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TRANSACTIONS

30th
NATIONAL SAFETY CONGRESS

GENERAL SUBJECT AND
INDUSTRIAL SESSIONS

CHICAGO
OCTOBER 6-10, 1941

NATIONAL SAFETY COUNCIL, INC.
20 North Wacker Drive, Chicago

Foreword

THE Transactions of the 30th National Safety Congress and Exposition of the National Safety Council are published in two volumes. Volume I contains the General Subject Sessions and the Industrial Section Sessions. Volume II contains the Street and Highway Traffic, Commercial Vehicle, Transit, Child Education, Home Safety and Farm Safety Sessions.

Volume I is distributed automatically to the industrial members of the Council. Volume II is sent to those members who are believed to be interested chiefly in the sessions it contains. However, other members of the Council may obtain Volume II upon request.

All types of Council members have found it advantageous to distribute these Transactions volumes to foremen, supervisors, executives and other officers of their organizations, who make use of the information they contain in organized accident prevention programs. On page 9 of this volume some practical suggestions are made for the profitable use of these Transactions.

Extra copies of Volume I may be obtained by Council Members at the following rates: 1 to 10 copies at $2.00 each; 11 or more copies at $1.75 each. Extra copies of Volume II may be had at 75 cents each.

The Transactions are a condensed record of the proceedings of the Congress, reproduced here for reference purposes. The papers, addresses and many of the discussions have been edited to delete extraneous matter and emphasize those parts which outline ideas of particular usefulness in safety organization and all other accident prevention procedures. The volumes are, therefore, a somewhat abridged version; the original manuscripts, however, are available in the files of the National Safety Council.

The National Safety Council, at its Congresses, seeks to eliminate from discussion matters which are not pertinent to the aims of the Congress, or which may be contrary to the Council's policies. However, it cannot accept responsibility for all the views expressed, either in the matter presented or in the discussions based upon these papers.

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Dusts, Fumes, Gases and Vapors

THURSDAY MORNING SESSION

October 9, 1941

Methods of Combating Industrial Health Hazards

A Symposium

Presiding:—WALTER S. PAINE, Manager, Engineering & Inspection Department, Aetna Casualty & Surety Company, Hartford, Conn., and Vice-President for Industrial Safety, National Safety Council.

Ventilation and Exhaust Equipment

By GORDON C. HARROLD, Ph. D.

Industrial Hygiene Laboratories, Medical Department, Chrysler Corporation, Detroit

It is difficult to give details on the many phases of ventilation and exhaust equipment which are applicable to the problems of protecting the workers' health.

Some general principles of every day usage can be covered however, as well as specific cases.

Thus for gases, less pipe velocities are needed than for fumes, mists or dusts. The lower specific gravity of gases leads to various modifications for their handling. Carbon monoxide gas which is slightly lighter than air could be taken upward. However, when mixed with automobile exhaust gas the apparent specific gravity of the mixture is raised so that it is much more feasible to remove the gas by means of staggered floor grills. Even more important than specific gravity is the temperature of the gas mass as increased temperature causes the heated air to rise.

For this reason numerous exhaust systems are built without forced draft and are suitable particularly in smoke removal where high toxicity is not encountered. Gases such as hydrogen chloride or hydrogen cyanide are of such toxicity that a totally enclosed hood with up-draft exhaust is preferable. The factors of concentration and relative toxicity play an important part in the choice of exhaust systems. Of further interest is the question of whether any cumulative poisons or those leading to chronic illness may be present. The older up-draft exhaust systems have in many cases been replaced with back or side draft ventilation even for gases lighter than air because of the danger of carrying the hazardous material through the breathing zone of the worker. Only in such cases as result from the gas being generated above the breathing zone of the worker should canopy and other types of overhead hoods be used. A combination of back and up-draft will take care of all such situations and should a canopy be open on all sides a solid partition can usually be built in the center of the operation to provide a back wall for both sides of the exhausted operation.

Liquids which give off vapors or mists are both simpler and more difficult to treat. Since the liquid is usually confined in a tank, the focal source only need be considered to prevent local spreading of the contaminant. The difficulty comes in devising simple and inexpensive systems which will not interfere with the worker. Recent tank studies have shown a number of facts which either have not been generally understood or have not had experimental proof offered to substantiate the belief of individual experimenters.

It seems necessary to caution against careless use of formulae. Thus the formula developed by Brandt seems to indicate that as the tank becomes wider the amount of ventilation required per unit becomes less. The author points out that the work of Battista, Hatch and Greenberg proves that increased width results in increased power losses and inefficient operation. Silverman emphasizes the importance of flanges which increase tank velocities from 20 to 33 percent. When the height of the flange is equal to the width of the tank the ventilation requirement is reduced 20 percent. While this is not always practical it is shown through his calculation that maximum efficiencies are obtained as the flange angles are increased and that the ideal situation is found when a completely closed hood may be used.

The width of slot openings is not very important where we have flanges. This is not true of unflanged hoods where the reduction of slot width will give lower velocities at the remote corners. As shown by Dalla Valle and Brandt, the slot velocity exerts rapidly decreasing influence as the distance from the face of the exhaust hood increases, and that two slotted openings, one on each side of the tank, are more efficient than the one slot due to the higher velocity obtainable at the most remote part of the tank from the exhaust slots. It is pointed out in nearly all these papers that disturbances of work operations, extraneous air currents, and vapor turbulence must be overcome by a sufficiently high velocity at the most remote portion of the tank. For this reason, the formulas are not a true criterion unless all outside conditions are evaluated.

It was pointed out that with flanged slots, decreasing the depth of the liquid below the slot reduced the air required by about 15 to 20 percent. This is probably due to decreased turbulence as an unflanged hood is not affecttd by the depth of liquid. It is also pointed out that a single long tank suitably partitioned is more efficient than several small tanks. Also of interest is an efficient manifold system to deliver equal quantities of air to all parts of the slot. Silverman has shown that ventilation requirements vary with the physical characteristics of the liquid substance in the tank. Thus in one instance he shows that flange slots increase efficiency with decreasing depth of liquid but that highly volatile liquids will be lost through entrainment and evaporation so that the depth would have to be increased for efficient operation with such substances.

A case of this kind is thoroughly discussed by Witheridge et al in regard to the ventilation of trichlorethylene degreasers. They showed that vertical slot ventilation caused the lowest solvent loss increase but was least efficient in reducing solvent exposures. A round hole system caused the highest solvent loss increase and required approximately twice as much power as the horizontal slot type to reduce solvent exposures to 100 p.p.m. The maximum solvent loss increase due to ventilation during continuous use of this degreaser was 2 gallons per 9-hour day or 1.2 gallons per square foot of tank area per 100 hours' operation. No significant relation between ventilation rate and solvent loss was shown.

A ventilation rate of 615 c.f.m. around the 20' perimeter of the tank using the horizontal slot or round hole system reduced the average trichlorethylene concentrations in the operator's breathing zone from a maximum of 400 p.p.m. without ventilation to below 100 p.p.m. The vertical slot system required a ventilation rate of 1400 c.f.m. to accomplish the same result.

Dust

When solids in the form of dust must be removed, considerable attention must be given to the collector system, the velocities in the pipes, and the design of the piping system. In addition, the face of the exhaust hood should be so designed as to be close to the source of dust generated.

1. While great emphasis is now being laid on wet collector systems it should be understood that such systems will not remove large amounts of the dust sizes which are significant from the health standpoint. Cyclones, unless of the micro variety, which will not handle the larger volumes of air often encountered, suffer from the same handicap.

Cloth or bag filters will collect these small particles but the maintenance costs are high. Electrical precipitation is also very efficient but is often too expensive to install and maintain.

The velocity of air in the pipes should be sufficient to prevent deposition. This velocity may be as high as 4500 linear feet in the case of lead dust. Since too great a velocity is wasteful and results in excessive pipe losses the system should be so designed as to eliminate the need for excessive velocity. Short distances to collectors, coupled with straight sections of pipe with no sharp bends, are aids in this endeavor. When sections of branch pipe are joined to a main pipe the joining angle should be 30 degrees or less.

A corollary of Dalla Valles work is that the exhaust hood should be as close as possible to the source of dust formation. The ideal would lead to a total enclosure to reduce openings to a minimum and thus cause the resultant face velocities to be much higher.

Often gases and fumes are collected together and usually the limit of air requirements is set by the velocity needed to keep the pipes from plugging up. In some cases as in foundry operation, back draft exhaust is resorted to in order to collect the airborne dust. Then a separate downdraft system keeps dust from getting into the air.

Welding of various kinds produces iron fume, fumes from the flux and gases such as nitrogen dioxide and ozone. The iron fume apparently is only a nuisance dust but the manganese, fluorides, etc. resulting from the welding flux are harmful. The gases noted are harmful when in sufficient concentration.

Work performed in the Chrysler Laboratories indicated that this situation would not be harmful in open spaces unless heavily coated rods were used. In tanks and closed spaces, dangerous concentrations of both gases and fumes could be predicted. Various types of exhaust systems have been devised. The most common one depends on a hood attached to flexible metal pipe so that the face of the hood may be placed in near proximity to the work. Other types range from floor grills to hood canopies, each type being adapted to the kind and size of the pieces to be welded.

In closed tanks, the "Airbooster" as made by M.S.A. provides a means of readily exhausting air from each tank or closed space, or if desired, a large volume of air at relatively low velocity may be introduced into the closed space. These units are portable and provide a good answer to jobs which change or move about frequently.

Personal Protection

Another means of providing safety when toxic substances are present is the use of individual air supplied hoods either open about the eyes or closed depending on the efficiency desired. In paint operations, the open type is satisfactory and vision is not obstructed while for more rigid control with more toxic substances the closed eyepiece type is more desirable. The numerous respirator, canister, and self contained breathing types, need no mention here except that the purpose they serve is well understood.

Light Metals

A new problem is now confronting safety and ventilation engineers in the growing use of magnesium and aluminum alloys. These metals are in themselves non-toxic—so much so that wounds inflicted by sharp articles will become infected much easier than those inflicted by heavy metals. They are hazardous in finely divided form due to the fire and explosion hazard. The various hazards and precautionary measures are receiving attention in various periodicals but we wish to emphasize certain aspects relating to exhaust and ventilation systems.

Ordinary type dust collectors should not be used for removing magnesum or aluminum dust. A special dust collecting system which utilizes a water spray nozzle to knock out the dust so that it may be carried away as a sludge is demanded. Good ventilation is necessary to remove the hydrogen which is formed. All piping should be in straight line with no sharp turns and should be smooth on the inside so that no dust remains in the piping system. The sludge should be collected in drums and disposed of at frequent intervals either by mixing with 5 parts by weight of sand and burying in a dump, or covered with oil and burned. It should be noted that this is one of the few cases where magnesium, in particular, can be wetted with water but it should be noted that the sludge should not be allowed to become half wet but should be thoroughly flooded at all times. The parts of the system where work is done should be of non-sparking material. It is not safe to collect this material in filter screen or cyclone collectors, nor should sparking type metals be allowed to get into the ventilation system.

We have pointed out some of the specific items involved in ventilation in connection with health and safety hazards. Some of the limiting factors in a large scale ventilation program should also be dealt with. Indiscriminate installation of exhaust ventilation without a careful evaluation of the extent of the need will lead to extremely high first costs of installation. The engineer who installs a system three or four times as elaborate as needed to control a given complaint may "control" a situation but at an excess cost of thousands of dollars. The next step after this excess air has been exhausted from the plant, must be to supply fresh air which in the industrial north must be heated for eight months of the year. Even with closely controlled systems, this factor of heated air is a real limitation. In many instances, power houses have had to be greatly enlarged because of such programs. The power needed to run motors and auxiliary equipment is also a limiting factor. A system which is too small will not be criticized on the above score but if its purpose is not fulfilled, the entire layout may have to be scrapped.

Always to be considered is whether the installation is to serve the purpose of removing toxic materials or those which may be classified as nuisance contaminants. Both are legitimate requirements but it should be clearly understood that one system is to protect health directly and the other to provide comfort. Proper consideration can then be given to the question of "how much" and "what kind" of ventilation is to be installed.

A common sense program will include exhaust ventilation as one very important aid but only as related to other possible methods of solving the problem involved. When substitution is feasible and economical, or revision of process if possible, these may provide a cheaper, more satisfactory answer. At times, personal protection will best serve the purpose and in some instances a few simple rules of operation and maintenance may be all that is needed. Ventilation often proves the only answer, but indiscriminate ventilation is the poorest and most costly answer that can be devised. A system should be completely designed at one time with no additions without a complete revision of all parts of the system. It is, of course, permissible to completely design a system in such a way that units may be added from time to time but this should be a part of the original consideration. Conversely systems well designed and installed to meet the condition encountered in the degree necessary are major aids in any health program.

Measuring Concentrations of Toxic Substances

By S. W. GURNEY

Laboratory Director, Liberty Mutual Insurance Company, Boston, Mass.

Frankly, on this subject of industrial health hazards we do not know as much in a precise way as we do about guarding belts, gears, points of operation, and the like. That industrial health is an important subject is attested by the fact that we now have a relatively new profession called Industrial Hygiene, which might be defined as a study of working environments including all of the air contaminants as well as abnormal conditions of temperature, humidity and even now of atmospheric pressure. The criterion is the effect upon the health of workers, either immediate or delayed. A few technical schools have started courses in industrial hygiene and the number of chemists and medical school graduates who are going back and taking these courses is a further measure of the increasing importance of this general subject of industrial health.

Not many plants have experienced industrial hygienists on their staffs; in fact it would be impossible for them to do so as there are not enough of them to go around. I believe that there are very few in this meeting this morning who would call themselves industrial hygienists. With this assumption in mind I have tried to plan this paper for the ordinary safety engineer and the safety committee man who doesn't remember his chemistry too well—but who does feel that he should know more about the possible health hazards in his plant. He may also be somewhat worried about claims for alleged health damage that have been submitted and may wonder if there is anything he can do about it himself. It certainly would be fine if every plant large enough to have even one man wholly interested in safety could arrange to have one trained as well as interested in the fundamental problems of industrial hygiene. However, this would take a long time to accomplish and for the present we shall have to get along with what we have.

I should like this morning to try to tell plant safety men what they can do along this line without the benefit of specially trained industrial hygienists. I am assuming that you know the names of, and are familiar in some way with the materials used in connection with the operations in the plants where you are. This includes the dusts, fumes, vapors and gases, the solvents and other chemicals that are used, produced as necessary by-products of, or enter at all into the manufacturing processes in any way. If you do not you certainly should find them out—and perhaps this is the first thing you can do.

We are safe in saying that wherever a toxic substance is used an exposure exists. For example, if you have in your plant a process using benzol you undoubtedly have a benzol exposure. If somewhere in your plant you are melting lead or a lead alloy for any purpose, an exposure to lead exists in that part of the process. This does not mean necessarily that a health hazard to benzol or to lead exists, but we can say that we do have the exposure.

Now over the years by means of animal experimentation, and by the results of human experience, it has been shown that low dosages of these toxic materials which exist as air contaminants are pretty well taken care of by the healthy human organisms. High dosages in the time factor as well as the concentration are not well handled and damage to various organs and tissues may result from continued exposure.

Further, these same studies, both animal experimentation and industrial experiences have shown that the principal way the toxic material gets into the body is through the respiratory system. It is true that some industrial poisoning takes place through swallowing and some through direct absorption through the skin. However, the important thing we have to remember is that most of the toxic materials used in industry get into the system where they can produce their damage through the common process of inhalation.

For some time a number of important committees have been working on the problem of establishing what we might call a threshold dosage of these industrial toxic materials. A number of individual experts have defined threshold concentrations as those below which health damage is very unlikely. State code committees have drawn up tentative thresholds covering most of the well-known industrial solvents and chemicals and suggested that these limits be used to measure the dividing line between what on one hand constitutes a safe exposure and on the other one that may produce definite health damage. The American Standards Association has appointed a sectional committee of well known experts to correlate all of these data and to establish threshold limits or maximum concentrations which we can use as guideposts or benchmarks in determining whether or not our own plant is a safe one to work in.

However, these threshold dosages do not mean that if you maintain a workroom air always below that concentration figure no one possibly can have any harmful health effects at all nor does it mean that if the concentrations are always above that figure that everyone is going to show symptoms of poisoning. They simply mean that below such concentrations most workers will not be measurably affected and that above it some health damage may be expected, given sufficient time. Behind some of these suggested exposure concentrations there is a wealth of experience and an impressive amount of factual data. Behind other figures there is very little in the way of experience and such figures represent what we might call an intelligent guess on the part of people whose intelligent guesses we respect Thresholds need precise measurements.

Because we need to know what degree of

carbons such as carbon tetrachloride, trichlorethylene, and the like, most people have no trouble in recognizing the contaminant as a chlorinated hydrocarbon as a general class down to around 10 to 25 ppm., although it is difficult to distinguish them apart. I believe that the safety engineer who is willing to do a little sniffing around the plant is going to find out a lot about some of the air contaminants as to their source location and where they go to. There is one thing about the chlorinated hydrocarbons that I should like to mention and that is the fact that nasal fatigue enters into the picture very shortly and after a few minutes in the exposure your nose loses much of its ability to distinguish these solvents. The sense of smell is recovered by a few minutes in the fresh air. The same thing is very true of concentrations of hydrogen sulfide. There is no need to point out that the very toxic carbon monoxide and the very common carbon dioxide gas in the pure state have no odor. However, carbon dioxide in a brewery around the fermenting vats has a peculiar tickling sensation to the nose which is quite characteristic and after a few minutes around 500 or 600 ppm. in that process you begin to have a feeling that all is not quite as it should be.

I know of several instances where the sense of smell has been used as a practical measuring rod. The foreman of a large plating shop doing much cyanide plating uses and has demonstrated the fact that a hydrogen cyanide smell is a sure sign that the electrical system or the plating bath concentration needs attention. Although hydrogen cyanide is extremely toxic it can be detected by smell well below the suggested threshold dosage of 20 ppm.

Many of the solvents and mixtures such as the lacquer solvents in industry are not particularly toxic and exposures constitute more of a nuisance than they do a real health hazard. Nuisances, however, can be real and we do not want to remain complacent just because no real health hazard can be proved. There is also the very real danger of getting into the explosive range with some of these lacquer solvent mixtures of low toxicity.

There is another way of estimating concentrations and I can recommend it to you if you are in doubt as to whether or not some process should be further enclosed or ventilated or otherwise protected to keep down the concentration. It should be used with caution and understanding. Safety engineers often ask me whether or not a coating process or a mixing process or even such things as vapor degreasers should not have something done about them. To such inquiries I frequently ask the safety engineer to go out and stand alongside of the operator of the process in question for as much of the day as the operator does himself. I further ask him to tell me just how he feels at the end of this period. It is remarkable how often after going through this the safety engineer comes to the conclusion that further protection is necessary, at least very desirable. Now you know that there are lots of smells, irritating gases and the like that workers finally get used to—and they will probably affect you much more violently than they do the experienced operator. On the other hand I wonder if we are right in asking people to work in disagreeable atmosphere where they have to "get used to it" before they become reasonably reconciled to their job.

There is one other way we have of estimating exposure that is probably not as good as the three I have mentioned but nevertheless it has its uses. I refer to complaints on the part of the workers themselves. Safety engineers should be close enough to workers in the departments where toxic materials are used so they will get verbal reports of any complaints or objective symptoms that arise.

I recall two fatalities this year allegedly caused by high exposure to carbon tetrachloride vapor. There may have been other cases but these two were such that I had access to the reports of the investigations. They were both rather simple jobs of cleaning metal objects with carbon tetrachloride and the whole operation was by hand. Both operations had been performed occasionally for a number of years, but as a result of large defense orders the time spent at these operations had increased considerably. Both men are on record as having complained considerably. They had been nauseated several times. They complained of feeling tired and restless for quite some time before they finally became really seriously sick. An alert safety man nosing about the plant looking for trouble might well have picked this up and recognized it as a measure of excessive exposure. Both cases terminated fatally and in the medical picture at autopsy showed about what one would expect in an acute case of carbon tetrachloride poisoning. It is interesting to know that afterwards air samples were taken in a number of positions around the operation and concentrations well over 100 ppm., the suggested threshold dosage, were found.

I think if we investigate our plants thoroughly we will find that there are a number of processes and operations involving toxic materials or at least materials with some degree of toxicity that have for years been carried on safely without complaint or symptoms or any other evidence of health damage. The reason for this was the infrequency of the operation or the small quantity used or the short time of exposure. With increase in production a number of these processes have speeded up so that gradually the weekly degree of exposure to the dust, fume, vapor or gas has been increased. As a result of defense orders processes that used to take place every other Thursday are now being carried out every day. What used to be a short time job of 15 or 20 minutes now stretches out over two or three hours. Complaints do not always mean that a serious health hazard exists, but they should be red flags to any safety man that since his original investigation conditions may have changed to render the exposure much more serious than it was. From years of experience in this business I am of the opinion that the average worker does not complain about dust or fume or irritating vapors unless he had a good reason to do so and the wise safety engineer will recognize this and at least investigate.

There are a number of air contaminants that can only be measured by the accepted methods of sanitary air analysis and certainly precision measuring can be done only by such means—but taken all together the safety engineer himself, using reasonably his sight, sense of smell, his own sense of feeling when exposed as the workers are plus a knowledge of what the workers on some of these unpleasant jobs are saying and feeling has at his command several useful measuring rods with which he can evaluate the health hazard in his plant.

Personal Respiratory Protective Equipment

By DR. J. H. STERNER

Director, Laboratory of Industrial Medicine, Eastman Kodak Co., Rochester, N. Y.

The need for personal respiratory protection in many types of industrial operations is now well recognized, but the problem of determining in a specific instance whether a respirator is required, and what type is best indicated, is sometimes not a simple one.

Every type of respirator places some restriction on the wearer, and although it may be only a slight inconvenience and insignificant compared with the protection it provides, it must be recognized as a compromise. Ideally, all operations would be conducted so as not to contaminate the air which must be breathed, or the degree of contamination, would be kept at safe levels by ventilating devices. Only after the primary effort to achieve this ideal has proved to be impossible or impractical should the use of personal respiratory protective equipment be considered. Too frequently the apparent simplicity and the immediate economic advantage in merely providing respirators are the deciding factors in the choice of this type of protection. An understanding of the purposes, operations, and limitations of respirators is essential if respiratory protection is to be safely and intelligently applied to the varied types of hazards which exist.

There are, however, many industrial situations where the use of a respirator is specifically indicated for the protection of workmen; situations where it is impossible or impractical to secure a safely respirable atmosphere by other means. The definition of an irrespirable or unsafe atmosphere is admittedly sometimes difficult. A discussion of the methods for determining if the air is safe for breathing is beyond the scope of this paper, but mention should be made of the recently increased impetus toward establishing safe threshold values—the Maximum Allowable Concentrations which are being determined in increasing numbers for potentially toxic materials which may be volatilized in industrial processes. For this discussion, it is assumed that a respiratory hazard exists, that circumstances make it impractical to eliminate the hazard by other means, and that some form of personal respiratory protective device must be worn to permit the individual to safely carry on his work.

Many types of respirators have been found useful, and since many are commercially available, it is logical to examine them before investigating the factors which should determine the selection of a respirator for a specific hazard. Schrenk of the Bureau of Mines has classified personal respiratory protective equipment as follows:

(1) Those that afford protection by removing atmospheric contaminants ("Air purifying"), and (2) those by which a respirable atmosphere from an uncontaminated source is supplied to the wearer ("Air-supplying, or air-supplied").

The question as to the efficiency of respirators is satisfied in part by the arrangements for testing and approval setup by the Bureau of Mines of the U. S. Department of the Interior. For some years this organization has given an official approval to certain types of respiratory protective devices which pass the rather rigid requirements specified. There are, however, useful respirators which are not included in the approved list and which give adequate protection for many types of exposures. In the opinion of the writer, it is better to choose a respirator with a Bureau of Mines Approval, if a respirator of the types eligible for approval is indicated in the specific exposure. This is particularly pertinent when the opportunity and facilities in the plant for checking the efficiency of respirators are limited. In lieu of official approval, the integrity and recognized qualification of the manufacturer must rank high in the considerations for accepting the specifications given with a particular respiratory protective device.

What are the factors that should be considered in selecting a respirator for a specific hazard?

In many instances the actual selection will not require a step by step examination of each of these factors—the choice will be more or less obvious and made by simple "inspection," but if the selection is to be the best possible one, these principles must be examined, recognized, and applied. In most cases, a standard model of one of the commercially available devices will be satisfactory, but not infrequently the circumstances of exposure are such that some degree of modification gives a more adaptable and useful protection. How these individual factors may influence the choice of a particular type of respirator, or require a modification due to the peculiarities of the exposure, will be considered in some detail.

1. *The oxygen content of the contaminated atmosphere.*

Normal air contains nearly 21 per cent oxygen, but this oxygen content may be greatly reduced in covered tanks, in vaults or cellars without ventilation, and in other confined areas, particularly where fires or explosions may have consumed the oxygen or where large quantities of gases or vapors may have been generated. Although an individual may not be in serious danger as long as 12 per cent oxygen is present, a respirator giving an adequate supply of oxygen must be used in all situations where there is the danger of an oxygen deficiency.

2. *The exact nature of the specific contaminants.*

It is extremely important to know the exact nature of the contaminating material—not only the chemical properties, but all the physical forms in which the materials may be encountered in the particular exposure. In addition to the respiratory protection, it may be necessary to prevent contact with the eyes and skin, hence the nature of the contaminant also determines the type of face piece or covering which is to contain the respiratory device. Of the two general classes of respirators, it has greater import in the selection of the air-purifying type. A particular absorbent may have a relatively high restraining capacity against one type or physical state of a contaminant and have little or no value against others. For example, a filter which gives effective protection against lead fume may permit the passage of significant amounts of lead in a gaseous form. Or a canister which will satisfactorily restrain the vapors of a chlorinated hydrocarbon solvent may be much less effective against gases accidently generated by the combustion of this solvent, such as phosgene.

There are a variety of absorbing materials which are used to "filter out" the contaminants in air-purifying respirators. There is no one "universal absorbing material." Since there is a direct relationship between the amount of the specific absorbent and the quantity of material absorbed, it is desirable to have as great a quantity of this specific absorber as possible. Occasionally, because of uncertainty as to which type of canister is indicated, the use of an "all-service" type respirator is recommended. This respirator affords protection against practically all types of gases, vapors, fumes, or smokes encountered industrially and would give protection by absorbing the contaminant in one or two of its layers, but its capacity for absorption would be much less than if the container were completely filled with the specific absorber. In contrast to the air-purifying respirator, the air-supplied type gives respiratory protection against all types of contaminants.

3. *The concentration of the contaminants and the duration of exposure.*

These two factors are considered together, for the concentration and duration are both important functions of the total capacity or "life" of a given amount of absorbing material. Theoretically, the air-supplied respirators afford effective protection against any concentration of contaminant as long as the air supply continues. The concentration and the duration of exposure impose very definite limitations upon the air-purifying types. Very little information is available concerning the absolute capacities of the varied types of absorbing materials for the variety of contaminants—even those against which they are most effective. In practice, the point of exhaustion of a given amount of absorbent is obvious if the odor of the contaminant is noted (it is assumed that the face piece is well fitted). Unfortunately some very toxic materials are odorless, for example, carbon monoxide, and other substances vary greatly as to their tendencies to fatigue the olfactory sense as the concentration of the gases or vapors passing thru the exhausted absorber increase gradually and thus may not giv[e] an adequate warning. In such cases, the ab[]sorber type of respirator must be used wit[h] caution, and the exhaustion of the absorbin[g] capacity controlled by limiting the time o[f] use.

Concentration alone places a definite limi[]tation upon the use of air-purifying respira[]tors. The Bureau of Mines has approve[d] canister masks for protection against 2 pe[r] cent by volume of acid gases; organic vapors and carbon monoxide, and 3 per cent o[f] ammonia, and such approval indicates th[e] effective life of the absorber at this level i[s] at least 30 minutes. No published data coul[d] be found which gave the absolute uppe[r] limits of protection either as to concentration or capacity.

If the respirator has a Bureau of Mines Approval, the efficiency for a given concentration and a given time has been tested. For lower concentrations than the upper approval limit it is probably safe to assume a straight line relationship for the effective life. Thus, a canister effective against 2 per cent vapor for 30 minutes can be assumed to give protection against 1 per cent for 60 minutes, against 0.1 per cent for 600 minutes.

Since the efficiency of the air-purifying (mechanical filter) respirator for dusts, fumes, and smokes increases with use, the effective life is determined not by its failure to restrain the contaminant, but by its increased resistance to inspiration. When this resistance becomes uncomfortable, it is not uncommon for the wearer to relax the fit of the mask, and while he then can breathe more easily, the protection is lost.

4. *The character of the work to be done and of the work space.*

Here must be considered, whether the work is of an emergancy or non-emergency type, the amount and rate of physical exertion that must be done, the movements required in performing the work, the distance to be covered in the operation, the shape, size, and restrictions of the working space, and the time permitted for putting on the device. It is essential that devices for emergency situations give complete respiratory protection, and that special provision be made against failure of the device and the resultant exposure to an immediately dangerous atmosphere. Emphasis is on complete protection, with comfort and convenience important, but secondary. In non-emergency situations it is assumed that the individual could escape from the harmful atmosphere without any protection. Devices for these situations usually give more consideration to the comfort and convenience of the wearer. To illustrate how ore or a combination of the above factors have required the modification of standard equipment, the following examples are given.

In one manufacturing operation large quantities of a variety of solvents are evaporated in a completely inclosed apparatus, and the workman, on the outside of the machine, has not appreciable exposure. Occasionally it is necessary for him to place his head inside the machine, with a consequent exposure to high concentrations of hot solvent vapors. The work inside the machine is of such a nature that it must be started within a few seconds when the need arises, and the exposure may continue from a few seconds to many minutes. The workman must have protection for breathing and for the eyes. Because of the high concentrations, an absorber type respirator unless supplied with a prohibitively large amount of absorbing material would be quickly exhausted. Standard air-line models equipped with a full-face piece were tried, but required too long a time for the operators to put them on. Finally one of this type was modified by attaching the face piece to a spring type head-band in such a manner that the respirator could be put on in a few seconds. The short hoseline can be plugged in at any one of the numerous convenient terminals around the machine, and the simple insertion initiates an adequtee flow of air. The mask and hose attachment can be removed as quickly and easily as they were applied. This respirator has proved to be a very satisfactory solution to a difficult problem.

In this instance the high concentrations encountered favored the choice of the air-supplied mask over the absorber type, but the expense and difficulty in obtaining and maintaining a satisfactory air source seemed to outweigh this first indication. Other factors, the ease and speed of applying and removing the mask determined the final selection, since the positive pressure of the air-supplied respirator permitted this modification much more readily and safely.

In another instance it was found that the use of a small cartridge absorber type respirator was giving inadequate protection against the high concentrations of vapors encountered in spray painting the interiors of buildings. The alternatives in supplying additional protecion were to increase the quantity of absorbing material, or to use an air-supplied type. The relatively large volume of absorbent necessary to give complete protection for an eight-hour exposure to the high concentration of vapors, required either an inconventiently larger container or frequent refilling of a small one. A valid objection to the standard air-line models was that when it was necessary to move scaffolding or to perform other work in the room being sprayed, the painter must, to retain his air source, carry the supply line wherever he went, an inconvenient and even dangerous impediment to climbing on and off scaffolding and ladders. If he cut loose from the airline ,he was exposed to the residual concentrations of five to ten thousand parts per million, an appreciable cumulative exposure during the course of a day.

An airline respirator was modified to include a charcoal cartridge and automatic shutoff valves on both sides of the connection between the supply line and the respirator line. Thus when the airline connection is severed, the intake of air begins automatically thru the cartridge and continues until the reconnection with the airline again automatically closes the small valve in the base of the cartridge. These modifications frequently require considerable experimentation until a satisfactory result is obtained, but the protection and safety afforded is adequate compensation.

5. *Other environmental factors, such as temperature and humidity.*

Temperature and humidity may influence the selection in at least two ways since (1) they have a definite effect on the capacity of certain types of absorbents, and (2) they affect the comfort of the wearer. The effect of moisture on the life of activated charcoal against gasoline vapors has been shown in studies by the Bureau of Mines. The capacity of the dry charcoal (0.35% moisture) was six to twelve times as great as that containing 21 per cent moisture (in equilibrium with air at 25 degrees C and 85 per cent relative humidity, and showing no sensible moisture). The efficiency of hopcalite, an absorbent (actually a catalytic agent for changing carbon monoxide to carbon dioxide) is readily destroyed by moisture. It is frequently difficult to control the temperature and humidity of the air for air-supplied respirators. The lines carrying the compressed air for general plant purposes even though the latter may be pure for respirator use, frequently parallel steam lines or pass thru hot areas, resulting in uncomfortably high temperatures at the terminals. Otherwise satisfactory compressed air may have had the moisture removed because of certain operating requirements, and the relative humidity values below 10 or even 15 per cent may cause discomfort and dryness in the respiratory tract.

6. *Personal factors: comfort, sex, age, physical condition, intelligence, cooperation, etc.*

Most of the respirators now available, if in proper working condition, can be worn, even for long periods of time, without appreciable discomfort if the wearer has become psychologically adjusted to the situation. It is probable that the chief cause of failure of protection in exposures where respirators are provided is the mental and physical discomfort due to faulty operation or maintenance—the clogging of filters, the unclean condition of the face piece, the unsatisfactory fitting to the contour of the face. Unless the workmen are exceptionally enlightened the uncomfortable protection will seem worse than the hazard of the exposure. In general women adapt to the wearing of respirators less easily than men, and this relation increases with the size of the face piece or covering and the amount of equipment involved. Age and physical condition must be considered, especially when devices such as the self-contained oxygen breathing apparatus is to be worn in emergency operations. The intelligence and cooperation of the workmen are obvious factors.

7. *Control of personnel exposed—education, supervision.*

Too frequently the employee is merely handed the respirator with the order to "go ahead and use it." Instruction as to the reason for the protection, the exact situations under which he shall wear the respirator, the signs of faulty operation and what he shall do to correct them, and the care and cleaning of the device, must depend upon the particular circumstances, but it is better to err on the side of too much rather than too little. The education must include the supervision, and the supervision of the supervision. Rarely, the enforcing of protection cannot be accomplished by securing the cooperation, and altho it should be the last resort, compulsory measures may be required.

8. *Facilities for the care and cleaning.*

This very important condition to the proper functioning of respiratory protective equipment deserves more consideration than it usually receives. In plants where a number of respirators are used, provision should be made for the collection, cleaning, repair, and return of the respirators. In this connection, it should be stressed that, if possible, each man should have his own respirator, suitably marked, so that it is returned to him after cleaning. If it is impractical to provide each individual with his own respirator, provision must be made for thorough cleaning and repair if necessary before it is used by another workman. Where an individual is responsible for the cleaning and maintenance of his own mask, there must be systematic supervision to insure its being done. Yant, in the article previously referred to, suggests several methods for cleaning and sterilizing different types of equipment.

It is unfortunate that a simple formula cannot be derived which might be applied in every instance to indicate the most effective type of personal respiratory protection. For the majority of hazardous industrial exposures, the selection of a satisfactory respirator is a relatively simple one, but the factors discussed above must be recognized and applied if the choice is to be the best one. When the conditions of the hazard are unusual, it may be necessary to examine in considerable detail each of the factors, to weigh the advantages and disadvantages, and to repeatedly modify the device until a practical, safe, and comfortable form of protection is obtained.

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TUESDAY AFTERNOON SESSION

October 7, 1941

Presiding:—GENERAL CHAIRMAN J. R. TENNEY, Superintendent of Safety, Western Maryland Railway Company, Hagerstown, Md.

Grade Crossing Accidents

Presiding:—CHAS. E. HILL, General Safety Agent, New York Central System, New York City.

The Highway Grade Crossing Accident Situation as Viewed by the Railroad Claim Department

By WM. J. HOLDEN

District Claim Agent, New York Central System, Cleveland, O.

In 1940 over 1,800 people were killed and 4,500 injured in grade crossing accidents and for the first six months of 1941, 880 were killed and over 2,200 injured.

There are approximately 230,000 highway grade crossings in the United States, each a potential accident hazard. The cure, if there is one, and we believe there is, lies primarily in education and law enforcement, and education must always begin with fundaquiring the driver of all motor vehicles to come to a full stop before proceeding over the crossing, yet these warnings are constantly ignored and accidents occur.

What, then, is the solution of the problem? Where do we go from here?

Grade crossing elimination is glibly suggested, but that is not entirely feasible. There are too many grade crossings in this country to hope for their complete elimination, although the creation of additional crossings should be discouraged and, where possible, adjacent crossings should be consolidated. The thought is suggested that speed governors on all automobiles might tend to curb the speed maniac who insists upon going to his home in Heaven, "on high." But all crossing accidents do not involve speed maniacs, so that alone will not solve the problem.

In the final analysis does not the solution lie largely with the motorist himself? We have discussed the necessity for education and law enforcement, yet we always have with us a certain proportion of automobile drivers who fail to drive in a safe or sane manner. Each year new models of automobiles become faster, both in their get-away and sustained traveling speed, and so long as we have automobiles that permit travel at a high rate of speed and so long as we have motorists who make chance rather than safety their rule of conduct, just so long will there be grade crossing accidents. The problem calls for a continued and coordinated educational campaign sponsored by the railroads and the public authorities.

WEDNESDAY AFTERNOON SESSION

October 8, 1941

The Relationship of Off-Duty Injuries to a Sound Safety Performance

By J. T. WILLIAMSON

Superintendent, Relief and Employment Departments, and Chairman, Board of Pensions, Chicago, Burlington & Quincy Railroad Company, Chicago

Because of one particular phase of my work, the administration of our employees' insurance organization, known as the Burlington Relief Fund, it has been brought forcibly home to me how much pain and suffering and loss occur because of injuries. I also have had an unusual opportunity to observe the effect of personal injuries on the successful functioning of a large railroad organization.

I have reviewed many thousands of reports of injuries, and I can say, from my investigations, that nearly all the injuries were avoidable; practically every one of them was caused by a direct disregard of the prime principles of safety. This direct disregard of the principles of safety is responsible for most of the off-duty injuries, as it is for the on-duty injuries. A moment's inattention or a little careless act is responsible for so many accidents.

A great many of the injuries which occur off duty are the result of carelessness on the part of someone else. This is particularly true of highway accidents. Not long ago, in one month, four of our employees were killed in automobile accidents: four valued employees, men of long training.

As a man performs when off duty, so he will, as a rule, perform when on duty. Man does not change from minute to minute, hour to hour, day to day, or month to month. He cannot be a careless individual at 7:30 in the morning and then when he goes to work at 8 be a careful individual. So I say if a man makes a practice of ignoring the ordinary rules of safety when off duty, you may be sure that he will act in about the same manner when he is on duty.

Last year, out of the 20,000 members of our Relief Fund, 348 were injured while off duty.

to tresspass. They must have legitimate opportunities to give their ever-abundant energy and desire for action or they will turn to trespass and other destructive outlets.

The Boy Scouts of America has a membership of over 1,000,000. If we had leaders and places to meet we would double our membership. We know from surveys which have been carefully made that four out of five boys want Scouting. If the railroads of America will back Scouting with volunteer personnel for Scoutmasters we can go a long way toward helping you.

This is not theory. It is a fact proved beyond question of doubt by the Delaware and Hudson Road among others. John Long, who is here, can tell you of the results obtained by that road as a result of employing a Scout Executive, Mr. Macbride, who spent his time in developing Scouting along its right of way. Several other roads have done the same thing with excellent results. The Missouri Pacific was one of the first to adopt the plan.

The purpose of Scouting is *to train boys for citizenship and to develop character.* The program is one of education and activity is designed to achieve this.

Safety is an important part of this program, not the negative type of safety that would rob them of the chance to learn to defend themselves, by surrounding them with fences, but rather the bold constructive type that teaches them skills. Skills that will provide an opportunity for more adventurous activities with the maximum of safety. More swimming, canoeing, sailing, more mountain climbing and other activities that will fulfill the desire for action and at the same time provide education and build self-reliance.

One of the safety skills that we attempt to teach is that of evaluation and judgment. How to distinguish between the things that can be done safely if done well and those that are foolhardy and destructive. To carry out such a program we need resourceful men of courage, character and leadership ability who will willingly give time to a fascinating game that will produce tangible results.

There is no doubt in my mind that if the railroads of America will give backing to the Boy Scouts of America by providing volunteer personnel and providing professional workers when that is possible, that the Boy Scouts of America will in turn through its program help the railrods of America to solve its problem of trespass.

"No Trespassing, Please"

A technicolor motion picture film, made by the Erie Railroad, was shown at this point, the *narrator* being Lt. J. M. Collins, Police Department, Erie Railroad Co., Jersey City, N. J. A general discussion of trespassing problems closed the session.

THURSDAY AFTERNOON SESSION

October 9, 1041

Presiding:—General Chairman J. R. Tenney.

What Part Should Safety Rules Play in the Safety Organization and Program of Steam Railroads

By THOMAS H. CARROW

Superintendent of Safety, The Pennsylvania Railroad, Philadelphia

Nature's law provides that standing in front of a moving train will result in death. To circumvent the application of this law, man's law or, shall we say, rule, say: "Look in both directions for approaching trains before stepping on or crossing railroad tracks." Experience shows that if there are no violations of the rule there will be no penalties exacted under the law.

Nature's law says that if you stand on the

TRANSACTIONS

31st NATIONAL SAFETY CONGRESS

General Subject and
Industrial Sessions

CHICAGO

October 27-29, 1942

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20 North Wacker Drive, Chicago

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Dust, Fumes, Gases and Vapors

WEDNESDAY MORNING SESSION

October 28, 1942

Presiding:—STUART F. MEEK, 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 points of generation and preventing their dispersion to the workroom. Consequently, unless the process is changed, the hoods or enclosures 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 precept is correct, a discussion of fundamentals 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-Gage), 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 most cases the system will of material exhausted, or leakage losses caused by loose cleanout doors, broken joints, holes worn in duct (most frequent in elbows), poor connection to exhauster 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. Tampering 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 & Casualty 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:

usts	Toluene
arbon Monoxide	Xylene
ydrogen Sulfide	Trichloroethylene
ydrogen Cyanide	Carbontetrachloride
ılfur Dioxide	Carbon Disulfide
xides of Nitrogen	Nitric Acid
nmonia	Chromic Acid
iosgen	Hydrofluoric Acid
ad	Hydrochloric Acid
dmium	Sulfuric Acid
nzene	

Others which are more directly associated to specific industries are:

Trinitrotoluene (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

Silica-bearing inorganic dusts are probably found in all of the above industries. For example, mining of the iron ore in the steel industry presents exposures to free silica dust in considerable quantities. Buffing, polishing, and grinding operations done very 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 crystaline 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 dusts, 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 (1) 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 experienced in direct microscopic work, is eliminated.

Other methods for evaluation of this 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 Fahy. (5) This procedure calls for the use of 10 c.c. of isopropyl alcohol in the midget impinger. The chemical determination is based on the reduction of TNT to triaminotoluene, 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 whch 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 dinitrophenol, 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 p.p.m. 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 hopcalite which oxidizes carbon monoxide 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 milliammeter. The source of suction 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; three 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 handpump. 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 p.p.m. 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 produces 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 iodometrically, 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 p.p.m. 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_3N, 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 a threshold limit of 10 p.p.m. has been suggested.

For the testing of sulfur dioxide, the American Public Health Association (A.P.H.A.) (10) refers to an 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 spit 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-Ilosvay 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 p.p.m. have been proposed for these gases, atmospheres which by odor or color indicate the presence of nitrous fumes should always be viewed with suspicion.

Ammonia

As stated elsewhere, ammonia is an important raw material throughout the chemical industry. It is a strong respiratory irritant for which safe limits ranging between 50 and 85 p.p.m. have been recommended (Russian investigators 13-39 p.p.m.; State of Massachusetts 50 p.p.m.; Flury and Zernik 85 p.p.m.).

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 solution 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.A., 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 pigments. 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 experienced analysts usually well-trained to handle minute quantities of lead in their work, it is preferable to take large air samples wherever possible to facilitate the laboratory work. With the large impinger and the electro-static precipitator with sampling rates of 1 and 3 cubic feet of air per minute respectively, this is not a problem. With the midget 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 handcranked 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. 1.5 mg. per 10 cubic meters of air. For a 30 minute sample with the midget impinger, only 3 cubic feet of air have been handled. This represents only 0.013 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 (U.S.P.H.S.) (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. Exposures 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 cases 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 rivets (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 consideration 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-fouling 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 hazards 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. Althouh 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 expedient 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 towards a phototube, interfering 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 not specific as it is subject to other light intercepting media such as smoke and fog.

There are also other methods for determinations 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 toluene 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 nitration by bubbling the air through nitric acid with subsequent colorimetric determination, or condensation of the vapors followed up by laboratory analytical procedures for the final evaluation. While methods of this type may be satisfactory for scientific purposes, for routine sampling in control work in industrial plants, a combustible gas indicator is far more expedient. 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 p.p.m. can be detected, which is approximately the accepted toxic limit for these solvents. For benzene with a safe limit of 75 p.p.m. (19) a modified combustible gas indicator has been placed on the market, which measures concentrations ranging between 0 and 1000 p.p.m. 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 mostly 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 examined 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, so 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 Disulfide

This substance which at ordinary temperatures occurs as a liquid with a high vapor pressure, generates toxic vapors for which relatively low safe limits have been suggested by various authorities. Russian investigators have recommended a threshold limit of only 3 p.p.m. for prolonged exposures, while the British Department of Scientific and Industrial Research has suggested a value of 10 p.p.m. and our own State of Massachusetts, 20 p.p.m. 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 those most commonly encountered. Of these, nitric acid has been discussed under another heading. Exposures to chromic acid resulting in chrome ulcers 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 baths. Hydrofluoric and hydrochloric acids also exist in gaseous form as hydrogen fluoride and hydrogen chloride respectively. A safe limit of 3 p.p.m. has been suggested for the former, while it has been set at 10 p.p.m. 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 A.P.H.A.

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   - Leaflet No. 6—Carbon Disulfide
   - Leaflet No. 7—Carbon Monoxide
   - Leaflet No. 8—Phosgen
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Selection, Use and Maintenance of Respiratory Protective Devices*

By H. H. SCHRENK
Chief Chemist, Health Division, Bureau of Mines
and
S. J. PEARCE
Associate Chemist, Gas and Dust Section, Central Experiment Station, Bureau of Mines, Pittsburgh, Pa.

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H. H. Schrenk, chief chemist, Health Division, Bureau of Mines and

S. J. Pearce, associate chemist, Gas and Dust Section, Central Experiment Station, Bureau of Mines, Pittsburgh, Pa.

There are several well-recognized procedures for controlling exposure to hazardous atmospheres in industry. They include (a) substitution of less toxic material, (b) enclosure of processes, (c) wet methods, (d) local exhaust, (e) general ventilation, and (f) use of respiratory protective devices. In addition to their employment as a control measure in occupational exposures, respiratory protective devices also are essential in emergencies that may arise from failure 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 after comparatively short exposures, or that may produce injury only after prolonged or repeated exposures. Also, it may be necessary to use such devices against a single type of contaminant, against a combination of various types, or in atmospheres deficient in oxygen.

To meet the conditions mentioned, various types of respirators have been developed. Two basic principles have been utilized in their development--purification of the inhaled air by removal of the contaminant (air-purifying respirators) and supplying a respirable atmosphere to the wearer from an uncontaminated source (atmosphere—air or oxygen-supplying respirators).

Air-Purifying Respirators

Air-purifying respirators include canister gas masks and chemical cartridge respirators for removing gaseous contaminants and mechanical-filter respirators for removing particulate matter or dispersoids. Canister gas masks and chemical cartridge respirators may be equipped with filters for removing dispersoids, thereby giving protection against both gaseous and particulate contaminants. As these devices provide protection only by removing contaminants, it is obvious that sufficient oxygen must be present in the atmosphere to support life.

A canister gas mask usually consists of a full facepiece connected by a flexible breathing tube to a canister that may be carried in a harness on the chest, under the arm, or on the back. The canister contains the materials for removing the contaminants and purifying the air. These materials remove the contaminants either by chemical reactio or by physical absorption, as on activate charcoal. As no single substance has bee discovered that will remove all types o gaseous contaminants, the canister fill depends on the type of contaminant agains which it is designed to protect. Fortunately materials are available that will protec against groups of compounds; therefore, a multiplicity of materials is not required.

For example, activated charcoal will absorl organic vapors, and alkaline materials sucl as soda lime and caustite will remove aci gases. Ammonia may be removed by silica gel or by various materials impregnated witl such substances as copper or cobalt salts Carbon monoxide is removed by catalyti oxidation to carbon dioxide by Hopcalite, a special preparation of manganese and copper oxides. The protection that a canister affords depends on the material with whicl it is filled. For example, a canister may b filled with activated charcoal alone and giv protection only against organic vapors, o it may be filled with all types of the materials mentioned and give protection agains all gaseous contaminants. For protectio against a single contaminant the use of a single absorbent is desirable, as the life o the canister is longer, thus providing mor economical protection.

It is therefore extremely important t know the contaminants against which a canister will protect. To assist users in eas identification, a classification of gas-mas canisters has been developed in conjunctio with a color code. This code, which is a American standard used by all manufacture of gas masks in the United States, is a follows:

Canister, type letter	Contaminants proctected against—	Colors
A	Acid gases	White.[a]
B	Organic vapors	Black.[a]
C	Ammonia	Green.
D	Carbon monoxide	Blue.
AE, etc.	Dusts, fumes, mists, fogs, and smokes in combination with any of the above gases or vapors	One-half inch contrasting bla or white stripe around the ca ister near the top.
AB	Acid gases and organic vapors	Yellow.
ABC	Acid gases, organic vapors, and ammonia	Brown.
N	All of the above atmospheric contaminants	Red. Filters are included in t canister, but stripes to indica them are unnecessary.

[a]Canisters for a single gas or vapor other than ammonia or carbon monoxide shall have a ½-i colored stripe around the canister near the bottom. The color of the stripe will be assigned.

Canister gas masks have been developed primarily for protection against atmospheres immediately dangerous to life and are used mainly in emergencies. Therefore, first consideration has been given to complete respiratory protection to prevent even momentary failure that might result fatally. These masks, however, are not designed for protection against extremely high concentrations, and in Bureau of Mines Approval Schedule 14E concentrations are limited to two per cent by volume, with the exception of ammonia, for which the limit is three per cent. The service life of the canister depends on the individual characteristics and the amount of absorptive material used. Although these masks are designed primarily for emergency use, they will, of course, give good protection for non-emergency situations, and filters may be incorporated to remove particulate matter.

Chemical cartridge respirators usually consist of a small cartridge or canister attached directly to a half-mask facepiece. The materials for removing the contaminants are the same or similar to those used in canister gas masks, and filters may be incorporated to remove particulate matter. These devices may be considered small gas masks and are designed for protection in atmospheres that could be breathed by workmen without protection, but that might be irritating or disagreeable or produce injury to health after prolonged or repeated daily exposures; hence, primary consideration has been given to lightness, compactness, and comfort.

Mechanical-filter respirators usually consist of a filter arrangement of some fibrous material such as felt or paper, in a holder connected directly to a half-mask facepiece. The filter consists of fine fibers criss-crossed to form a maze or intricate network of tortuous passages. The dust, fume, mist, and fog are removed by physical trapping when the air is drawn through this material. The filtering efficiency increases as the dust load on the filter increases. The service life of the filter, therefore, does not depend on recognizable leakage, as does that of the gas masks, but on increase in resistance of the filter to a point where resistance to inhalation becomes excessive or uncomfortable. Although the filters will remove all types of particulate matter, the extent to which the material is removed depends on the characteristics of the particles, such as size and state. Also, the amount of permissible leakage depends on the toxicological significance of the material. Therefore, various types of filters are used; that is, a filter may be satisfactory for silica dust and not satisfactory for a toxic dust such as lead or cadmium, owing to the greater toxicity of the latter. A filter that is satisfactory for dust (mechanically generated, as by grinding) may not be satisfactory for fume produced by heating or burning, as in lead burning, owing to particle-size differences. On the other hand, a filter satisfactory for silica dust is considered satisfactory for all other fibrosis-producing dusts and nuisance dusts; and a filter considered satisfactory for lead dust is considered satisfactory for other toxic dusts, the toxicity of which does not exceed significantly that of lead.

Mechanical-filter respirators have been designed for protection against atmospheres that are not immediately harmful; therefore, primary consideration has been given to lightness, compactness, and comfort.

Atmosphere-Supplying Respirators

Respiratory protective equipment that supplies a respirable atmosphere from a source independent of the wearer's immediate atmospheric environment is of two basic types—a hose type, in which air from an uncontaminated source is conveyed to the wearer through a hose or tube, and a self-contained type, in which a supply of oxygen is carried by the wearer.

The air-supplying respirators commercially available may be divided into three types: Hose masks, air-line respirators, and abrasive blasting helmets, hoods, or masks.

Hose masks consist of a tight-fitting, full facepiece, breathing tube or tubes, a harness, a comparatively large-diameter, noncollapsible hose line, and a hand-operated blower. The harness and hose are strong enough for retrieving the wearer in an emergency, and the hose must not collapse under heavy weight and must not kink. The maximum length of hose approved by the Bureau of Mines is 150 feet. The use of a hand-operated blower assures that a second person will be present in the event of difficulty. Also, the attachment of the hose to the blower and the large diameter of the hose permit breathing without undue resistance, even though the blower is not operated. The intake to the blower must be in uncontaminated air.

Hose masks are sturdily constructed, as they are designed to be worn in atmospheres immediately dangerous to life and to afford protection against all types of atmospheric contaminants and atmospheres deficient in oxygen.

Special-type hose masks without blower and generally used with about 25 feet of hose also are available. Although the hose, breathing tubes, and facepieces are essentially the same as those for hose masks with a blower, the harness is much lighter and the device is designed for lightness, compactness, economy, and simplicity of operation. Such masks are designed for non-emergency use or for use in atmospheres not immediately dangerous to life.

Air-line respirators usually consist of a high-pressure air-supply system, a hose of relatively small internal diameter, a detachable coupling, and either a full or half-mask facepiece, or even a helmet or a hood. As the air for this type of respirator usually is supplied from a high-pressure compressed-air system, it must be checked to see that it does not contain objectionable or harmful contaminants. Dust from dust, oil mists, odors, and even carbon monoxide may be present if the compressor becomes too hot; therefore, critical attention should be given to the air supplied to these devices.

Although this respirator will give respiratory protection against all types of contaminants, it is designed for routine protection against concentrations of contaminants that are not immediately dangerous to life or health. It is thus limited, owing to the possibility of leakage around the half-mask facepiece and also to the fact that no provision is made so that the wearer can breathe respirable air, should the air supply fail.

Abrasive blasting respirators are essentially air-supplying respirators that have been modified by the addition of a suitable covering to protect the head and shoulders against impact and abrasion by rebounding material. They are designed primarily for use in abrasive blasting operations and not for use in atmospheres that are immediately dangerous to life.

The most common devices for supplying oxygen to the wearer are self-contained oxygen breathing apparatus. These apparatus consist of a cylinder of compressed oxygen, a reducing valve, an admission valve, a breathing bag, breathing tubes and mouthpiece with valves for direction of inspired and exhaled air, a regenerator for removing carbon dioxide, and a cooler. They operate on a closed-circuit principle, and the entire device is worn by the user. When the cylinder valve is opened the oxygen flows through the reducing valve, thence through the admission valve, into the breathing bag, until the bag is expanded to a point at which the admission valve automatically cuts off the supply of oxygen. Oxygen is breathed from the bag, and the exhaled air passes through the regenerator to permit removal of carbon dioxide, thence through a cooler, and back to the bag. As oxygen is consumed, the bag tends to collapse, and the admission valve automatically admits additional oxygen.

Self-contained oxygen breathing apparatus give respiratory protection against all types of atmospheric contaminants in any concentration that can be endured by the skin but require gas-tight goggles in atmospheres irritating to the eyes. They also protect against atmospheres deficient in oxygen and are designed for protection against atmospheres that are immediately dangerous to life.

Selection of Respirators

The use of respiratory protective devices as a control procedure requires as much consideration as any other control method. In the selection of a respirator, thorough consideration should be given to various factors involved, such as:

a. the chemical, physical, and toxicological properties of the substances against which protection is required

b. the effect of the processes and conditions of use of the substances as they relate to the possible formation of significant secondary products

c. the processes and conditions of their use as they relate to the dissemination of contaminants

d. an evaluation of actual and potential hazards to determine whether conditions immediately dangerous to life or health might arise or whether injurious effects would be produced only after prolonged or repeated exposures

e. the nature of the duties to be performed by the wearer of protective devices as they relate particularly to restriction of movements

f. an understanding of the principles, design, scope of use, limitations, advantages, and disadvantages of the respiratory protective equipment available.

Virtually all applications of respiratory protective devices are specific and require individual attention. Examples of typical conditions with indication of choice of appropriate respiratory protection are given.

Atmospheres deficient in oxygen may be extremely hazardous and immediately dangerous to life. Only oxygen breathing apparatus or a hose mask with blower should be chosen for protection under such conditions. Final choice between these two devices will depend on working conditions.

For example, for rescue work in mines, the men must proceed for considerable distances from a source of fresh air. Obviously, hose masks would not be satisfactory, as wearers are limited to a distance of 150 feet; therefore, oxygen breathing apparatus must be used. However, for use in entering confined spaces, such as tanks and manholes, hose masks are generally preferred because they are easier to maintain and relatively little training is required to use them. Air-purifying devices should never be worn in atmospheres deficient in oxygen.

By very high concentrations is meant those exceeding two or three per cent. Either oxygen breathing apparatus or hose masks with blowers are the logical choice, and again final selection will depend on working conditions. Although gas masks might afford some protection, they would not be a good choice, because very high concentrations indicate a confined space with possibility of low oxygen; moreover, the absorbents would be used up rapidly. The marked discomfort produced by such irritating gases as ammonia and sulfur dioxide and the danger of poisoning through the skin by absorption of hydrogen cyanide limit the concentrations that can be entered.

Concentrations referred to here are those not exceeding approximately two per cent but nevertheless immediately dangerous to life. Oxygen breathing apparatus would, of course, be applicable, as would hose masks with blowers and gas masks. Owing to their weight and maintenance and training requirements, oxygen breathing apparatus probably would not be used. The hose mask would be satisfactory and might be chosen if the encumbrance of the hose line were not too great. The most probable choice would be a gas mask, because of its light weight, ease of maintenance, and the small amount of training required by the wearer. The appropriate canister should, of course, be chosen.

Low concentrations are atmospheres that can be breathed without protection but that will produce discomfort and possible chronic injury after repeated exposure to them. Hose masks and oxygen breathing apparatus would give satisfactory protection, but they would be given little consideration for such a situation for the reasons already outlined. Gas masks, chemical cartridge respirators, or air-line respirators would be satisfactory. Final choice would depend on actual conditions and freedom of movement required by the worker.

For pneumoconiosis-producing and nuisance dust, air-line respirators and pneumoconiosis-producing- and nuisance-dust respirators or all-dust respirators could be chosen. If the dust concentration is exceedingly high, air-line respirators would be preferable. If the conditions of work are such as to interfere with the use of an air-line, mechanical-filter respirators will serve satisfactorily, even though they are awkward to wear for many kinds of work.

For toxic dust, air-line respirators, toxic-dust respirators, or all-dust respirators would be a logical choice. The final decision will depend on local conditions of work and the materials being used. Knowledge of the concentrations likely to be encountered and of the safe or permissible concentration is necessary in evaluating the protection afforded.

Fume is particulate matter formed by volatilization and condensation, as in lead burning. Fume is defined because it is a term used loosely to refer to gases, vapors, and particulate matter. Such usage is confusing and may lead to serious injury if a mechanical-filter fume respirator is used for protection against some toxic gas or vapor against which it affords no protection. For fume as defined above, air-line respirators or mechanical-filter fume respirators would be the logical choice, and final decision would depend on local working conditions.

Frequently protection must be afforded against a combination of gases and particulate matter (dust, fume, mist, and fog). If the atmosphere is not immediately dangerous to life, air-line respirators are generally recommended. However, gas masks equipped with a suitable filter or cartridge-type respirators equipped with a suitable filter may be used. Final decision not only would depend on the local conditions of work as they relate to freedom of movement but also on thorough consideration to ascertain whether gas masks or cartridge respirators would give the desired protection.

Use of Respirators

Although choice of a suitable respirator is important, other considerations are equally so. Obviously, if a respirator is to do the job for which it is chosen, it must be worn properly and be kept in good condition. Frequently persons do not know how to wear a respirator, and if it is not clean it is unpleasant to wear. Better protection and fuller cooperation doubtless would be obtained if the respiratory protective devices were kept under the supervision of a responsible person who would see to it that the wearer is properly instructed in the use of the device, that the device is cleaned and disinfected regularly, and that it is maintained in first-class condition.

No instructions are necessary when hard hats or hard-toed shoes are given to workmen, as they are used to wearing such articles. Too frequently respirators are handed out in a similar manner. Even the simplest respirator is comparatively much more complicated than protective hats or shoes and is a device that most workers are not accustomed to wearing. The principles on which each device is based, its field of use, and its limitations, as well as the essential parts, should be explained to the wearer in terms he can understand. Detailed instructions with practice should be given to all persons who are expected to wear such devices. Further, an explanation of the importance of wearing the respirator should be helpful in obtaining more complete cooperation.

For example, in the use of mechanical-filter respirators attention should be called to the importance of a good facepiece fit and proper but comfortable adjustment of the headband, and also to the fact that increased resistance to inhalation indicates that the filter should be cleaned or renewed.

In the use of gas masks good facepiece fit is also necessary, and the proper canister must be chosen. As the wearer depends on odor or irritation to warn when the canister is exhausted, he must be acquainted with the warning properties of contaminants for which protection is worn so that leakage will be detected readily. Persons using gas masks in toxic atmospheres should have had preliminary training in the use and limitations of the equipment.

All respirators approved by the Bureau of Mines are furnished with an approval label that gives concise information on use and limitations. Also, more detailed instructions that have been reviewed by the Bureau accompany all approved devices. Both approval label and instructions should be consulted by the user.

Cleaning and Disinfecting Respirators

Respirators, particularly the facepieces should be scrubbed daily after use with lukewarm water and soap. This not only is good hygienic practice but also prolongs the life of the rubber, as otherwise the dirt, oil, and perspiration from the face may cause rapid deterioration. Respirators should also be disinfected at regular intervals. If a respirator is worn by the same person, disinfection once a week probably should be satisfactory in most instances, depending on conditions of use and thoroughness of cleansing with soap and water. A respirator that has been worn once should be disinfected before it is given to another person to wear.

There are several procedures for disinfecting respirators; however, as certain respirator parts may be damaged by the disinfecting agent, the manufacturer should be consulted as to the best procedure for his device. This warning is particularly pertinent at present, when the use of substitute materials is so common.

Common disinfecting procedures include scrubbing or immersing the respirator for 10 minutes in 70 per cent alcohol, two per cent cresol, or a solution of formalin made by mixing one part of 40 per cent formaldehyde in nine parts of water. When such agents as cresols are employed as disinfectants, the parts that come in contact with th skin should be rinsed thoroughly with water, as some persons are highly sensitive to such materials.

Cleaning and disinfecting afford an opportunity for cleaning or replacing filters, inspecting valves, headbands, facepieces, and metal parts that might be distorted.

Maintenance and Storage

A most important phase of any control procedure is maintenance. Choice of proper equipment and adequate instruction are completed projects, but maintenance is a continuous problem requiring constant attention. As such it should be supervised by someone thoroughly familiar with the apparatus being used.

Washing and disinfecting the device affords an opportunity to inspect it for minor repairs. In addition, it should be inspected thoroughly at monthly or longer intervals, depending on the apparatus, conditions of use, and storage. Devices for emergency purposes should be inspected after each use to assure that they will be in good condition and immediately available if an emergency arises. After the equipment has been cleaned and inspected and any necessary repairs made, it should be stored properly.

A good procedure is to have a central place of storage, possibly with sub-stations at strategic points if the plant is large. Storage should be in essentially dustproof containers away from sunlight and in a cool place (not near radiators or steam pipes). Small devices, such as dust or chemical cartridge respirators, can be kept in paper or cellophane bags. These devices may be numbered and assigned to some one person, who returns them at the end of the shift to the central station for cleaning and replacement of filter elements, and for repairs if necessary. Thus, wearers are assured clean devices in good working order for each day's use. This program may be facilitated by assigning two respirators to each person, one being used while the other is being serviced.

Larger devices, such as gas masks and hose masks, usually come equipped with a sturdy case or trunk that can serve as a storage place. If they are stored at strategic points for emergency use, they might be placed in a case with a glass window that requires breaking of a seal to assure that they have not been used or tampered with. The seal should bear the date of the last inspection.

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Steam Railroad Section

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†As elected by delegates in Congress session.

TUESDAY AFTERNOON SESSION

October 27, 1942

Presiding:—O. F. GNADINGER, Supvr. of Safety, Elgin, Joliet and Eastern Railway Co., Joliet, Ill.

Greetings From Safety Section, A.A.R.

By P. F. BUCKLE

Supt. of Safety, Chicago, Burlington & Quincy Railroad Co., Chicago

It is, of course, an honor and a privilege to be able to bring to this meeting greetings from the Safety Section of the Association of American Railroads.

There never has been a time when it was so important that those of us who are engaged in accident prevention endeavor to consolidate our positions, to do everything within our power to promote harmonious relations between all safety agencies in the interest of producing the maximum of cooperative effort in this most worthwhile of activities.

Whatever may have taken place in the past that brought about disunity or lack of harmony between these two important agencies should now be forgotten, and it should be the duty of each and everyone of us to make these two organizations as effective as possible, above everything else, in the interest of winning this war, never forgetting the humanitarian aspect of our responsibilities. We can only bring these things to pass by subordinating our personal prejudices or desires for the common good. I hope I shall always be able to do this and I need the help of every one of my associates in bringing this to pass. Whatever accomplishment has come to the Safety Section during the time that I have been privileged to serve the Section as chairman has resulted because of the cooperative effort of all active members of the organization; for that I am deeply grateful.

We cannot continue these two organizations and have them function as we desire them to function unless able men are willing to serve as officers, as chairmen of committees and as members of these committees, giving freely of their time and best efforts for the benefit of the sections and their respective endeavors. Both of these organizations are necessary, especially during these times which "try the souls of men." The Steam Railroad Section needs to be a strong, going concern to take its place in carrying out the War Production Fund program. The Safety Section should back this endeavor to the full. Personally I pledge that support.

It is again a privilege and an honor to bring to the Steam Railroad Section greetings from the Safety Section of the A. A. R and I think all of us ought to keep in mind the need for strengthening friendships. The gift of friends, to my mind, the most potent and pleasant thing in life, becomes increasingly important with the passing of the days

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and leaders. In fact, it is a well recognized concept that the sergeants, from buck to master, run the army. In like fashion, the foremen run the industry. They know their men. But they can become mentors not only in technical procedures but in all the factors which make for well being. They can learn and pass on simple first aid regulations which are safe as well as numerous precautions which will reduce hazards. A few hours of instruction to the members of this group (foremen) will be fertile seed sown upon rich soil.

The output of many a plant can be gauged by the active integration of the organization coupled with the good health of the employees. But every task does not require a Hercules. In fact, there are many jobs that can be performed with dispatch by a man with one leg, one eye, etc. It becomes then the task of fitting the qualities, attributes, and skills of the applicant to the duties to be accomplished. It is well known that handicapped men and women are among our most loyal, faithful, and conscientious workers.

WEDNESDAY AFTERNOON SESSION

October 28, 1942

Presiding:—O. F. Gnadinger, Supvr. of Safety, Elgin, Joliet and Eastern Railway Co., Joliet, Ill.

Safety and Labor Relations

By H. J. HOGLUND

Chicago, Burlington & Quincy Railroad, Chicago

Labor relationship has much to do with the attitude of mind of the worker, and upon this attitude of mind hinges the thinking before acting which is so fundamental to safety.

Because of lack of control of action, because of thoughtlessness or because of mental laziness, needless accidents occur, and prevention constitutes a real problem to perfect the attitude of mind.

Good housekeeping, keeping tools and machinery in order eliminates much exposure to hazard, and its importance cannot be overemphasized, but despite these precautions accidents occur unless there is good labor relationship.

For years safety officers have been preaching safety, and the results speak for themselves; they are reflected in the record of the American railroads. You started way back in the early 20's talking about the three E's of safety—cardinal principles of great importance—yet consciously or otherwise, you added a fourth E which stands for the enthusiasm you have steadfastly maintained. Safety is the work of morale builders and morale cannot be built without the Nth degree of enthusiasm. Our supervisors should keep this in mind.

Primarily the supervisor is responsible for the safety of his workers, and he should devote a great deal of effort to the art of handling or leading men. Generally speaking, this skill can be acquired only through leadership training. The worker's attitude toward his job, his company, his fellow workers and toward his supervisor is, to a greater extent than some realize, the essence of good labor relations.

Everything possible should be done to avoid irritating workers. Irrespective of all other conditions surrounding a man's job, if he has an irritating type of supervisor, he will not perform his work cheerfully, and he is not, under such conditions, likely to be as

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THURSDAY AFTERNOON SESSION

October 29, 1942

Presiding:—O. F. GNADINGER, Supervisor of Safety, Elgin, Joliet & Eastern Railway Co., Joliet, Ill.

Notes By W. R. LOFGREN

Ass't. Supt. of Safety, Chicago & North Western System, St. Paul, Minn.

A highlight of the entire program was that portion conducted by the inquisitive Mr. W. J. Flannigan, Superintendent of Safety, Northern Pacific Railway, who desired to know so many things. This type of program is outstanding and reminds us very much of the lively "rump" sessions of 1939 at Atlantic City and last year at Chicago. The delegates also requested a great deal of information and the response was energetic.

Mr. Flannigan's first interrogation dealt with the involvement of hand signals in a large number of train accidents and the fact that failure in this respect could probably be charged to the new employee—the rules providing that utmost care must be exercised by train, engine and yardmen in order to prevent taking signals that may be intended for other trains. The question in connection with supervision of older employees and likewise the training of new employees to see that proper signals are always given was answered by Mr. Cates of the Seaboard Air Line, who stated the practices in effect on the SAL.

A number of delegates participated in answering the next item which covered the causes accounting for the largest group of train accidents, i. e., overrunning meeting point, disregard of stop and caution signals, which would mostly be chargeable to the older employees, and how they were being prevented by (a) physical examination, (b) rules examination, (c) surprise test and (d) checking dispatchers and operators for accuracy and compliance with the rules providing for issuance of train orders. Other subjects covered were higher speed, advance yard limit boards, proper respacing of automatic block signals and checking of brakemen on assistance given to conductors and engineers in watching train order signals, time and meets. Messrs. Hellweg (D&H), Phillips (Wabash) and Lofgren (CStPM &O) responded to questions.

Train Accidents

The inquisitor called attention to the increase in train accidents per million locomotive miles run in 1941 over 1940, and in connection with checking speed restrictions, observance of block signals, not permitting second or other sections of regular trains to proceed on yellow block, strict compliance with Rule 99 instead of merely "decorating" and other means of preventing collisions, Mr. Allison of the Baltimore and Ohio was called upon and gave a very good description of plans employed to train and supervise employees to comply with the rules.

Mr. Washburn of the Milwaukee Road made an excellent response to the question of manner of preventing hand brake accidents by describing the CMStP&P hand brake instruction car which has been on the road since last February. (See *News-Bulletin* Number 3 of March 31st). Mr. Lowe likewise described the plan of the Southern Pacific Company of having the different types of hand brakes mounted on a platform at two locations—Klamath Falls and Dunsmuir—where train and yardmen are hired and given complete instruction in operating hand brakes safely. In this connection, Mr. Collett of the Santa Fe suggested that a 16 mm. sound film be prepared on the proper operation of hand brakes, etc., Chairman Gnadinger advising that preparations for a sound slide film were being made by the Committee on Education, Safety Section, AofAR.

Question if constant checks were made to make certain that proper elevation of curves and other track maintenance stand-