127. *Toxic Gases.* The commonest of the highly toxic gases are carbon monoxide, hydrogen sulphide, nitrous oxides, and cyanogen (including hydrocyanic acid gas.) All of these violently poisonous and in high concentrations will cause death in a matter of minutes or even seconds.

128. *Carbon monoxide (CO).* This is the commonest of all toxic gases. It is formed whenever carbonaceous matter (almost any combustible material) is burned. The carbon first burns to carbon monoxide which in turn burns to carbon dioxide (CO_2). If oxygen does not reach the flame rapidly enough to burn up all the carbon monoxide before it can escape from the high temperature and cool below its burning point, it will remain carbon monoxide. Therefore, whenever a furnace or stove is too tightly dampered or a fire is smothered in any degree, carbon monoxide is almost sure to escape into the surrounding air in large amounts. All internal combustion engines discharge carbon monoxide. It is usually present in the stack gases from all types of furnaces. Only perfect combustion would leave no carbon monoxide unconsumed so that wherever there is fire the possibility exists that some CO is escaping.

129. The poisoning effect of carbon monoxide is due to the fact that the blood will take it up much more readily than it will oxygen. Therefore very small concentrations (as little as 200 parts per million)* will progressively reduce the oxygen carrying power of the blood causing headache, flushed face, dizziness, and weakness in 6 or 8 hours. Concentrations ten times as great will cause unconsciousness and death within an hour, and high concentrations almost instantly. Since it is odorless, tasteless, colorless, it gives no warning of its presence. The "gassy" or "smoky" odor commonly associated with the escape of gases from a fire should always be regarded as a warning of the probable presence of carbon monoxide; but the absence of odor or smoke should not be regarded as evidence of a safe condition.

130. *Hydrogen sulphide.* This gas is highly poisonous. Breathed in high concentrations it is almost instantly fatal. Very small amounts breathed over a long period of time may cause chronic poisoning. It is a nerve poison, causing paralysis. It will also irritate mucous membranes such as those of eyes and lungs. Exposure to it increases susceptibility. Therefore, a person once poisoned even mildly should be removed from any further exposure. Its characteristics odor of rotten eggs is not a dependable guide to danger, for any considerable concentration quickly anesthetises the sense of smell and the odor seemingly disappears.

131. *Nitrogen oxides (nitrous fumes.)* These gases are insidious powerful lung irritants. While poisoning can also occur by absorption through the lungs, the chief hazard is acute lung irritation. High concentrations of nitrous fumes can quickly cause a fatal type of bronchitis. Exposure to concentration too low to cause any serious immediate feeling of suffocation or irritation may be followed hours later by an increasing lung discomfort which may be fatal in a matter of hours or days. This fact is very important because nitrous fumes are given off by strong nitric acid and by many processes in which nitric acid is used. The chief danger comes from spills, breakouts and the cleaning of tanks, vats and equipment used in processes in which nitric acid is used and for the storage of nitric acid or nitrates.

132. *Cyanogen and hydrocyanic acid gas.* These are among the most poisonous of substances. Since they are readily absorbed through the skin. It is necessary to prevent any considerable skin contact as well as their entry into the lungs. These gases are likely to be given off whenever cyanides are heated or are used under conditions that may cause chemical reaction.

133. Any of the ordinary cyanides (potassium, sodium, or calcium cyanide) break down to yield large volumes of hydrocyanic acid gas when treated with acid. Moisture causes a similar but slower action so that the cyanides must be fully protected against moisture.

* *100 parts per million is accepted as the maximum acceptable concentration for continuous exposure "American Standard."*

134. Preventive methods must be suited to the specific situation. Great care must be taken to avoid even momentary exposure to high concentrations. Control methods must be such that respiratory protective devices are not necessary. Also precautions against breakouts and other occurrences likely to involve exposure to quickly lethal concentrations of these gases, must be applied with unfailing thoroughness and adequacy.

135. *Dusts.* The dusts of toxic substances will, generally, produce the types of injury characteristic of the respective substances. However, many dusts not ordinarily regarded as toxic can produce lung changes, the nature and extent of which will depend upon the substance in question, the dust concentration and the total length of exposure. Years of exposure to dust are usually necessary for definite damage to develop. However in the case of free silica, exposure to very high dust concentrations may greatly shorten the time necessary to produce damage.

136. *Silica and Asbestos Dusts.* Two dusts are particularly harmful, silica dust which causes silicosis, and asbestos dust which causes a disease of the lungs called asbestosis. Silicosis is caused only be breathing silica dust.

Silica (SiO_2), ordinary quartz, is the oxide of silicon. No other compound of silica, of which there are many, will cause silicosis. However, most rocks contain silica. Most sands and sandstones are nearly pure silica. Granites and many other massive rocks contain large amounts of it. It is unsafe to assume that any rock is without some free silica. Most rocks also contain silicates, but these will not cause silicosis.

137. Silica dust breathed in sufficient concentration for a long enough time (usually many years) causes the gradual development and growth in the lungs of tissue that resembles scar tissue (fibrosis). As it grows, it not only blocks off portions of the lungs but it causes them to lose their elasticity progressively, their power to expand and contract. The victim becomes increasingly "short winded". Many silicotics, however, die from tuberculosis, because silica reduces the defenses the body normally has to tuberculosis. Hence men who have well-developed silicosis are especially likely to develop tuberculosis also.

138. There is increasing evidence that many other rock dusts may cause the slow development and growth of fibrous tissue in the lungs (fibrosis), but the action is much slower than in the case of silica and seldom if ever disabling. Also while silicosis, once well established, tends to continue to develop even though the victim is removed from exposure to silica dust, there seems no evidence that the same is true for any other dust except asbestos.*

139. Prevention lies in keeping the dust out of the air. As pointed out in paragraph 36, for continuous work exposure, the concentration of free silica dust particles below 10 microns (1/2500 inch) in size should not exceed three million particles per cubic foot of air. A similar value applies to asbestos. Definite maximum allowable concentrations for various dusts are being arrived at as rapidly as accumulating information permits. However, authorities mention 20 to 30 millions as levels that should not be continuously exceeded for rock dusts in general. There is general agreement that even the most harmless dust, such as chalk, should not exceed 50 million particles per cubic foot.

PREVENTION FUNDAMENTALS

The following items are offered to managerial personnel as being of fundamental importance in the prevention of occupational disease:

1. *Know the nature of the potentially hazardous substances used in your establishment and the significance of each of the exposures that may be involved.*
2. *Set up and maintain the specific control measures indicated.*
3. *Make definite assignment of responsibility for all phases of the preventive program.*
4. *Establish contact with State, Federal or other available technical services in the occupational disease field.*
5. *Make definite provision to insure that the disease possibilities involved in the use of new substances, changes in make-up of familiar substances, changes in process or work methods and the like will in each instance receive adequate advance consideration.*

**See Part 1 Bulletin 21, Division of Labor Standards, U. S. Department of Labor. (Report on National Silicosis Conference.)*