

TRANSACTIONS

31st NATIONAL SAFETY CONGRESS



General Subject and
Industrial Sessions

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Annual Meeting of Members

TUESDAY EVENING SESSION

October 27, 1942

The Annual Meeting of Members of the National Safety Council at the 31st National Safety Congress and Exposition, was called to order in the Grand Ballroom of the Sherman Hotel, Col. John Stilwell, President, presiding.

Following the singing of the Star Spangled Banner by the assembled delegates, Colonel Stilwell announced a quorum present in person or by proxy. He then gave his annual address to members.

Other business being disposed of by vote of the members, Colonel Stilwell called for a report of the Nominating Committee. The report was made by Mr. H. J. Griffith, who read the slate prepared by the Committee. There being no further nominations from the floor, the slate was cleared by directed vote. The names of the newly elected direc-

tors of the Council appear elsewhere in the Transaction.

One of the highlights of the Congress was the presentation of an honorary life membership to William H. Cameron, one of the founders of the National Safety Council and its managing director until his retirement last July. The membership certificate, a solid gold card inscribed with a statement of Mr. Cameron's devoted service to the cause of safety, was presented to him by President Stilwell at the Annual Meeting.

Colonel Stilwell then introduced the next two speakers of the evening, Ned H. Dearborn, Executive Vice-President, National Safety Council, Inc., and William A. Irwin, Chairman War Production Fund to Conserve Manpower. The meeting adjourned at the conclusion of Mr. Irwin's speech.

Annual Address to Members

By COLONEL JOHN STILWELL

President, National Safety Council, Inc.

Ladies and Gentlemen

The welcome I extend to you today bears a deeper significance for our national welfare than ever before.

You are welcome. You are doubly well come in this special year of 1942, for you have come at the height of the peril and the greatness of a great branch of the national defense. You have been needed never before

your efforts as safety leaders been so indispensable.

Many of you make a two-fold contribution to the nation in these days of its greatest peril. You come—as you always have—as safety leaders—as conservers of the nation's manpower. Thousands of you come this year also as producers of its fighting equipment. As such you feel even more keenly the sharp edge of our desperate necessities. As such,

Dust, Fumes, Gases and Vapors

WEDNESDAY MORNING SESSION

October 23, 1942

Presiding—STUART F. NIXON, M.D., Asst. Medical Dir., Chrysler Corp., Detroit

Maintenance of Exhaust Systems An Important Safety Measure

By JOHN M. KANE

Engineer, American Air Filter Company, Inc., Louisville, Kentucky

In recent years the safety engineer's responsibilities have increased by leaps and bounds. Under his widening control logically comes the checking of exhaust systems for the control of hazardous dusts and fumes.

This discussion will assume that such hazards are evaluated by the industrial hygienist or safety engineer. Where exhaust ventilation is required, the ventilation engineer makes recommendations for exhaust capacities, system and hood design to control the condition. It will be further assumed that this coordination results in an effective exhaust system removing the dust or fumes at the point of generation and preventing their dispersion to the workroom. Consequently, unless the process is changed, the hood or enclosure altered, or the method of material handling revised, the hazard should remain controlled as long as the exhaust system functions properly. The word "properly" can rightly be underscored because in many cases little attention is given to such an installation after the project has been completed. Yet mechanical exhaust equipment and dust collectors require the same attention that machine tool and other plant equipment require and usually receive.

If this principle is correct, a discussion of instruments may assist the safety engineer

in quickly setting up a routine check on the performance of an exhaust system and catching any reduction in the system's effectiveness. The tools required under most cases are a manometer (U-Tube), and a short piece of rubber tubing. The engineer must also have an understanding of static pressure losses and hood suction.

While hood suction readings have rightfully fallen into a state of ill repute as a means of measuring air flow, they do offer a quick and accurate method of measuring relative air flow. If the hood suction is known while an exhaust system is functioning properly, its continued effectiveness can be assured as long as the hood suction does not reduce from its original value. An expansion of this statement should indicate why this simple measurement can be used as a ready check.

The Exhaust System

Exhaust ventilation is by far the most predominant means of controlling dust hazards. The fundamental elements and the design are not altered, whether the purpose of the exhaust system is to remove toxic or explosive particles, or simply to prevent dispersion for reduction in workman fatigue, improvement of visibility or general betterment of working conditions. In any case the system will

of material exhausted, or leakage losses caused by loose cleanout doors, broken joints, hoses worn in duct (most frequent in elbows), poor connection to exhaust or inlet.

Losses in suction can also be charged to additional exhaust points added to the system (sometimes systems are designed for future connections and more air than required is handled by present branches until future connections are made), change of setting of blast gates in branch lines (blast gates

adjust the air distribution between the various branches. Jampering with blast gates can seriously affect such distribution and therefore gates should be locked in place immediately after system has been installed and its effectiveness checked). Increased pressure loss through dust collector due to lack of maintenance, improper operation, wear, etc. vary with the collector design. Refer to operation and maintenance instructions furnished with the collector or consult the equipment manufacturer.

Testing Toxic Atmospheres

By N. R. BERNZ

Chief Industrial Hygienist, The Fidelity & Guaranty Co. of N. Y., New York, New York

In manufacturing, many operations and processes of one industry are common to those of another, although the two industries may be engaged in the production of entirely different types of goods. For example, welding is used very extensively throughout the aviation, shipbuilding, automobile and steel industries; this applies also to spray painting, electroplating, buffing, grinding, and many other operations. Similarly with raw materials, various kinds of acids, organic solvents, etc., are found in almost any type of plant. For this reason there are certain industrial poisons which appear much more frequently than others and which may be found throughout the entire defense industry. Some of these are:

Dusts	Toluene
Carbon Monoxide	Xylene
Hydrogen Sulfide	Trichloroethylene
Hydrogen Cyanide	Carbon tetrachloride
Sulfur Dioxide	Carbon Disulfide
Oxides of Nitrogen	Nitric Acid
Ammonia	Chromic Acid
Phosgene	Hydrofluoric Acid
Lead	Hydrochloric Acid
Cadmium	Sulfuric Acid

Dimethylolurea (dust and vapors)
Ammonium Picrate (dust)
Mercury (vapors)
Aniline
Radon
Thoron

As will be seen by examination of the above list, some of these substances are present as raw materials, others are final products, while a third group occurs as by-products generated in the various operations. Typical of the first group are the various acids, organic solvents, chlorinated hydrocarbons, ammonia, and carbon disulfide. In the second class we have TNT and ammonium picrate, while the remainder are commonly occurring dusts, fumes, gases and vapors of a toxic nature generated in various industrial processes. While the theoretical possibilities for exposure to toxic substances in the above industries are far too numerous for tabulation, this list represents those most commonly encountered.

Dusts

Some of the most dangerous dusts are probably found in all of the above industries. For example, mining of the iron ore in the steel industry presents an exposure to the silica dust in considerable quantities. During polishing and grinding operations there may

be considerable exposure to iron dust, which may be in the form of iron filings, iron chips, iron shavings, etc.

For the purpose of this discussion, dust may be defined as follows:

1. The inorganic and asbestos, which may be of particle size measured microscopically.

2. Organic dust, amount of which, weight, typical of dust.

3. Synthetically compounds which dust, such as TNT. These substances, however, are not considered in this discussion.

Beats, above a dust such as lead, etc., trace of which is another heading.

The most common type of dust is the liquid, which is usually in the form of a fine mist or fog, and is made from microscopically small particles of liquid. The sampling technique for dusts is simple, but the equipment is expensive.

The sampling equipment is simple, but the job associated with it requires considerable time and effort. The microscopical method for counting of dust is the most accurate method in which is based on a direct exposure in a chamber.

Other methods

extensively in a great many industries, generate inorganic dusts, which for the most part consist of aluminum oxide and silicon carbide, but also include free silica in amorphous and crystalline forms.

For the purpose of quantitative determination, dusts may be divided roughly into three classes, as follows:

1. The inorganic type such as free silica and asbestos, which is collected and the number of particles per unit volume of air determined microscopically.

2. Organic dusts of natural origin, the amount of which is usually determined by weight. Typical of these are tobacco and flour dusts.

3. Synthetically manufactured organic compounds which may occur in the form of dust, such as TNT and ammonium picrate. These substances when present as air contaminants in low concentrations are generally evaluated quantitatively by chemical means.

Besides above types, there are also metallic dusts such as lead, zinc, cadmium, manganese, etc., some of which will be discussed under another heading.

Inorganic Dusts

The most common method for evaluation of this type of dust is to collect air samples in liquid solutions by means of an impinger (1b) and to make the quantitative determination microscopically. When calculating the dust concentration, usually expressed in number of particles per cubic foot of air, the microscopic calibration factor, the volume of the sampling liquid, and the size of the air sample are taken into consideration.

The sampling procedure, microscopic arrangement, and calculations are extremely simple, but the actual counting is a tedious job associated with severe eye strain and requires considerable experience before dust counts can be relied upon. In recent years the microprojection method (2) has been used for counting of impinger samples. With this method in which the microscopic field is projected on a translucent screen, the eye strain associated with direct microscopic work is eliminated.

(3) Method for evaluation of the type

of dust are by means of electrostatic precipitators (3) and various types of "grab" samplers. With the electrostatic precipitator, the dust is collected in a dry state and either weighed as is, or suspended in water and counted in a manner similar to that employed with the impinger method. Several of the grab samplers have microscopes incorporated with the sampling device and these are calibrated in such a manner that the number of particles per cubic foot of air can readily be obtained by almost instantaneous readings (4).

Organic Dusts (Natural)

This group as a rule is not classified by medical authorities as fibrosis producing dusts, and hardly warrants any discussion in this paper. While claims do exist to the effect that some dusts in this class have produced respiratory irritation, bronchitis, asthma, etc., these dusts are generally looked upon as nuisances rather than occupational disease producers. No official physiological threshold limits have been established and sampling of this type of dust for the purpose of evaluating an occupational disease hazard has little or no meaning.

Most of these dusts, however, are explosive when dispersed in certain proportions in the air and require control from this point of view. Considerable work to establish explosive limits for this type of dust has been done by the United States Department of Agriculture.

Synthetic Dusts

In the manufacture of TNT and ammonium picrate, both of which represent basic war industries, we are confronted with toxic raw materials as well as hygienically injurious final products. In this industry great quantities of toluene, anhydrous ammonia, sulfuric and nitric acids are used, all of which are classified as industrial poisons. TNT and ammonium picrate are themselves systemic poisons as well as skin irritants known to have produced fatalities and severe cases of dermatitis.

A method for sampling and determination of TNT was described recently by Pinto and Faly. (5) This procedure calls for the use of 10 cc. of isopropyl alcohol in the impinger

impinger. The chemical determination is based on the reduction of UNR to triamino-toluene, and finally, a colorimetric comparison with known standards.

Ammonium picrate is highly soluble in water which therefore can be used as the collection medium in an impinger when sampling for this material in industrial atmospheres. The deep color which results upon solution of ammonium picrate in water is also evident in extremely low concentrations and for this reason a direct colorimetric comparison of the sample with known standards can be made. With this method there is a possibility of interference from dimethoxybenzene, the extent of which has not been determined (6).

Carbon Monoxide

This is a very toxic gas encountered in various industrial activities. The toxic limit for this gas is generally accepted as 100 ppm. for prolonged exposure. To the public in general its presence is most commonly associated with automobile exhaust and gas burning appliances utilizing manufactured gas with a high percentage of carbon monoxide. As a result of incomplete combustion it may also be present when burning natural gas or other fuels. In industrial operations involving baking ovens, drying kilns, coke ovens, blast furnaces, etc. carbon monoxide is frequently encountered. In industrial processes in general, and particularly where chemical reactions are involved, carbon monoxide may be generated as a dangerous by-product. In prism grinding, which is closely allied with the defense industry, a high quality iron oxide rouge is required. Occasionally this material is manufactured on the premises as an adjunct to the prism grinding work. This involves the use of oxalic acid for production of iron oxalate which is later decomposed by heat to yield iron oxide rouge. In this process carbon monoxide as well as other gases are generated.

Several methods have been developed for the quantitative determination of carbon monoxide, but only the two most expedient procedures employed in industrial hygiene work will be discussed here. One of these is the carbon monoxide indicator based on the catalytic reaction of hydrogen which is oxidized to carbon dioxide.

The small electric current produced by the heat of the reaction through a thermocouple is calibrated in terms of carbon monoxide concentration which is read directly on the dial of a millimeter. The source of current in this instrument is a small centrifugal blower, the motor of which is operated either from a built-in 6 volt battery or from a 110 volt lighting circuit through a transformer.

Another convenient method for estimation of carbon monoxide though less sensitive and not so accurate is the use of palladium chloride ampoules. In this reaction the palladium chloride is reduced to metallic palladium thereby producing a stain, the intensity of which is in direct proportion to the amount of carbon monoxide in the atmosphere under observation. The stain produced is compared to known color standards for evaluation of the carbon monoxide present. This method is not specific for carbon monoxide, however; there are other reducing gases which also will produce a stain in the presence of palladium chloride. Incidentally, the standard method for carbon monoxide evaluation, adopted by the British Department of Industrial Research (7) consists of a palladium chloride test paper through which the air to be sampled is drawn by means of a hand pump. The stain thus produced is compared with a standard color chart.

Hydrogen Sulfide

Hydrogen sulfide is a very toxic gas with a disagreeable odor. It is found in many industrial operations where sulfur or sulfur compounds are used, but primarily it is encountered in the artificial silk, chemical and petroleum industries. Safe limits varying between 20 and 50 ppm by volume have been suggested by various State authorities in this country.

The most rapid method for determination of hydrogen sulfide is undoubtedly the use of a hand operated instrument consisting essentially of an aspirator bulb and a detector tube through which the air sample is drawn. The detector tube contains a chemical substance which when in contact with hydrogen sulfide measures a discoloration the length of which is in proportion to the amount of hydrogen sulfide present and can be measured on an attached scale. It can also be determined qualitatively, either by bubbling

through a sodium hydroxide solution and titrating with iodine, or by bubbling through potassium iodide starch solution and a measured amount of standard iodine in which reaction the disappearance of the color indicates the end point (8).

Hydrogen Cyanide

This gas for which the industrial hygiene bureaus of California, Connecticut and Massachusetts have established a safe limit of 20 ppm by volume, is found in electroplating operations, heat treating, etc.

A portable instrument of the type discussed in connection with hydrogen sulfide, has been developed for hydrogen cyanide also. I have been informed, however, that the hydrogen cyanide detector in its original form proved less satisfactory and that it has been withdrawn from the market temporarily pending further research.

Chemical tests are available for detection of hydrogen cyanide, such as the prussian blue and thiocyanate reactions, both of which are specific for this gas but allegedly not sensitive enough for concentrations encountered in industrial hygiene work. Other methods suitable for determination of this gas in small concentrations are the Congo red-silver nitrate and the benzidine-copper acetate test papers. These methods, which have been adopted as standard tests by the British Department of Industrial Research, are non-specific, however, so that the possible interference of other gases such as HCl , H_2N , SO_2 and H_2S should be taken into consideration.

In a method suggested by the Air Hygiene Foundation (A.H.F.) the air sample is bubbled through 0.5 per cent potassium hydroxide after which the determination is made by titrating with silver nitrate (9).

Sulfur Dioxide

Exposures to sulfur dioxide gas are common in the petroleum industry, rubber works, and sulfuric acid manufacturing. Sulfur dioxide is also encountered in bone and glue works, magnesium foundries, and other industries where sulfur compounds are used. It is an extremely irritating gas for which the safe limit of 10 ppm has been sug-

gested. For the testing of sulfur dioxide, the American Public Health Association (A.P.H.A.) (10) favors the iodometric method (11) by means of which the air sample is passed through a gas wash bottle containing a measured amount of standard iodine in potassium iodide-starch solution. The disappearance of the color indicates the end of the test, after which the amount of sulfur dioxide present can be calculated.

The British Department of Industrial Research employs a starch-potassium iodate test paper through which the air sample is drawn by means of a handpump. The sulfur dioxide reduces the iodate to iodine with the production of a stain the degree of which is compared to known color standards.

Oxides of Nitrogen

This is a group of gases, some of which are extremely toxic. They are produced when nitric acid comes in contact with organic materials and certain metals, during chemical nitration processes and burning of nitrated materials; they are also present in small quantities during electrical discharges in the air. Above gases may, therefore, be found in such industries and operations as ammunition works, photographic film manufacturing, nitric acid plants, electroplating (bright dipping), detonation of explosives, electric welding, etc.

During the chemical reactions that accompany above operations, a mixture of oxides are formed. The hazardous nature of this group, also called "nitrous fumes" is due primarily to the nitrogen dioxide, a reddish brown gas which reacts with water and upon respiration forms nitric acid in the lungs. The result is often pulmonary edema which frequently proves fatal. The fact that the respiration of these gases does not produce any immediate discomfort in spite of their toxicity, makes them doubly dangerous. A person may be exposed to these fumes and experience only a slight respiratory irritation immediately following the exposure, while the case may develop into a fatal condition by next day.

For example, I know of a case in a nitric acid plant where a man was engaged in filling nitric acid into carboys in a department with a wooden floor. One of the carboys accidentally broke causing the acid to

flow over the wooden floor, producing the brown nitrogen dioxide gas in great volumes. The operator not being familiar with the toxicity of this gas and experiencing no immediate physiological warning, remained on the job attempting to clean the floor by mopping up the acid, instead of leaving the work place for fresh air. As a result a considerable portion of this gas was probably inhaled. He became seriously ill a few hours later and died within 48 hours. Cases of men becoming sick while doing electric welding inside tanks or in other confined spaces are often referred to in the literature. Many of these cases are undoubtedly due to oxides of nitrogen generated in the electric arc.

While there are several methods known for the quantitative determination of oxides of nitrogen, testing for these air contaminants is not so simple as that for some of the others discussed in this paper. Incidentally, in view of the cumbersome procedures involved in testing for these gases, the amount of ventilation required for their control after blasting in mining and tunnel work is sometimes based on the amount of carbon monoxide present, which can readily be determined. With explosives designed for a low oxygen balance resulting in a relatively high carbon monoxide concentration and correspondingly low volumes of oxides of nitrogen, this is a safe and expedient procedure.

For actual detection of nitrogen dioxide, the method employing starch-potassium iodide test paper is probably the best known. This paper when damp is colored blue in the presence of nitrogen dioxide. The method is non-specific, however. Other, specific methods for evaluation of nitrogen dioxide, and sensitive at low concentrations are the Griess-Illoway and the Bismarck Brown tests. With both methods, the air sample is bubbled through chemical solutions after which the quantitative determinations are made in the laboratory by colorimetric analysis. Although physiological safe limits up to 40 ppm have been proposed for these gases, amonophers which by odor or color indicate the presence of nitrous fumes should always be detected with suspicion.

Amonia

Small quantities of ammonia in the air are not harmful, but in larger quantities it is a serious

hazard. It is a respiratory irritant for which safe limits ranging between 50 and 85 ppm have been recommended (Korean investigators 18-30 ppm; State of Massachusetts 50 ppm; Flury and Zerkel 85 ppm).

Ammonia vapors can be evaluated directly in the field by bubbling the air sample through a measured volume of 0.1 N hydrochloric acid in water or titration using phenolphthalein as an indicator. The appearance of a pink color indicates the end point. From the amount of acid used and the size of the air sample, the concentration of ammonia vapors can be calculated (8).

Sulfuric acid can also be used with above method. In another method, recommended by the A.P.H.C., the air sample is collected in sulfuric acid but the final evaluation is made in the laboratory by standard analytical means.

Lead

Exposure to this metal occurs very extensively in nearly all types of manufacturing. The most frequently encountered forms of lead are fumes, dust and dispersed pigment. These occur around lead melting operations, soldering, welding of metals covered with lead-bearing paints, and in spray painting work.

Sampling of lead-contaminated atmospheres is usually done either by means of the impinger or by the electrostatic precipitator. When the impinger is used, as is frequently the case when investigating spray painting and many other types of work involving lead dispersion, the sampling liquid may be either distilled water or dilute nitric acid.

Regardless of the collection method used, the final evaluation of the amount of lead present is done in the laboratory by various analytical methods, the description of which is beyond the scope of this paper. It probably should be emphasized, however, that although some of these methods are highly sensitive and the expected analysis usually well within the range of minute quantities of lead in that work, it is preferable to take large air samples when ever possible to send into the laboratory with the proper equipment and the electrostatic precipitator.

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with sampling rates of 1 and 3 cubic feet of air per minute respectively, this is not a problem. With the midjet impinger, on the other hand, with a sampling rate of only 0.1 cubic foot per minute, this becomes a tiresome task, especially if the handranked instrument is used. Let us take, for example, a case in which the atmospheric lead dispersion is just about on the border line of the safe limit, i. e. 15 mg. per 10 cubic meters of air. For a 30 minute sample with the midjet impinger, only 3 cubic feet of air have been handled. This represents only 0.015 mg. of lead in the air sample, which evidently requires a fairly sensitive analytical method and careful handling for a successful completion of the test.

Cadmium

The United States Public Health Service (USPHS) (16) suggests as a safe limit with respect to toxicity of cadmium fumes a concentration of 1 mg. per 10 cubic meters of air.

The metal is used extensively as a coating of iron and steel for rust prevention, as well as in structural steel to impart certain properties. Exposure to cadmium and cadmium fumes may, therefore, be encountered in such operations as electroplating, welding of cadmium-bearing iron and steel as well as many other processes where work involves cadmium-plated articles. Some of you are probably familiar with the case of cadmium intoxication in a plant in Ontario, Canada, a few years ago, when 14 persons were poisoned—two fatally—during annealing of cadmium plated sheets (17).

As in the case of lead, sampling for cadmium fumes or dust may be done either with the impinger (with water as collection medium—A.P.H.A.) or by the electrostatic precipitator and the samples evaluated in the laboratory by gravimetric or colorimetric analytical methods.

At this point it probably should be brought out that for sampling of metal fumes, the impinger has a lower collecting efficiency than the electrostatic precipitator, which should be taken into account when comparing results obtained on samples collected with the two instruments (18).

Mercury

The present emergency has greatly accelerated the use of mercury, not only in our ammunition works, but also in many other plants directly or indirectly connected with the defense industry. In some cases entirely new uses have been introduced for this metal. For example, a recent development is an anti-landing paint containing mercury, now used in our shipyards. Application of this mercury-bearing paint by means of spraying naturally introduces a serious exposure to mercury poisoning and calls for careful control; this applies also to the manufacture of the paint. Due to the great demand for mercury and the shutting off of foreign supplies, many old mercury mines are now being reopened so that refining of this metal with accompanying occupational disease hazard, has expanded considerably during the past year.

The toxic properties of mercury as a respiratory hazard when present in the form of vapors or in a finely divided metallic state are probably fairly well-known to most men concerned with industrial health. A safe limit, toxicologically, of about 2 mg. per 10 cubic meters of air appears to be generally accepted for inhalation exposures. Although the metal has a relatively low vapor pressure at ordinary temperatures, investigations have shown that sufficient vapors are emitted to produce a mercury hazard in rooms where this material is used in metallic form.

A number of methods are available for the evaluation of mercury vapors in air. One of the most expeditious procedures is probably by means of the Nordlander apparatus utilizing a selenium sulfide test paper, the color of which darkens in the presence of mercury. The amount of mercury present is estimated by comparing the degree of darkening with a standard color chart.

Another more recently developed method involves an optical instrument based on the opacity of mercury vapors to ultra violet light of a certain wave length. In this instrument, therefore, when ultra violet light of a specific wave-length is directed toward a phototube, ionizing mercury vapor will reduce the light received by the phototube and consequently also its current flow, which in turn is calibrated in terms of mercury concentration. This instrument is the specific type of

subject to other light intercepting media such as smoke and fog.

There are also other methods for determination of mercury, entailing condensation of the vapors and subsequent electrolytic deposition of the metal, chemical reaction methods, etc. The first two mentioned above, however, are the most expedient and yield immediate results during the field investigations.

Benzene (Benzol), Toluene and Xylene

These three aromatic hydrocarbons are widely used as industrial solvents and ingredients in a number of chemical reactions. Toluene, for example, is an important raw material in our ammunition manufacturing, especially in the production of trinitrotoluene. With the increased demand for nitrate and the corresponding scarcity of this material, benzene is rapidly taking its place as a solvent in many industries. Xylene, which besides being an important solvent, also does enter as a raw material in certain chemical processes, at present associated with the defense industry and therefore used in great quantities. For instance, in a plant I visited recently xylene is used in the production of a certain type of resin, which in turn is employed in an article manufactured for the United States Army.

All these three materials are classified as industrial poisons, although there appears to be some confusion as to the relative toxicity of each. Benzene is generally considered as the worst offender, although this may not be due to a greater toxicity of the material *per se* but to the fact that it has a higher vapor pressure than the other two so that for a given temperature more of it will be found in the air. However, that may be, the toxic effect of all of them, once dispersed in the air, is generally recognized and therefore indicates the need for strict control wherever they are used.

For the evaluation of these materials some chemical as well as physical methods are available. Most of these, however, are complicated and cumbersome, involving such operations as saturation by bubbling the air through nitrate acid with subsequent colorimetric determination of condensation of the vapors followed up by laboratory analytical procedures for the final evaluation. While

simple gas indicator is a more expeditious. Most of these devices, used primarily for fire prevention work, are designed to read to within 1% of the lower explosive limit of the gas or vapor under test. For above substances with lower explosive limits around 1% by volume, this means that concentrations down to 100 ppm can be detected, which is approximately the accepted toxic limit for these solvents. For benzene with a toxic limit of 75 ppm (19) a modified combustible gas indicator has been put on the market, which measures concentrations ranging between 0 and 1000 ppm. A spectroscopic method for determination of benzene and toluene in air has been described by Cole (20).

Chlorinated Hydrocarbons

Of these trichloroethylene and carbon tetrachloride are probably most frequently found. They are used extensively as metal cleaning agents, the former in regular degreasing machines on a production basis and the latter for work of a more occasional nature. These materials, with their grease dissolving properties are regarded by medical authorities as very injurious to the fatty tissues of the human body.

As in the case of other substances referred to above, there are chemical methods for quantitative determination of vapors from these materials, but they are usually too cumbersome for routine sampling. Optical instruments are available, however, for rapid evaluation of such vapors dispersed in the air. The best known of these is probably the portable interferometer in which the difference between the refraction of air (the comparison substance) and that of the gas mixture to be determined is measured. This difference is calibrated in terms of concentration of the gas or gases under observation. Naturally the same readings will be obtained for all gas mixtures resulting in the same refractive index on the instrument is therefore not specific. With information, however, as to the type of air contaminant concerned in a particular problem it is an exceedingly useful instrument applicable to the investigation of a great variety of gases and vapors.

Carbon Dioxide

This substance which at ordinary temperatures occurs as a liquid with a high vapor pressure (critical large vapors) for which

relatively low safe limits have been suggested by various authorities. Russian investigators have recommended a threshold limit of only 5 ppm for prolonged exposures, while the British Department of Scientific and Industrial Research has suggested a value of 10 ppm and our own State of Massachusetts, 20 ppm. While there is a wide divergence between these values, they all tend to indicate the potential dangers connected with exposures to vapors of carbon disulfide.

Although this solvent may be encountered in a great many industrial operations, it is found primarily in the viscose- and rubber industries where it constitutes an important raw material.

For evaluation of these vapors, the Air Hygiene Foundation recommends drawing the air through an alcoholic potassium hydroxide solution to form potassium ethyl xanthate which is determined iodometrically. The British Department of Scientific and Industrial Research uses a colorimetric method consisting of bubbling the air through diethylamine and copper acetate forming a colored compound the intensity of which is compared with standards. In view of the inflammability of these vapors, a rapid method of their evaluation in high concentrations would be by means of a combustible gas indicator. Unfortunately, however, the sensitivities of these instruments as built at present are not low enough to get within the physiological safety range of this material.

Acids

In this group probably nitric, chromic, hydrofluoric, hydrochloric and sulfuric acids are three most commonly encountered. Of these nitric acid has been discussed under another heading. Exposures to chromic acid resulting in chronic effects and the perforated nasal septum are frequently found around chromium plating tanks. A safe limit of 1 mg per 10 cubic meters of air has been established for chromic acid which in electroplating work occurs as a mist over the plating bath. Hydrofluoric and hydrochloric acids also exist in gaseous form as hydrogen fluoride and hydrogen chloride respectively. A safe limit of 5 ppm has been suggested for the former, while it has been set at 10 ppm for the latter.

Sampling for nitric, chromic, and sulfuric acids is usually done by bubbling through a sodium hydroxide solution, hydrofluoric acid

through potassium hydroxide, and hydrochloric acid through glycerol-potassium carbonate-water solution. For the final laboratory evaluation I refer to standard methods of the APHA.

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Leaflet No. 3—Sulfur Dioxide
Leaflet No. 4—Benzene
Leaflet No. 5—Nitrous Fumes
Leaflet No. 6—Carbon Disulfide
Leaflet No. 7—Carbon Monoxide
Leaflet No. 8—Phosgene
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Selection, Use and Maintenance of Respiratory Protective Devices

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There are several well-recognized procedures for controlling exposure to hazardous atmospheres in industry. They include (a) substitution of less toxic material, (b) change of processes, (c) wet methods, (d) local exhaust, (e) general ventilation, and (f) use of respiratory protective devices. It is difficult to treat atmosphere as a hazard in general in occupational exposures. The most serious hazard is the one which is not recognized and which may arise from the

use or improper use of other control equipment.

Respiratory protective devices usually are employed to supplement other methods of control, as a temporary expedient, or when other methods are not readily applicable or practicable. It seems reasonable to assume, however, that where respirators are used, consideration has been given to the factors involved, and that the devices can provide satisfactory protection if used properly. Their use should not be arrived at simply by a process of elimination of other methods that are more difficult to apply.

Atmospheric contaminants include gases, vapors, dusts, fumes, mists, and fogs. Respiratory protection against these contaminants may be required for concentrations that are immediately dangerous to health or life.

may produce a depleted atmosphere of oxygen.

To meet the need of respiratory protection, two basic types of devices have been developed: (a) self-contained breathing apparatus, and (b) supplied-air breathing apparatus.

Self-contained

breathing apparatus consists of a gas mask and a filter. The filter is a canister containing a chemical substance which removes the toxic material from the atmosphere. The gas mask is equipped with a mouthpiece and a nose clip. The canister is attached to the mask by a hose.

A canister is a cylindrical container which holds a chemical substance which removes the toxic material from the atmosphere. The canister is attached to the mask by a hose.

Canister

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Canister

new will eliminate these hazards. Passage ways, exit doors, openings, ditches, etc., should all be kept clear and free as possible of these items. Cables installed in ducts or suspended overhead will eliminate this hazard.

A welder or a worker, on whatever job he may be doing, must be conscious not only of his own safety but of the safety of others working near at hand. By his own safety efforts, his own work not only is

made easier and safer, but his fellow workers' opportunity for doing their jobs faster and safer is furthered.

These many factors—proper clothing, protective equipment, ventilation, goggles, fire prevention, elimination of tripping hazards, and the regard for others helps all of us individually and collectively to conserve our efforts so that each of our jobs can be done faster and better.

Health Aspects of Welding

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The purpose of this paper is to offer some practical points for the better protection of the health of welding operators. It is not intended as an exhaustive research document. The health hazards of welding may be classed as "real and unreal". The former should not be ignored, nor should the latter be allowed to enter untried them. The real hazards are not mysterious; they should be easily understood by any reasonably well trained operator and means for protection are available and effective when used.

A welding operator is usually exposed to all the general accident hazards common to the industrial field in which he is working. Structural iron workers, ship builders and the like are exposed to increased accident hazards. As a large proportion of welding operations are in connection with such work, this may be one reason for the common assertion that welding is a dangerous and unhealthy occupation.

Another possible source for the charge that welding is a health hazard is the circumstance that the formulas of most weld coatings are "trade secrets" so that there is an opportunity to indulge in all sorts of speculation as to the danger to health from the "secret" ingredients in these coatings. Actually, very few coatings would appear to

have introduced any important health hazards. As for the "mystery," most of these coatings have been patented. Not long ago the Bureau of Mines issued an Information Circular (11) giving much detailed information on the composition of welding rod coatings and fluxes. This was based on patent information, purposes served by the various ingredients and analyses of many typical coatings. This and other reports remove the "mystery."

A third and perhaps the most important reason for the assumption that welding is a health hazard, are the dramatic deaths which have been reported in a relatively few instances following massive exposures to welding fumes in strictly confined spaces without suitable protection for the operators. That such incidents do not reflect a general hazard is well shown by the fact that in the past three years the number of welding operators has increased some 400% and in the past ten years consumption of welding rods has increased some 230% with scarcely any increase in such fatalities.

Until quite recently the health problems of welding have been approached from a speculative rather than scientific viewpoint. Unfortunately in a number of instances even by itself (and especially with little attempt to

which exposures of which evidence available have attributed an amazing variety of ill to welding exposures. These include digestive disorders and malnutrition, liver diseases, respiratory affections even including cancer of the lung, circulatory, blood and glandular changes including thyroid disease and Hodgkin's disease, various skin diseases, neurological changes, sterility, and various other complaints. A careful analysis of these reports generally shows little or no evidence of any connection with welding exposures. The agents usually blamed for these various ailments would ordinarily be present in entirely negligible concentrations, if at all.

Such substances as silica, asbestos, manganese, chromium, nickel, cobalt, various other metals and even iron have been given as "potential hazards" in welding fumes. These have been charged with directly causing ill health or serving to activate other conditions such as pneumonia, tuberculosis, etc. With the exceptions shortly to be mentioned, there seems to be no evidence to indicate that they are present in a form or an amount which would constitute a health hazard. Some have stated that welding operators "are dying every day, and others suffering permanent health impairment as the result of their work" and charge that no studies have been made to identify or control the hazards. Anyone at all familiar with the research which has been done and is still going on in this field will realize that such charges must be due to ignorance or prejudice. The very thorough study conducted by Branton and Walsh (2) and the experimental work and observations in this field by many other investigators (3), (4), (5), (6) tend to show any trace of ill health among welding operators, or any outstanding type of illness among them.

The Real Welding Hazards

The real hazards peculiar to welding are essentially from: (1) radiation and (2) atmospheric by gases and fumes.

Radiation presents the hazard of intense heat, glare and of ultraviolet exposures. Probably all operators even casually exposed to welding rays are so familiar with the need for eye protection in this work that the need of eye protection there is not in any way new or to ultraviolet rays,

but only glare from the intense light. The eyes must be protected by suitable colored lenses. In electric arc welding there is not only the glare but enough ultraviolet radiation to call for a deeper shade of protective lens for the eyes, and also a face shield and protective clothing to cover all skin areas which might be exposed. At present no attempt will be made to go into details as to this form of protection, as there are easily available from a number of sources, especially the American Standard Safety Code for the Protection of Heads, Eyes, and Respiratory Organs (7) (8).

Hazards from radiation are not confined to the welding operator alone, but also involve his helpers and others working in the immediate neighborhood, usually considered to be within twenty-five to one hundred feet in the case of arc welding. Any workman within this area should be protected either with suitable goggles or by the use of screens. If screens are used they should be so designed as to interfere as little as possible with ventilation. Some types of operation can be done in ventilated booths, which may serve to reduce the hazard to others. Not only must direct rays be kept from the unprotected eye, but reflected rays must be considered. This invariably calls for the use of dull non-reflective paint on areas which may otherwise serve as reflectors.

Excessive exposure of the eye to ultraviolet radiation damages chiefly the outer structures of the eye, causing conjunctivitis of varying degrees. The damage is analogous to a blistering sun burn of the skin and if the exposure is severe very painful reactions will occur, with some temporary visual disturbances. Ultraviolet rays do not penetrate the lens or injure the deeper structures of the eye. Experimental cataracts have been produced in rabbits by prolonged exposure to ultraviolet rays, but in actual welding experience lens changes do not occur and optic nerve injury is impossible from a physical standpoint.

Before leaving the subject of radiation it should be mentioned that in welding there is no exposure to short waves like the x-ray. This has been demonstrated repeatedly by having welding operators wear dental x-ray film in their pockets. No evidence of film darkening has been demonstrated as due to the radiation.

tion in welding, level of all acidity. This is mentioned because this charge has recently been revived in some quarters. It was originally made during the last World War and several investigations proved it to be unfounded. There is no valid evidence to support such a theory.

Gas Hazards

Among the much discussed hazards of welding are those due to gases. These gases may be essential to the type of welding as the oxygen and acetylene in oxyacetylene welding or they may be produced through the reactions occurring in the welding process as oxides of nitrogen, ozone, or in some cases of imperfect combustion carbon monoxide. It is hardly necessary to state that oxygen as used in welding does not produce a health hazard. Misused, for instance as a substitute for compressed air in ventilating small spaces, it may increase the hazard from burns, as any material will burn more actively in the presence of an excess of oxygen. Ozone, a "peroxygen," may be formed in the welding arc and in concentrations of over 1 ppm may act as a pulmonary irritant. On leaving the arc, ozone rapidly ceases to exist as such and many investigators have demonstrated that even in confined spaces a dangerous concentration is not found in the air breathed by an operator. It is extremely doubtful that ozone is anything but a theoretical hazard in welding.

While speaking of oxygen, mention may be made of the hazard said to be due to "oxygen deficiency" from welding. This could occur only in very confined spaces as in tanks or some of the small compartments in ship hulls, and the like. There may have been some accidents due to oxygen deficiency in such locations but in all probability investigation would show that this condition already was present in the area before welding operations were attempted. In the case of oxyacetylene welding where a certain proportion of oxygen is drawn from the atmosphere the welding flame will usually become entirely self-sustaining for its purpose and the deficiency recognized before the oxygen reaches a level too low to be dangerous to the operator. Also the heat generated by the welding arc will tend to displace atmospheric oxygen and this will be sufficient to maintain a safe level before dangerous oxygen

depletion occurred. "Oxygen deficiency," then can be put into the category of unreal hazard.

One not infrequently sees references to the toxic effects of unburned acetylene or the "impurities" present in acetylene gas. Acetylene is a simple asphyxiant gas not in itself a poison. It has had fairly wide use as an anesthetic. A hazard would exist only when the gas is present in such concentration as to reduce the oxygen in the air breathed so that not enough remained properly to supply the body. As the lower explosive limit of acetylene in air is about 2 1/4 - 3% it is evident that in the presence of a flame an explosion would result long before the concentration would appreciably reduce the available oxygen in the air. As for the alleged hazard from impurities—arsine, phosphine, hydrogen sulphide or ammonia—this purely theoretical hazard is based chiefly on early analyses of acetylene made from materials of foreign origin. No significant amounts are present in acetylene produced today from raw materials from North American sources. Recently tests were made for arsine in dissolved acetylene from four commercial producers and not even a trace was detected. The minute amounts of impurities sometimes found in acetylene are of course, destroyed in the flame. The health hazards from acetylene and its "impurities" belong in the "unreal" class.

Gases formed in the flame or arc are the oxides of nitrogen, sometimes called "nitrogen fumes." They are not nitrous oxide, but are nitric oxide and other higher oxides of nitrogen. In the concentration present in connection with welding they are so diluted as to be harmless. Under other conditions of exposure these fumes may present other hazards but in welding the real hazard is as a pulmonary irritant. Except in small rooms or in very confined spaces as in tanks, etc., no dangerous concentration would be likely to occur. Just what is a dangerous concentration has been undergoing considerable discussion in the last two or three years. The classic figure of 35 ppm by volume in air, admittedly was based on very limited observations but has proved a fairly satisfactory working standard. Just as much more or less exposure experiments were beginning to indicate that 20 ppm or even up to 100 ppm might be a safe limit for a day's work.

other on what basis is not clear, are advocating a "safe concentration" of only 10 ppm. Certainly a study of available evidence indicates that in welding operations concentrations of 50 ppm or less have not produced symptoms, and that probably under many conditions this amount may be exceeded without harm. Protection will be discussed under fume protection.

Carbon Dioxide and Carbon Monoxide

Carbon dioxide is produced by the oxy-acetylene flame and by the electric arc but never in concentrations of physiological importance. Carbon monoxide may be produced through imperfect combustion as when starting welding or cutting of cold material or through the combustion of organic matter which may be present on the surface to be welded, or in the coatings of rods used. There is considerable divergence of opinion on the degree of hazard from carbon monoxide in welding. A careful comparison of the various reports seems to indicate that the danger of a significant concentration is very slight under all ordinary conditions of welding. If standards of ventilation indicated by other features of the work are followed the hazard from carbon monoxide should be non-existent.

Probably the most discussed health hazards of welding are those due to fumes. These are chiefly metallic, from the material being welded or used as a coating on that material or in the welding rod or its coating. The composition of welding fumes is so varied that this furnishes a wonderful field for the discovery of hypothetical and unreal hazards. These fumes also are the source of some very real hazards. If proper precautions are taken to avoid the real and recognizable hazards, the same precautions should eliminate the theoretical hazards. Welding is now in such general use and the number of metals and their combinations involved is so great that there are probably but few metals which may not be handled by a welding operator.

The most common complaint due to fume is that of metal fume fever. This often is called "flu" or "cold" and is usually a self-limiting condition which disappears within a few days. It is usually caused by the inhalation of fumes from zinc or zinc-coated materials.

time fume, from welding of galvanized material, or brass, or from using rods with a high zinc content. Zinc should not be considered "highly toxic," however, as this condition is an acute, self-limiting reaction of short duration and without known after-effects or complications. In a large number of those affected a considerable degree of immunity is established so that subsequent attacks are very mild or lacking altogether. The permissible limit of zinc fume in the air has been suggested at 15 milligrams of zinc per cubic meter of air. If this concentration is not exceeded it is unlikely that any cases of metal fume fever will occur. (6)

The most serious condition likely to result from metal fume exposure is probably lead poisoning. This is not a hazard common to all welding operations, but only in the relatively few cases where welding or cutting is done on material previously covered with lead paint, coated with metallic lead, or where lead has been introduced as an alloy as in certain steels. In such cases very definite protective measures will be required.

Next to lead ranks cadmium as a potential hazard. Largely cadmium has come into more general use as a rust-proof coating for steel in place of zinc. It enters into some alloys. The fume may produce a pulmonary irritation and edema resembling in many ways the effects from inhaling oxides of nitrogen.

A wide variety of other metals have been mentioned as injurious. Manganese, chromium, cobalt, copper, tin, antimony, zinc, nickel, aluminum, tellurium, vanadium, titanium and many others. As encountered in welding fumes the amounts are usually definitely less than those known to have toxic effects, and it is doubtful if any reports alleging injury from these metals in welding can be substantiated. Manganese has been most frequently suspected, but a study of the reports of alleged effects fail to show any conclusive evidence and the amounts involved are below those known to have produced effects. The charge that even small amounts of manganese predispose to pneumonia is not borne out by the known experience of welding operators.

Other materials than gases or metal fumes have been suggested as causes of respiratory irritation. These are the dusts of metal, especially iron, steel, and aluminum.

their presence

there is which may involve stacks and presence of red coating. Fluorine action is inhibited in long periods of time to the extent.

To sum up, are not in and protective measures should not they are.

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Their presence calls for special ventilation.

There is one other source of real hazard which may be present in many operations involving aluminum or some of the "stainless" steels and alloy metals. This is from the presence of fluorides in many of the fluxes or rod coatings used for this work. Hydrofluoric acid may be formed and the fume if inhaled in appreciable concentrations or for long periods may cause considerable irritation to the nose and throat or even pulmonary edema.

Prevention

To sum up: The real hazards of welding are not many, are generally easily identified and protective measures are available and effective when used. These real hazards should not be minimized or passed by. Briefly they are due to:

1. Radiant energy—ultraviolet and visible light.
2. Oxides of nitrogen.
3. Metal fumes—lead, cadmium and zinc.
4. Fumes from organic residues or wastes.
5. Fumes from fluoride-containing fluxes and rod coatings.

Protection from radiant energy has already been outlined. Protection from the rest is almost wholly a question of ventilation. Various means of approach have been tried to establish standards for ventilation. Standards in terms of concentration of contaminant expressed in parts per million by volume for the gases or milligrams per cubic meter for metallic and other fumes have been suggested, as have standards expressed in number of air changes per time unit. Both methods have value and studies made along these lines have done much to solve some of the difficult points in ventilation requirements. Unfortunately, it is very difficult to obtain quickly and easily a determination of fume concentration on a given operation. Local conditions may also change the efficiency of measures based on rate of air change. Notwithstanding some of the practical difficulties in applying such standards in specific cases, several general rules of ventilation have been evolved which have proved to be of considerable help.

Various studies of present day practice have been made which indicate that welding out of doors or in large shops seldom results in any serious air contamination except in the case of lead. In spaces of less than 1000 cu. ft. and especially inside tanks, ship holds, etc., special ventilation is necessary. Usually the exhaust of contaminated air is much more effective than an attempt to force fresh air into the space. In stationary locations this can generally be done with properly located exhaust fans or by the use of hoods and ducts to withdraw fumes as near as possible to their source. Portable exhaust systems have been designed which are adapted to field needs.

In the case of gases such as oxides of nitrogen or the rare instances of carbon monoxide, if sufficient ventilation is maintained from the beginning of the operation and sufficient to insure good visibility and to insure a comfortable temperature there should be no gas hazard even in confined spaces.

If lead or cadmium fumes are present the only complete protection is by the use of air supplied masks. These are of three types—air supplied by special blower, air supplied from compressed air system, and masks with larger hose without use of forced air supply. If compressed air is used from a general supply, special filters and pressure regulators are required. In the last named type with no forced air supply the length of hose can seldom be over 50 feet. In confined spaces one of the above devices should be used. Out of doors or in large well ventilated shops and for moderately short exposures one of the filter type respirators approved by the Bureau of Mines for lead fumes may be satisfactory. In any confined space at least local exhaust ventilation is required when there is exposure to zinc or fluoride fumes, or to fumes from heavy deposits of organic wastes and sludge. Air supplied respirators offer, of course, the most positive protection.

Briefly, a minimum standard of ventilation is one that will be sufficient to insure good visibility at the point of operation, and insure a temperature within a reasonably comfortable limit. In confined spaces this would call for exhaust ventilation. In case of lead or cadmium exposures air supplied masks are required. No serious hazard is apt to be present except in confined spaces or when lead is involved. Special standards for venti-

lation in welding of leaded steel have been given by Halsey (3). General requirements for ventilation are given in more detail in the reports of Tabbens and Drinker (6) and in Special Bulletin No. 5 of the U. S. Department of Labor, "Control of Welding Hazards in Defense Industries" (9) and by Henson (10).

Summary and Conclusions

1. Health hazards in welding may be divided into "real" and "unreal".

2. Real hazards should not be ignored or minimized. They are usually easy to recognize and effective preventive measures are available.

3. Unreal and hypothetical hazards are often alleged. If indicated precautions are taken to guard against the real hazards, the unreal will disappear entirely.

4. Hazards from radiation in welding are limited to eyes and skin. No systemic effects have been demonstrated. Means of protection are well known and available.

5. Hazards from air contamination can usually be controlled by ventilation and in some instances by respiratory protective equipment. Hazard from CO is essentially limited to oxides of nitrogen, ozone and carbon monoxide hazards are all minor in portable oxygen delivery. In general, hazards are due to the welding operation and to other gases. Some hazards, for example, fumes are limited to times from lead, cadmium, zinc or lithium, and lead, cadmium, zinc or lithium fumes from other materials when present are usually in non-toxic amounts or could be removed by protective measures indicated for the well recognized hazards just mentioned.

6. No reliable evidence has been presented to show that welding operators have poorer health and accident record than other workmen working in the same environment or that they show any characteristic type of illness which could be associated with their work.

7. From the health hazards in welding, exposures are not great and can be well controlled by correct use of the equipment and by welding and its auxiliaries without a corresponding increase in illness.

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