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SAFETY

METHODS FOR PREVENTING
OCCUPATIONAL AND OTHER
ACCIDENTS AND DISEASE

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INTRODUCTION

THIS book is the only comprehensive work on safety that has yet appeared in the English language. It is a handbook of practical information for every one interested in industry. It shows how big business can be good business, in surrounding the workers with the adequate safeguards to protect them at work and in promoting the essentials of shop hygiene. Two sentences from President Wilson's inaugural address might be applied here:

"Society must see to it that it does not itself crush or weaken or damage its own constituent parts. The first duty of law is to keep sound the society it serves."

The author has illustrated the underlying principles of the world movement for safety and industrial hygiene by means of typical examples, showing the methods through which simple and practical safeguards are being applied to further these ends. This application has resulted in lowered costs and increased production, with cumulative tendency toward greater knowledge, caution, and self-control on the part of the workers.

While the subject of accident prevention and shop hygiene has been treated in a broad way, the treatment has necessarily been limited to include only those features common to the generality.

This book proves the author's contention that 50 per cent. of industrial accidents are preventable, by examples

taken from many sources, among others the prevention work in the shops and plants of the Pennsylvania Railroad Company, the Midvale Steel Works, and the United States Steel Corporation, where the reduction of serious shop accidents last year was 63 per cent., 61 per cent., and 45 per cent. respectively.

From official connection with the great International Expositions of the last decade: as delegate from the United States Government to the International Congresses of Housing, Hygiene, and Demography, Workmen's Insurance and Accident Prevention at Paris, Berlin, Rome, London, Vienna, and Milan; as corresponding member of the Imperial Technological Museum of Vienna and the Illuminating Society of London; as secretary of the American Section of the International Committee for Improved Dwellings, and Chairman of the American Section of the International Committee of Workmen's Insurance, the author has had unusual opportunities for studying these problems at original sources here and abroad. "Every life saved is a national asset" is the philosophy of the wise men in Europe. What they save America often destroys. The sanctity of life is a lesson industrial America must learn.

All unnecessary social waste is one fundamental cause for the increased cost of living, since, in addition to loss of services, it imposes an additional burden on the taxpayer in the increased expenditures of our great city departments of health, charity, education, and police. To-day, through our lack of foresight an army of producers are thrown into the ranks of another great army of consumers, and through their disablement and wage-earning incapacity, are diverting money which ought to go to dividends, profit, increased wages and salaries, into

rivers of expenditure for these social and industrial dependents and defectives. Conservation of human life means a credit balance on the ledger of social efficiency.

Dusty trades, industrial poisons, and occupational diseases run the cost of needless deaths and disablement well up into nine figures. This socio-economic waste can be cut in two.

The author is thoroughly familiar with the best shops and plants in all sections of our own country, having studied actual conditions in every industrial state in the Union.

In acknowledging indebtedness it is important to mention that opportunities for utilizing the collections and archives of the American Museum of Safety and the kind co-operation of its president and heads of departments greatly facilitated the work.

In covering the general subject of industrial hygiene the suggestions and notes of Professor Rambousek, of Prague, were of great assistance. Acknowledgment is made to Director Hirschberg of the Allgemeine Elektricitaets Gesellschaft, Berlin, for facts and illustrative material. Dr. Charles A. Doremus and Mr. L. B. Marks very kindly gave the benefit of their revision of the chapters on Chemical Industries and Illumination respectively. In the section devoted to the theory and practice of fire prevention acknowledgment is made to R. H. Newbern, superintendent Insurance Department of the Pennsylvania Railroad Company, for permission to use his valuable papers, "Private Fire Brigades" and "Private Fire Departments and Fire Drills," dealing so exhaustively with these subjects.

The author is particularly indebted to C. L. Close, manager of the Safety, Relief, Sanitation, and Welfare

Bureau of the United States Steel Corporation, for his most generous co-operation in placing the latest technical and photographic material, together with statistical information contained in the archives of his department, at my disposal.

I wish also to thank Miss Adelaide Wood Guthrie for her valuable aid in the preparation of this book and in seeing it through the press.

It is believed that men of affairs, business managers, officers, the upper employees, students who are entering upon industrial careers, and that portion of the public which is interested in the industrial issues of the day, in social welfare, and in broad humanitarian considerations will find a distinctive value in the first general exposition which has been made in the English language of the vital subject of safety.

XVI

INDUSTRIAL POISONS

IN the fight against industrial disease and industrial poisoning systematic co-operation of all concerned is absolutely necessary. The services of the medical man are required as a toxicologist, as a hygienist, as a practical physician, but particularly as workmen's doctor; the technical man is called upon to co-operate as constructive engineer, as manager or official of the works, as factory or insurance inspector, or inspecting engineer. Of utmost importance for the success of protective measures is the energetic co-operation of employers and employees and of the organizations of both.

An effective measure for protection against occupational danger is the selection of workers whose physical qualifications develop high resistance. Only those of the best physique should be employed in occupations endangered by poisons.

A selection of the physically strong is partially made automatically, inasmuch as the weaker ones are compelled by repeated illnesses to leave, or are eliminated in consequence of chronic ill health and shortened life. This natural selection, causing not only social and physical misery, but also unemployment, disease, and early death, should be supplanted by a selection of the physically capable through an expert medical examination before they are accepted for employment.

Suitable instruction should be given in schools as to the dangers connected with the various occupations; and there should be medical examination of pupils, particularly of scholars entering into industrial trade-schools, with a view to their physical suitability for the occupation selected.

As before mentioned, those persons naturally weak should be entirely excluded from work offering any possibility of poisoning. It is advisable, further, not to expose to this danger for too long a time workers who are accepted for such employment. They should be granted, apart from other protective measures, a shorter working period and frequent recesses.

Change of work—that is, change from injurious employment to work in the open air—should occur at periodic intervals. These changes are particularly recommended where industrial poisoning may result from the gradual absorption of poison; during the period when the dangerous substance is not handled the organism has time to eliminate the stored toxins, thereby avoiding any serious results.

By means of rational change of work in dangerous employments schooled and strong regular workers are obtained who are acquainted with the danger and know how to meet it. On the other hand, an enforced change of work, due to frequent illness among employees, causes a further increase in the frequency of the disease, as the new-comers, not being skilled, are more exposed to the danger. The prosperity of an industry often materially depends on the existence of a trained set of workers. A change of work rather than a change of workers is, therefore, particularly desirable in establishments where there is great danger of poisoning. Employees in these

places should be medically examined not only when accepted for employment, but also at regular periods afterward. In this way the physically unfit may be eliminated and handed over for treatment.

Records should be kept of the workers exposed to danger of poisoning, their state of health, the result of the periodic medical examinations, and of the diseases, their duration, symptoms, treatment, and cure. In many countries where the keeping of such records is required by law it has been found of great advantage to the employers.

The health of the workers should be a matter of constant supervision by inspectors, foremen, or anybody able to recognize the first signs of poisoning, capable of rendering first-aid treatment and of supervising proper precautionary measures.

In addition to the customary first-aid equipment oxygen apparatus is especially useful. Helmets and respirators should always be at hand for members of the rescue corps. These should never enter premises, apparatus, gas-tanks, drains, and similar places in which poisoning has occurred, or in which there is the probability of a poisonous atmosphere, or into which poisonous gases and vapors may enter, without protection. Provision should also be made for giving trained medical aid promptly.

Workers who handle poisons should be instructed with regard to the character and action of these substances, the initial symptoms, and, particularly, all the means and measures necessary for rendering first aid to their fellows. The best hygienic provisions, protective devices and measures are valueless when the worker does not use and follow them. Not only should instruction be given with regard to the object and use of devices, but

workers should be urged and, if necessary, compelled to use them.

Instruction to workers, especially those just entering dangerous employment, may be given in various ways. Apart from lectures on the subject concise instruction should be available in the form of notices and illustrated placards displayed in the workrooms or handed out as leaflets. Official leaflets are drawn up and published by some governmental departments, the employers being obliged to make known and distribute the same.

Of individual protective measures, those have the greatest importance which, as far as possible, prevent poison from contact with any portion of the body and from inhalation. If this is not completely possible, however, the poison should be quickly removed, so that it shall not penetrate more than is absolutely necessary. Such protection can be secured by means of suitable equipment for the worker, as, for instance, proper clothing, protectors for the mouth and nose, and scrupulous cleanliness when eating. It cannot be sufficiently emphasized that only these measures afford effective protection against industrial poisoning, particularly against those having a lingering chronic action.

The importance of wearing suitable clothing on the premises should be strongly impressed upon workers in dangerous trades. The ordinary or street-clothes should be taken off and replaced by special suits to be worn during working-hours. It is not sufficient for a working-suit, jacket, or apron to be put on *over* the ordinary clothing. The working-suit should be taken off before the midday meal and before leaving the factory and exchanged for the street-clothes. Working-garments should be cut perfectly plain, without folds or pockets, and should be

made of strong, smooth, washable materials. By removing the working-clothes before meals and before leaving the factory the poison is not carried into lunchrooms or into the homes of the workers.

Direct contact with poisonous substances should be avoided as far as possible. If, however, it is necessary for the workman to handle poisonous materials, moisten or dust his hands with them, gloves should be worn. This is particularly necessary when the poison is of such character as to easily enter the skin, producing skin-diseases, sores, and the like. When there is danger that poisonous substances might come in contact with the body it is wise to order that extra strong and impermeable working-garments be worn. When dealing with dusty, poisonous materials the workman should be provided with a suitable head-dress, as poisonous dust readily adheres to hair and scalp.

Employers should see the advantages of providing and maintaining suitable working-clothes for employees, where there is danger of poisoning. But, as before mentioned, the mere provision is not enough; employees must be compelled to wear them if the benefits are to be at all apparent.

Of very great importance is the provision of rooms for changing clothing, with adequate washing facilities and lockers for holding both the street and working clothes. Each worker should have an appointed washing-place and a locker for his individual use. The best type of locker is one divided by a partition into two separate compartments closed by separate doors, one compartment for the working-clothes and the other for street-garments. This separation of the clothing worn inside and outside the premises is of importance in factories dealing with poisonous materials.

Direct protection for the nasal passages is also necessary. For this purpose specially designed respiratory apparatus should be worn. Sometimes simply sponges or rags tied in front of the mouth or nose are sufficient. Generally, however, conditions require more complicated devices. Some of these surround only the mouth and nose; others, the entire face, like a mask; and there are still other types, as a helmet, which take in the entire head. These devices are all fitted closely by means of India-rubber mounts, and possess a breathing-aperture closed, generally, by two parallel grids of wire gauze, between which is a layer of cotton wool, through which respiration takes place. The cotton wool acts as a filter and retains all the dust. The outer grid either is removable or can be turned on a hinge so that the wool can be taken out and replaced by a fresh supply. Whether the mask surrounds only the mouth and nose of the wearer or the entire face and head, it should be constructed of material impermeable to air and provided with protected openings for the eyes when the type of protection renders it necessary.

There could be mentioned many different types of respirators; but in selecting the model best suited to any particular need, it must be remembered that, to be effective, respiration must not be obstructed, and the apparatus should be fitted with a valve to close automatically when inhaling and allow the air to escape unimpeded when exhaling without passing through the filter. Many respiratory devices do not fulfil these requirements, or do so only imperfectly. In course of time the pressure of the respirator is generally found to be troublesome, and often causes the face to become unbearably hot. Undoubtedly, breathing is rendered more

INDIVIDUAL RESPIRATORS AND CHECKROOM AT THE NATIONAL LEAD COMPANY'S PLANT

INDIVIDUAL LOCKERS AND BASINS IN ONE OF THE NATIONAL LEAD COMPANY'S WASHROOMS

difficult through a respirator, but this can be largely minimized by choosing a proper type. Discomfort is particularly felt when, for protection against poisonous gases, sponges or rags soaked in liquids are employed as respirators.

In general, respirators should be used merely as auxiliary means of protection. When a worker must temporarily be in an atmosphere filled with poisonous dust, the wearing of respiratory apparatus, preferably covering the entire head, is recommended. Respirators offer no, or very imperfect, protection against noxious gases and vapors, and respirators saturated with neutralizing liquids can be borne only for a short time.

When rooms filled with poisonous gases must be entered, the workman should carry with him the requisite stock of oxygen in a suitable apparatus, the oxygen in such apparatus being supplied to the helmet worn by the workman freely enough, so that his respiration is completely independent of the surrounding atmosphere.

Workers should be instructed about the importance of cleanliness. When dusty or vaporous materials are employed, the hands and mouth should be thoroughly cleansed before meals and when leaving the factory. Factory regulations should make compulsory frequent washing, as well as the removal of working-clothes before meals and before leaving the factory in the evening.

Washing and bathing should take place during working-hours, and without any loss of time and wages to the employees. Certain hours should be definitely fixed by the management during which the workmen may bathe in turn.

Eating, drinking, smoking, and chewing tobacco in premises endangered by impure air should be prohibited.

If possible, clean dining-rooms should be so constructed that the workers may enter them only through the changing-rooms and washrooms. In these rooms workers should eat the food brought with them or prepared in the factory kitchen. When no provision is made for dining-rooms, the workmen usually eat their meals in the workrooms, sometimes in the midst of unhealthful dusts and poisons. By providing separate lunchrooms it is possible to enforce the rule that working-clothes shall be changed before eating.

The old saying, "Cleanliness is next to godliness," holds especially good with regard to the welfare of workmen in factories endangered by poisonous materials. In numerous large industries the demands of cleanliness are now being met by the provision of bathing establishments for the employees.

For cleansing the hands, face, and other parts of the body exposed to dust and dirt, simple individual washing-basins are recommended; washing-arrangements used by several persons, such as troughs and channels, are entirely unsuitable. The basins, to be easily cleaned, must be made of porcelain or glazed enamel. The dirty water must readily flow from them; for this reason experience has proved tilting-basins to be best.

In all washing-arrangements, including baths for the workmen, an adequate supply of hot and cold water must be available. "Mixing-cocks" should be provided, in order that the desired temperature may be quickly obtained.

Workmen's baths can be arranged as shower-baths, full baths, or swimming-baths. Some establishments are furnished with all these types.

The shower-bath has many advantages, and, therefore,

is most frequently used for workmen's baths. The cost of providing this type is relatively small, as the apparatus is exceedingly simple. For this reason it is possible for the employer to place the baths at the disposal of the workmen free of charge. The bather is quickly and thoroughly cleansed. Shower-baths are also more easily maintained in good condition. When this type is installed it is a good plan to provide double compartments as bathing and dressing rooms. The walls as well as the floor of the compartments should be constructed of smooth, impervious materials. In the bathing-compartment the floor should slope down toward a trough from which the water may flow away. It is better to control the flow of water by means of a chain or other device than to have the water start automatically on entering the bath.

Suitable food for the workers is well-nigh essential for protection against industrial poisoning. Well-fed, strong workers are better able to resist the action of poisons; while badly fed workers, who generally suffer from digestive disturbances, are very sensitive to toxic influences.

It has been found that the excessive use of alcoholic liquors can be checked by provision of suitable beverages. In most cases of industrial poisoning the combination with chronic alcoholism has most serious consequences. Owing to the pernicious effects of alcohol on the kidneys, liver, digestive organs, nervous system, and assimilation of food, a number of points of low resistance are created for attack by the poison. Not only good drinking-water, but in certain cases coffee, tea, fruit syrups, and the like should be furnished the workers; milk is especially to be recommended. In many industries where the danger

of poisoning is great—notably of lead-poisoning—milk is supplied to the workers free of charge.

Every measure for strengthening workmen physically and increasing their general resistance to disease must be included in protective measures. Above all should be mentioned all movements whose purpose is to keep the workers as much as possible in the fresh air when not at work, to cultivate sport, and to strengthen the body. Much has already been accomplished in this respect by certain employers and by the workmen themselves in their various athletic organizations.

Experience has shown that the industrialist is more than recouped for the comparatively small initial expense of making the working-place as healthy as possible in advance, and using every precaution to maintain the health of the workers at the highest point of efficiency.

The greatest danger for the workman is occasioned by those poisonous substances which, by virtue of their dusty nature, their volatility, or gaseous form, render it impossible to keep the atmosphere of the workroom pure. Among the measures of protection the avoidance and removal of poisonous air plays the greatest part.

When the spread of impurities into the atmosphere of the factory cannot be entirely avoided, these must be overcome by introducing a sufficient quantity of fresh air. In addition, an attempt must be made to prevent the poisonous materials in the air from collecting and settling.

As far as possible those processes should be avoided in which poisonous materials are employed and by which the air is rendered impure. A substitution of less dangerous methods is sometimes possible without added expense. International prohibition of certain modes of production

has been under consideration, and in part carried out. To paralyze branches of industry by prohibitory measures works, of course, economic damage, not only to employers, but also to the employed and the community in general. Economic considerations must be weighed before carrying into effect prohibitory measures. If effective substitutes for injurious methods can be found, ways and means can also be developed to effect the change in production.

For instance, the dangerous development of dust can be avoided by employing "wet" methods when the product or material admits of it, such as the moist cleaning of white-lead chambers and wet dressing in smelting-works. Injurious gases and vapors can be avoided in glass-silvering by substituting the safer process for mercury amalgamation; also in fire-gilding, where the articles to be gilded are coated with mercury amalgam and the mercury is vaporized; in the manufacture of incandescent lamps, by replacing the mercury air-pumps and switches by apparatus without mercury; in the manufacture of matches, by using the red instead of the poisonous white phosphorus; in the manufacture of hats, by soaking rabbit-skins in a solution free from mercury salts.

As in the case of the individual, the most important factory protective measure against industrial poisoning is cleanliness—that is, in keeping the rooms and air of the factory free from impurities. Workrooms should be so constructed and arranged that they and the air contained in them can be easily kept clean.

Of course, light, high workrooms having jointless—preferably water-proof floors—are the best. The walls should be coated with a light-colored washable paint. Angles and corners should be avoided, just as in hospital

construction. The rooms should be frequently and carefully cleaned by washing or, better yet, by the more recent vacuum method. Impregnating the floor with oil is recommended in some cases. But this method of binding dust is not its removal, and where the action of the oil is relied upon regular cleaning is more likely to be neglected.

For keeping the air of a factory pure there must be sufficient air space and suitable change of the air in this space. These measures are of far more importance than may seem at first glance, as almost all the throat and lung disorders to which workmen are subject are in many cases directly related to the amount of oxygen contained in the air in which they work.

With regard to the cubic volume of fresh air allowed to each workman, the minimum amount has been legally fixed in many states and countries, but it has been found that when three or four times this quantity is provided the efficiency of each individual worker is raised to a point that far offsets any charge on the rental account.

Only rarely will the natural change of air in workshops—that is, through the pores of the building-material, cracks, joints of floors, through windows and doors—provide the necessary renewal. Under ordinary circumstances air is renewed only once by natural ventilation in about one to two hours, so that in keeping employees up to "concert pitch" the need of artificial ventilation is apparent.

The simplest method of airing rooms is by opening doors and windows—so-called draught ventilation. During work-hours, however, such ventilation causes annoyance, distraction, or indisposition, due to the impossibility of controlling the temperature accurately during winter and summer. By providing ventilator windows

these defects may be obviated and the windows used for permanent ventilation.

This method calls for the upper section of the window being made to rotate about a horizontal axle, so that it can be opened to the desired extent by means of an adjustable lever. Such arrangement, however, only proves satisfactory in summer.

Artificial ventilation is best provided by means of special openings and flues, arranged at the part of the room to be ventilated, and by means of which fresh air is introduced or the impure air drawn away. The former method is defined as pulsion, and the latter as aspiratory ventilation.

The difference in temperature between outer and inner air which causes an upward force can be artificially increased by utilizing the action of the wind, by heating the air in the ventilation flues, by mechanical force, blowers, and so on. When the force of the wind is used the openings of the ventilation flues should be changed for summer and winter ventilation. To increase the current of air in the ventilation flues the outside sections should be provided with top pieces—that is, suction and pressure head-pieces.

For increasing the draught the air may be artificially warmed by providing flames or stoves in the flues. The action of ventilating-flues is materially aided if they are introduced into existing chimneys and smokestacks. In some cases vertical ventilating-shafts are built into the building, or ventilating-chimneys, usually with top pieces, are extended above the roof.

For factories endangered by poisons, either in gaseous or dust form, ventilation is best secured by means of mechanical force or blowers. Where other driving-forces

are employed and the draught is dependent on such factors as the wind or outside air, it is hardly possible to secure proper regulation. This, however, is fully secured when ventilating with mechanical power, as the quantity of air supplied or drawn away by the ventilator may be mathematically calculated and adjusted to the power employed. The ventilating-plant, its form, mechanical equipment, consumption of power, and dimensions, depend, of course, on the requirements. But sufficient attention should be given the subject to obviate all waste of capital and energy. As correct design and arrangement determine the action, result, and fate of the plant, the services of an expert are required. This is particularly so when problems of ventilation in factories endangered by poisons must be solved.

When steam jet blowers are employed a jet of steam or compressed air is introduced into the flues through a nozzle, whereby a powerful suction action is produced. This action can be regulated by the action of the jet.

Injectors are recommended for removing acid vapors which corrode machinery, for exhausting explosive mixtures of dust, or in any case where the employment of other ventilators is not advisable and where there is sufficient excess steam, compressed air, or water for the motive power.

Rotary blowers are substantially wheels having blade-like flat spokes. They are inserted at various places in the ventilation flues according to the movement of air intended, and depend for their action on the fan principle.

According to the mode of construction, ventilators are differentiated into screw and centrifugal ventilators; and according to their action, into low, medium, and high pressure ventilators. They can be driven by belts, water,

steam, or, as is now very common, by electric power, in which case they may be coupled directly to the motor.

Screw-blowers, like ships' propellers, are almost always constructed of iron, and generally have spiral blades—sometimes only four light ones—inserted by means of frames, transversely, in the ventilation flue, on whose column of air they are to exercise a suction or pressure action. The air is driven in the direction of the axle of the ventilator, and generally it is possible by reversing the ventilator to exhaust or drive the air as desired. Such fans produce a low pressure, and are therefore called low-pressure ventilators. The current of air produced by them has a relatively low velocity, but when suitably designed such ventilators can move large quantities of air, and are particularly suitable for bringing about a general change of air within the workroom.

Centrifugal blowers are provided with cases inserted in the ventilating-flue in such manner that the air enters on one or both sides of the axle and passes between numerous straight radial spokes, by whose rapid rotation the air is thrown to the periphery, where the outlet is located and from which the ventilating-flue continues. As the speed of rotation is great, considerable velocity and high pressure are imparted to the current of air. When the pressure is at 120 mm. centrifugal blowers are called medium-pressure blowers; when higher they are called high-pressure. In the former a casing of sheet iron suffices, but in the latter cast-iron cases are usually required.

Medium-pressure centrifugal ventilators are employed for local ventilation—that is, removing impure air from its point of original high pressure for technical purposes; for example, conveying a current of gas at high pressure.

Shutting off the rooms affected by impure air or danger of gases from the remaining sections of a factory facilitates measures for limiting and combating the danger. This plan, however, which protects only the workers not directly occupied with the poison cannot be considered sufficient. The workman endangered must also be protected and enabled to work at his fullest efficiency. Completely inclosing apparatus and processes producing poisonous dusts and gases is possible only when it is not necessary to reach the apparatus or when the work may be carried on by mechanical means.

When, however, such arrangement is not possible the impurities must be removed at their source. As far as the work permits, the source of origin of the impure air should be shut off by means of boarding or sheet-metal partitions, so that only the working-place remains accessible. If this is impossible a funnel must be arranged in immediate proximity to the source of the impurities; this boarding, casing, or funnel, of course, to be connected with the ventilating-pipe in which the necessary draught is produced to carry away the dust or vapors. In the case of only slight development of dust, gases, or vapors, flues above the boiler, or chimney draughts, may suffice for successful local ventilation; but generally force must act on the ventilation tube to obtain the desired result. Medium-pressure blowers are most frequently used as exhausters.

In large factories, or in cases where exhaust is found to be necessary at many points, it is profitable to provide a centralized exhaust-plant. Such a plant consists in the opening of all the pipes leading away impure air into one common flue in which the necessary draught is maintained by the work of one or more powerful exhausters

connected with the flue. When the ventilating-flues are located near the floor, it is wise to provide outlets for the purpose of removing sweepings. Then, when cleaning, if the dust is swept near these outlets it is drawn off.

In removing impurities at their source the apparatus must act so that the current of air at the place of work moves away from the worker. It is preferable to draw dusts or gases vertically downward and, laterally, from the workman into the pipe or flue along the floor.

In calculating the amount lost every year through sickness and reduced speed on the part of the operator, it is well to consider this seemingly minor point: whether the poison-laden air is drawn away from the employee or flows past his nose and mouth.

The dimensions of the pipes and flues must accord with the force and nature of the exhausts. The system of pipes should offer as little resistance as possible to the passage of air; this may be accomplished by eliminating sharp bends in the piping, and by having them always open into the main flue at as obtuse an angle as possible.

Apparatus generating poisonous dusts and gases, wherever possible, should be inclosed and constructed in such a way that its action and ventilation are automatic.

With regard to the development of dust, the following processes must be considered: disintegrating apparatus of every kind, stone-breaking, and mills. In general, these can be provided with closed and ventilated cases. Ball-mills can always be completely inclosed, as they consist only of a rotating iron cylinder in which the steel balls are thrown to and fro, crushing the material. Poisonous, dusty materials—*i. e.*, white lead, gypsum, cement, and others of like nature—can be transported by conveyors, or pneumatically, in closed piping.

The dust created in packing certain materials can be almost completely avoided by using ventilated packing-machines.

More difficult is the confinement of dust when strewing, sifting, and mixing materials, because hand-work generally must be employed.

It is sometimes possible to inclose even this source of dust, however, by using boxes with armholes and having the top wall of glass. Ventilated tables can also be used for this purpose, having wire tops and connected by a funnel underneath with the exhaust-pipe. Such tables may be installed to advantage where the poisonous dust is a waste product, as, for example, glazing with lead or inspecting porcelain products.

When grinding, polishing, or similarly treating materials from which poisonous dusts are given off, wheels should be hooded as far as possible and connected with the exhaust system.

For preventing the spread of noxious gases and vapors, distillation and furnace-plants should be as tight as possible. It is better to have fans act directly on the furnace or distilling-apparatus, so that their walls are relieved from the pressure of the gases generated. In this way a small fall of pressure is produced within, which provides for their non-escape. Mixing-apparatus should be provided with mechanical stirrers, inclosed and well ventilated. The same principle applies to dryers.

Of great importance is the question of the ultimate disposal of the poisonous dusts, gases, and vapors removed from workshops and factories. When these are of non-rising character and large in volume, consideration of public opinion in the neighborhood of the works demands

When gases and vapors can be utilized they are condensed and absorbed, or supplied to other industries. But, in any case, the proper condensation and absorption of poisonous gases and vapors is of the utmost importance among protective measures. The more completely and carefully this is done, the more are the workmen protected against the possibility of illness, incapacity, and lowered vitality.

Condensation converts gas into solid or liquid form by means of cooling. In condensing-apparatus the path of the vapor to be condensed is lengthened as much as possible by passing through coiled channels and pipes, artificially chilled, and by enlarging the surface for condensation by means of perforated partitions, curved walls, chambers, boxes, and cylinders. The longer the path the more perfect is the condensation. The chilling is generally accomplished by means of water-sprays.

Poisonous gases and vapors can be absorbed by water or suitable solvents, the impure air rising in bubbles in vessels filled with the liquid. Absorption chambers and vessels are of various construction, and when necessary can be arranged in series. Absorption towers are also sometimes employed to great advantage, the air to be purified or the gas to be absorbed being admitted below, while water trickles down from above on the countercurrent principle. The construction and filling of these towers vary with the character of the gas or vapor to be absorbed. There are coke, lime, earthenware, slab, and other kinds of towers.

Materials recovered by condensation and absorption can be employed in various ways. Frequently they supply an intermediate product of the industry or a valuable by-product. Sometimes the gas which is led away can

be supplied to another industry, as, for example, when the production of sulphuric acid is connected with the roasting process. Worthless noxious gases should be burned if possible. This may be accomplished in the case of combustible or semi-combustible gases and when relatively harmless waste gases are produced by the combustion. It would, of course, be a mistake to burn poisonous sulphureted hydrogen and allow the product of combustion—injurious sulphurous acid—to escape. Gases are most suitable for combustion which yield carbonic acid and water vapor as the products of combustion. Frequently a very valuable heating-agent, or fuel, can be obtained, as when burning blast-furnace gases and others containing carbon monoxide.