Dusts, Fumes, Gases and Vapors

WEDNESDAY MORNING SESSION

October 12, 1938

Assembling in the Grand Ballroom of The Stevens Hotel, this meeting was called to order by Chairman Walter S. Paine, Manager, Engineering and Inspection Department, Aetna Casualty & Surety Company, Hartford, Conn., and Vice-President for Engineering, National Safety Council. Chairman Paine briefly outlined the session objectives, and then introduced the speakers.

Recent Developments in Detecting Hazardous Dusts, Fumes, Gases and Vapors

By WARREN A. COOK

Superintendent, Engineering Department, Zurich General Accident and Liability Insurance Company, Ltd., Chicago

In discussing the determination of injurious dusts, fumes, gases and vapors, I am very sure that you are not interested so much in a meticulous dissertation on such phases of the subject as whether the logarithm of the reciprocal of the hydrogen ion should be 9.5 or 9.0 for the determination of lead by the dithizone method, but rather in a discussion of this matter along broad lines, pointing out what types of potentially injurious materials should be looked for, whether determination of them is in order, a brief discussion on some of the more important and common methods of determination, and interpretation of the results obtained.

Foolhardy to "Work in the Dark"

Working in the dark without any means of illumination where there may be hazardous conditions serious enough to cause loss of life or severe injury would be considered most foolhardy; yet every day men conduct their operations in atmospheres containing dusts, gases, and vapors which may cause death or severe injury to health without being able to see or otherwise perceive the potentially hazardous condition.

Most gases and vapors can no more be seen than the well-known black cat in the coal cellar. Some of them cannot even be detected by odor, though odor is itself no reliable criterion as is evidenced by the gas, hydrogen sulfide, which has a most obnoxious odor but has caused many a case of poisoning.

How, then, are we to know whether the atmosphere in which we work is safe or injurious? Are we to wait until we see the effects of unhealthful or irrespirable atmospheres on our men or is it not more intelligent to determine, within the limitations of modern methods and practical applications, just what sort of atmosphere we are subjected to?

The importance of having facts before us is well illustrated by an atmospheric condition where a life could be snuffed out in a few minutes, even though the more common situation is where excessive exposures may require weeks, months or years to cause their injurious effects.

Thirteen years ago this month a powder crew was walking down the tunnel of a new water supply system of a Connecticut city. Their duty was to inspect the roof and the face, to see that all the shots were fired. On approaching the tunnel heading immediately after the blast, they found that flying rock had broken the compressed air line, which had been left turned on in order to blow the smoke and gas away from the face of the tunnel. The crew, consequently, ran into a heavy blanket of smoke, but they were hardened workers, used to smoke and gas, and a little smoke, even though they knew it contained carbon monoxide, did not hold them back.

They found the roof intact. But four of the holes had not fired. Caps with 3-foot fuses were inserted in sticks of dynamite, one for each of the holes. The gas condition by the time this work had been accomplished was beginning to make these men feel a bit groggy. Following the usual practice, the powder foreman sent the rest of the men back down the tunnel before he lighted the fuses.

The men walked back through the smoke to the car, about a quarter of a mile down the tunnel. There they waited for the foreman. Seconds passed. The time stretched to a minute. Down the tunnel came the boom of the blast—but no foreman. The men rushed to the heading and found the foreman stretched on the tunnel floor, nearly covered with rock from the blast, where he had collapsed from the effects of the carbon monoxide.

This is a true story up to a certain point, but I have omitted a part of the story, and the ending, I am glad to say, is pure fiction. The part of the story which I omitted was that carbon monoxide determinations were being taken when those men got up to the heading, and a concentration of .3 per cent carbon monoxide was shown to be present by means of the Hoolamite carbon monoxide detector. With such a high concentration, it was realized by the man making the determinations that it would not take long for exposed persons to collapse. He informed the crew of the condition and hurried them back to the car to wait until the smoke and gas had cleared enough to permit them to work safely and fire the blast.

The difference between fact and fiction in this case, between a brief delay and a fatal case of carbon monoxide poisoning, was the ready availability of a simple means of determining the carbon monoxide concentration on the job.

The present tendency in development of methods of determination of injurious materials in air is toward such simple, quick-acting devices. As many of you know, the Hoolamite carbon monoxide detector operates merely by pressing a rubber bulb ten times and comparing a purple color which develops in presence of carbon monoxide with a standard color scale mounted on the instrument—an operation which requires about a minute. Instruments of this type are especially important for gases which may cause acute poisoning such as carbon monoxide, hydrogen cyanide, and hydrogen sulphide.

An instrument for determination of hydrogen cyanide, similar to the Hoolamite carbon monoxide detector, has recently been developed by the United States Bureau of Mine workers, and, together with a number of other of these simple detectors, is now available commercially. Determination of such materials can accordingly be made much more widely than formerly when laborious chemical laboratory methods were necessary.

Potentially Hazardous Materials

The first step in an organized endeavor to avoid environmental conditions which may cause injury to health is a listing of all materials, used or produced, which may under certain conditions be deleterious. It was found in a study by the United States Public Health Service of potential hazards in a typical industrial area (1) that a considerable percentage, nearly 20 per cent, of the workers were exposed potentially to carbon monoxide. The report by no means intimated that this percentage of workers were being poisoned by carbon monoxide, but rather that if things went wrong and a concentration of the gas built up to injurious proportions these men might become poisoned.

So I suggest that you go through your plants and see what operations involve potentially injurious materials. Of the dusts, those which may produce silicosis occur not only in the well-known industries where major studies of conditions have been conducted but in other industries as well, though usually to a lesser extent. In silverware manufacturing, for example, one man may be exposed day after day to tripoli dust in making up a polishing compound for use within the plant. A list of industries in which such dust exposures may exist is given in the report of the National Silicosis Conference.[2]

The toxic dusts and fumes are more readily spotted. We recognize and guard against lead exposure in storage battery plants, but often overlook such an operation as where red lead is being mixed with a vehicle by a worker in one corner of the top floor of the plant to color lettering on a steel part. It is not so much whether a pound of lead or a ton is used in a day, but the extent to which it contaminates the air breathed by the worker.

Carbon monoxide, hydrogen sulphide, hydrogen cyanide have been mentioned as examples of gases. The first of these occurs where producer gas or water gas is used. The last named should be looked for where fumigating may be done from time to time. Where dry ice is used in quantity or fermentation processes are conducted, carbon dioxide is liberated and has caused deaths usually at the bottom of confined areas such as ships' holds and fermentation tanks.

Vapors are present wherever organic solvents are used. Death may result quickly where high concentrations exist as has occurred when a drum of solvent was dropped on a basement storage room floor and split open, and again where carbon tetrachloride was being used for fumigating a flour mill and the fumigator sprinkled the liquid in the basement as his last operation. It was his last.

Injury from continued exposure to solvent vapor at concentrations which cause their effect after weeks of exposure is the more common condition. The various solvents differ widely in the concentration of vapor necessary to cause injury. These are divided into groups in accordance with their toxicity in a paper delivered before the Northwestern University Symposium on Occupational Diseases a year ago.[3]

Where Should Determinations Be Made?

After going over your plants and learning where potentially hazardous materials are present, it is my suggestion that, before making actual determinations of concentrations in air or instituting control measures, you make a thorough survey of the conditions and divide the various operations where these materials are present into groups: (1) those which are obviously safe; (2) those which are admittedly causing injury to health or are worse than good industrial practice dictates; (3) those conditions where it is not readily discernible by general observation whether the exposure is within safe limits.

Certain conditions we know definitely and can say definitely will not cause injury to health. I would not say that those are to be forgotten, but at least they need not be the subject of initial action. If, for example, a gas containing 30 or 40 per cent carbon monoxide is used for hot plates, and those hot plates are connected with rigid conduit rather than with rubber tubing, you can feel reasonably safe that the carbon monoxide exposure is within safe limits, and I would not recommend that determinations be made. Where spray painting is being done in a well ventilated booth in such a manner that there is no excessive rebound into the face of the sprayer, determinations of vapor or pigment need not be made even though the odor of the solvent is detectable. From time to time it may be well for state authorities to check some of these lesser exposures; but there is a considerable number of such exposures which can be accepted as safe.

The second group of exposures—that where conditions are admittedly severe—is another where determinations are not essential. Institute control measures immediately. If there are clouds of dust containing free silica in your plant, go to work on them. If excessive lead absorption is shown by development of symptoms or by high basophilic aggregation percentages, reduce the lead exposure. It may be desirable to make determinations even in these cases either to provide a before-and-after picture of exposures to show what improvement is effected or to obtain a clear picture of just what part of an operation is responsible for the excessive exposure to the end that control measures can be more specifically applied. This latter use of air analysis data is of especial value where the materials are invisible as is the case with gases, vapors and even some of the more toxic dusts such as quartz and lead.

The principal use for determination of

injurious materials in air is where general observation does not give the necessary information. Suppose exhaust ventilation and partial enclosure have been installed to reduce exposure to a dust high in free silica. You might learn whether control measures are effective by waiting ten or a dozen years to see whether silicosis develops among those exposed. It is much more economical to run a group of dust determinations. A recent series of such determinations indicated that exhaust ventilation was adequate at an operation where pulverized silica was being transferred to the hopper of an elevator, but the manipulation was at fault.

Where fumigation with cyanide has been conducted, it has long been the practice to depend upon a time period of ventilation and upon the nose of the fumigator to establish that the premises are safe for occupancy. Now that a simple hydrogen cyanide detector is available, it is in order that determinations be made in every case before re-occupancy and, further, that every municipality where cyanide fumigation is carried on enact an ordinance covering such fumigation with the provision that determinations be made, especially in any dead air spaces, before the premises are considered safe for occupancy.

Hydrogen sulphide determinations are today being made routinely in the spinning rooms of viscose rayon manufacturing plants. Carbon disulphide determinations involve a more laborious procedure but are regularly made in a number of departments of the larger plants of this same industry. Operations are regulated so that any exposures to these materials are within safe limits, but the continual checks permit detection of any excessive exposures before injury to health develops.

A good general rule to adopt is to make determinations of concentrations of injurious materials in air wherever there is any question that these may produce deleterious exposures.

Methods of Determination

Discussion of methods of determination will be limited to certain general considerations, reference to complete descriptions of available methods, and comments of timely interest on a very few methods.

In the collection of samples, it is of utmost importance that these samples are such as to provide the desired information. It has been pointed out that one set of conditions exists today, and quite a different set of conditions may exist the next day; that if air analyses show conditions to be satisfactory on the first day, our eyes may be closed to the fact that conditions are much worse on the second day. So, rather than encouraging the installation of safeguards, we are setting up obstacles to them.

My plea is that methods of determination be used intelligently and honestly. If it is desired to show exposures under the most severe conditions, be sure to set up these conditions when you make the test; if representative conditions are desired, see that they are truly representative. Whether you yourselves make these tests in your own plants, whether you bring consultants in to make them, whether state departments, insurance companies, or some other agency makes these determinations, make a real effort to see that conditions are as represented when these determinations are made.

For a comprehensive discussion of equipment for conducting determinations of dusts, fumes, gases and vapors, may I refer you to a paper entitled "The Industrial Hygiene Laboratory."[4] This paper includes descriptions of both field equipment and laboratory apparatus, together with a discussion of their applications.

References to the methods themselves may be obtained in the reports of the Committee on Methods of Determination of Injurious Materials in Air.[5] These reports are available on application to the American Public Health Association.

The Preventive Engineering Committee of the Air Hygiene Foundation of America has recently developed a bulletin on Methods of Determination,[6] and in that bulletin are included only those methods which have been satisfactorily used in this country. The trouble with many papers on methods of determination is that they are woefully deficient in their practical qualities and simply do not work when put to the test.

You are all interested, I believe, in a brief discussion of the methods available today for dust determination and some of the up-to-date viewpoints on collection and determination of dust. It is my opinion that where it is desirable to know whether a condition is or is not safe in the light of investigations so far conducted in this country, it is well to collect samples by means of the impinger method. I will not go into the advantages or drawbacks of that method at the present time beyond bringing attention to the micro-impinger set-up as developed at the Bureau of Mines and now available commercially which largely overcomes the bulkiness of the original equipment.

It is to be emphasized that only the impinger will give impinger results. Due to the different characteristics of other methods of determination, you cannot get a duplication under a variety of conditions by the use of other instruments. However, other instruments, such as the grab samplers, which take a sample over a period of a second or two, are of very considerable value for a number of purposes. If an impinger sample collected over a period of an hour shows a high dust concentration exists, we may know what particular operations during that hour caused this high concentration. If we have a Zeiss konimeter, a Bausch and Lomb dust counter, or some instrument which will give us the concentration at any given instant, we can obtain precise information on those operations which are contributing most of the dust.

Furthermore, after we know whether a condition is safe or not, one of these quick-sampling instruments is extremely valuable as a control measure. Wherever a concern has a dust condition, determinations may desirably be taken by some of these quick methods regularly as a control. Whether they compare exactly with the impinger or not is of no great consequence; the important thing is whether conditions are holding at levels shown by the impinger to be safe. If dustiness is on the increase, a survey of dust producing operations should be made and control measures instituted.

Collection of lead dust and fumes is of timely interest with the commercial availability of the portable electrostatic precipitator. Most of us who have been sampling lead in this country have been using the impinger for the collection of these samples. This instrument is highly efficient for the collection of samples where lead dust is the material of interest. Where lead fumes are given off, we have evidence that the impinger collects these fumes at appreciably less than 100 per cent. We feel that the electrostatic precipitation method, which is about the most efficient method of collection, is a preferable instrument for materials of sufficiently fine division to be classed as fumes. This type of instrument has long been available, but only recently commercially; and I feel that where lead in the form of fume is encountered, the electrostatic precipitator should be used.

The facts which we have in the literature today concerning the production of lead fumes in workrooms where high temperature melting pots are used are based on the results of impinger samples, and so until we get further data from the electrostatic precipitator, we have a big question mark as to whether there is more lead fume in the air where lead melting pots are present than we had previously anticipated.

A year ago, the A.P.H.A. Committee on Air Analysis mentioned above obtained information from all the laboratories in the country conducting industrial hygiene determinations concerning what injurious atmospheric constituents had been analyzed, what methods were used and whether these were satisfactory.

Lead was the material which was determined by the largest number of laboratories. The next material of interest was hydrogen sulfide, and the reason being that most rayon manufacturers make routine tests for this gas.

If any of you believe that a man will not voluntarily walk into a dangerous hydrogen sulfide concentration, let me recount the experience of one of the promising young workers in industrial toxicology who walked into his laboratory one morning, about two years ago, found that a hydrogen sulfide cylinder had tipped over and the valve broken off. In trying to get the cylinder to an exhaust hood, he collapsed and was found dead in his laboratory by the janitor who arrived not long after. Certainly if an intelligent research worker, thoroughly aware of the toxic action of this gas, could so expose himself, we must not assume that the odor of hydrogen sulfide will cause the plant worker to avoid dangerous amounts of it.

Carbon monoxide was next in the list of injurious materials placed in the order of the number of laboratories making determinations of them. In addition to the small Hoolamite detector, previously mentioned, several types of detectors and continuous indicators are available commercially, both portable and stationary. A home-made device has just been suggested[7] whereby air is drawn past the filament of a cigar lighter for combustion and the CO_2 formed by any CO present is determined colorimetrically. This ingenious device may solve the problem where the exposure may not justify the expense of the continuous indicator.

Mercury was the next in line. Unfortunately we do not at the present time have a quick method for mercury. One method will give concentrations of vapors within injurious limits if the sample is of several hours duration, but we would like to be able to obtain the desired information with a ten or twenty minute sample.

The list then includes sulphur dioxide, hydrogen cyanide, ammonia and chlorine in that order.

Of the organic materials, the greatest number of laboratories made determinations of hydrocarbons as such.

The inflammable vapor indicator, originally designed to show whether an atmosphere was within inflammable limits, is of value for hygienic purposes in some cases, but just because an inflammable vapor indicator shows negative results is no good reason for assuming that the condition is necessarily safe from a hygienic point of view. One of these indicators has been sensitized so that it will give as low as 20 parts of a million of benzene vapor, but the minimum reading on most of these instruments is 1,000 parts per million.

Carbon disulphide has been of much interest.

A method has been developed, and is commercially available, for the determination of chlorinated hydrocarbons, such as trichloroethylene, with which we are becoming more familiar through its use in vapor degreasers. The chemical method will give chlorinated hydrocarbon concentrations in the presence of such other materials as gasoline, with which they are sometimes mixed.

A rapid physical method for the determination of all vapors and gases having a density substantially different from air (and this includes most of them—notable exceptions being CO, HCN, methanol, and ethane) is the portable interferometer. The operation, after calibration, involves drawing air through a cylinder, turning a dial and reading the concentration. Unfortunately the interferometer is not specific for any one vapor, merely measuring differences in densities. The cost of the instrument is high, but it is available through a number of investigators and some of the insurance companies, and, where many determinations are to be made, amply justifies itself.

Interpretation

In the interpretation of results, there are a number of important items to be taken into consideration. It is appreciated that the results must be referred to some threshold value such as 100 parts per million for carbon monoxide or 2 milligrams per ten cubic meters for mercury. There are several collections of such threshold values, that published by Bowditch[8] being one of the most complete.

In referring results of determinations to these standards, consideration should be taken of the duration of exposure of the worker and also the duration of the exposures used in developing the threshold limits. If a worker is exposed to a concentration of 20 milligrams of lead per 10 cubic meters of air for a period of an hour a week, we need have little apprehension that he will develop lead poisoning; but if a group of workers is exposed to this concentration as an average condition, then we can anticipate lead poisoning cases.

The conditions under which the air samples were collected must be carefully considered. In some instances winter conditions may be the more severe; in other cases, summer conditions. If open windows adjacent to a chromium plating tank cause high concentrations of chromic acid to be blown into the plating room, the results of determination should be interpreted to indicate the need, not of increasing the local ventilation, but of keeping adjacent windows closed.

Careful note should be made of all operations which may contribute to the exposure. The dust concentrations near a group of molders in an iron foundry may be excessive, but it is possible that the cause may be due not to the molding operations, but to an unprotected sand conditioning machine in the vicinity. Where conditions change rapidly, samples must be taken frequently or over a long period in order to permit proper interpretation. Where conditions are essentially static, a single brief sample may be adequate.

As previously mentioned, it is usually of such value to have available two types of collecting devices: one which takes a continuous sample over a long period of time, the other which gives the concentration at any given instant. The former gives valuable information on the average exposure of the worker, and the latter on the particular operation causing the major portions of that exposure. The results of both methods, used together, permit in many cases much more complete and valuable interpretation of existing conditions.

Know the limitations of the methods used and interpret the findings accordingly. We must remember that a screw driver is a very convenient tool and it has its use, but it should not be employed for making a mortise and tenon joint. These determinations have their definite value, but do not try to read more into them than they are worth. Determinations can be used more extensively to great advantage. Through determinations, we can learn whether the exposure to dust, fumes, gases and vapors is safe or dangerous even though we cannot see them. Let us not work in the dark, but rather, cast all light possible on these otherwise invisible hazards.

References

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Discussion

CHAIRMAN PAINE: This is a mighty important subject, and I know there are many who would like to discuss phases of it. Let us make our questions clear and concise.

A. G. SPEER (Western Electric Co., Hawthorne): Are you familiar with the fumes connected with arc welding, like iron oxide and ozone, and means of detecting them?

MR. COOK: A study has been made of iron oxide concentrations in connection with arc welding, with the thought that a large amount of iron oxide being breathed by the arc welder might injure his health. X-ray determinations have been made, and although the lungs looked very much as if they were severely fibrosed, it has been pretty conclusively shown that iron oxide does not cause injury to the lungs. This conclusion has been reached in two separate investigations.

The collection of iron oxide was made by the electrostatic precipitation method.

MR. SPEER: We had occasion to make such a determination but we used the impinger method, and we did not find toxic qualities or properties. We could not find any available data on that particular subject.

MR. COOK: A paper was published by Drinker, together with a number of other investigators, in the *Journal of Industrial Hygiene,* and the conclusion was that injury to health was caused by nitrogen oxides, with a possibility of ozone entering into the picture.

R. C. MELDRIM (Glens Falls Indemnity

Co., Glens Falls, N. Y.): Mr. Cook, do you believe that an arsine determination should be made in a metal pickling operation?

MR. COOK: Generally, no. I have seen no actual arsine poisoning from metal pickling, even though the literature includes such cases. As far as cases in this country are concerned, it has seemed to me to be largely a literature condition. In talking with Dr. Cunningham, of the Ontario Department of Health, Division of Industrial Hygiene recently, he mentioned a considerable number of arsine poisoning cases and I suggest you write him for further details. I have not seen any thorough investigation of the subject, and that has been one of the things that lead me to believe that the condition isn't sufficiently severe to cause us great apprehension. The experience in this country has hardly indicated the necessity of making such determinations. I have not made any myself. However I should like to see somebody make a series of them at a half-dozen locations where metal pickling is done.

F. L. WARNER (U.S.S. Lead Refinery, Inc., East Chicago): Do you feel that further investigation with the precipitator will change the present permissible limit of lead exposure that has been determined by the impinger method?

MR. COOK: The answer to that question is "No," but I feel that this further thought can be added: We have had many operations where lead dust was the prime exposure. Where the lead is in dust form, the impinger will get essentially the total amount of the lead; consequently where we have made physical examinations of large numbers of workers in such exposures, correlation of the results of physical examinations of workers and of incidence of cases of actual lead poisoning with concentrations of lead in air have fixed fairly definitely, within workable limits, just about how much lead can be considered to be safe. The threshold limit based on such exposure to lead dust would be the same whether the samples were collected with impinger or electrostatic precipitator.

On the other hand in rooms where lead casting is done, where there are lead melting pots, the impinger probably gives low results. The chances are that the concentration of lead in those rooms is greater than found by the impinger. But those impinger results, those that we have made, may have been around .2 of a milligram whereas 1.5 milligrams per ten cubic meters is definitely safe. Suppose instead of .2 of a milligram per ten cubic meters, there are two or three times as much present in the form of a fume as found by the electrostatic precipitator. Even if .6 or .8 milligram were present we would be within safe limits. This is further shown by the fact that physical examinations of workers in rooms where lead melting pots are present have demonstrated that there is no great lead absorption.

So my conclusion is that the collection of samples by means of the electrostatic precipitator is not going to confuse the issue at all. It is going to give us more accurate data on some of these exposures where lead is present in the form of fume.

G. W. DAUBENSPECH (Illinois Department of Labor, Chicago): How would you determine arsine in air around pickling tanks?

MR. COOK: It would be necessary to resort to a chemical method, and I think that I had better not use the time for a discussion of chemical methods.

J. W. FEHNEL (Metropolitan Life Insurance Co., New York City): You mentioned the use of the electrostatic precipitator in lead sampling. I have been doing that work myself along with the impinger samples, at various times, to correlate results on lead, both dust and fumes, since 1926.

Here is an interesting thing. I know that Bloomfield a few years ago made some tests in a large baking plant and found lead. He came up to consult with Dr. Wright about it, and it was concluded that the source of the lead was the paint they used. That sampling was done with the impinger. About two years ago I made an extensive survey in one of the General Motors plants where there were extensive soldering operations. I took impinger samples, and I got a series of factors that I presented in the report, and a short time later I was called on the carpet and told that my figures did not agree with their plant chemist's. So I consulted with the chemist. When he sampled with the electrostatic precipitator and I with the impinger, and we took them on identical reading levels, we got the same results. He had consistently gotten lower results—and we proved this later by checked samples—because he had his electrostatic precipitator mounted on a little truck that he pushed through the aisles, and the men working on a platform that was about 12 to 18 inches higher than his main aisle, which meant that instead of sampling at the breathing zone of the workmen, he was sampling at about his waist level.

ROBERT WINTERS (U. S. Metals Refining Co., Carteret, N. J.): We have overlooked one point, Mr. Chairman, and that is the metallurgical control, the heat control of the kettles. If you have a problem on hand, or if you are pouring lead and you heat your kettle up to 1,000 degrees Fahrenheit, if you can pour that same lead at 750 Fahrenheit, why pour it at 1,000 Fahrenheit, because the more heat you have, the more liberation of oxide? So we have reduced the hazard to a large extent now.

Mr. Cook stated that the impinger system is a little too cumbersome. I would say that where you have a definite hazard in the lead industry, have your impinger system a permanent system of the organization of your department and keep it there as a permanent fixture.

The question came up too, as to the merits of the electrostatic precipitator against the impinger, and I cannot agree with that statement at all because the fumes are made up of minute particles of dust—a fraction of a micron in size—and we found that the impinger system generally is just as efficient as the electrostatic precipitator, with the exception that we do have at least six impinger bottles in series, because you cannot get efficient sampling with one or two or three bottles. You must take enough bottles to get a reliable result.

Men Who Go Down to Their Death in Tanks—A Demonstration

By S. E. WHITING

Vice President and Chief Engineer, Liberty Mutual Insurance Company, Boston

The title of this feature, "Men Who Go Down to Their Death in Tanks," should be taken extremely broadly because, as you know, there are not only stationary tanks (of which we give you a very crude simulation in our demonstrations) but there are truck tanks and there are railroad car tanks, both of which are enclosed spaces. In our city streets we have thousands of manholes for utilities, power and telephone and sewage that are also enclosed spaces, or "tanks" as we call them here. You have trenches, excavations, shafts, tunnels, mines. In your factories, you have tanks again, small basement rooms, vaults, cisterns and sumps. Even open pits may prove hazardous. On board ships you have a very complete set of enclosed spaces, compartments and holds. Even when you go out into the open country, as we here look at it, you may find dangerous enclosures—grain bins, wells and the bottom of silos. So there are just as many varieties of enclosed spaces as there are pickles, and perhaps more.

Will you please remember that from this demonstration you are to visualize the potential conditions in your own plant where there may be enclosed spaces—and you will need a very great power of imagination to do so with our necessarily crude demonstration apparatus.

There are two hazards in enclosed spaces that we shall not dwell upon at length. In any enclosed space that has not much ventilation, that collects moisture and is dark, you will have a severe slipping hazard and an accentuated electrocution hazard—but we shall here consider only the typical asphyxiation and explosion hazards.

Most of those enclosed spaces are normally just as good to work in as outside spaces and that is part of the danger. Men have worked in tanks year after year with no trouble, only to have something extraordinary come up to contaminate the tank, something that they have not anticipated, to make that enclosure a hell hole, as we shall demonstrate in merely reproducing not an exaggerated situation but only what has actually taken place.

How do these spaces get into that condition? Merely because there is no free circulation of normal atmosphere. That is of fundamental importance because all animal life, especially higher animal life, must have a constant supply of normal atmosphere to sustain life. The normal atmosphere is remarkably constant in general and it is contaminated only locally. It is in largest part an inert gas, nitrogen, 78 per cent, with fractional percentages of rare gases that are equally inert. There is a small amount (a few hundredths of one per cent) of carbon dioxide from which plants grow. The remainder, almost 21 per cent, is oxygen, and we depend very definitely on oxygen to sustain life. Of course, we can hold our breath momentarily, but we cannot continue without that normal supply. We are particularly sensitive to it, we higher mammals.

In these tank situations, where there is lack of oxygen, men get panicky. They breathe more quickly, they are demanding more oxygen, but the supply is less, and they precipitate trouble. It is not true that you do not get into trouble until all the oxygen is gone, not by any means. You begin to get definite weakness and symptoms with perhaps 15 per cent instead of the normal 21. If you get down to 10 per cent —and I am only quoting the rough figures of authorities—you get into a condition where you cannot do anything, you cannot move, you become unconscious, you fall in collapse. If you go into an enclosure alone and get into that condition, you cannot rescue yourself. That is a very characteristic element of this hazard: men going alone into enclosed spaces, not knowing whether or not there is oxygen.

In addition to adequate oxygen we have to consider highly toxic substances, a fractional percentage of which in normal atmosphere will cause distress that renders us unable to leave the enclosure—like carbon monoxide, hydrogen sulfide, etc. Then, too, there may be small quantities of merely flammable gases which we can tolerate to breathe but if that small mixture with the air gets ignited it flames or explodes, creating a hazard so severe that the space becomes literally a "hell hole."

I mentioned carbon dioxide in normal air that in very small percentages is necessary to plant life. I will say further that all of us here in this room are exhaling carbon dioxide in small percentages, harmlessly. We have breathed the oxygen in and distributed it to all of our tissues where it combines with those tissues and is discharged through our breath as carbon dioxide. Again, at every soda fountain if there is any gas in the drink we take, it is carbon dioxide. All the beer we drink has carbon dioxide. Even all the strong liquor we drink had some carbon dioxide in it during the fermenting process by which it is made. Now that prohibition is over you can see how many tanks there are loaded more or less frequently with carbon dioxide.

It is this apparent harmlessness of carbon dioxide that gets us into trouble with tanks. But a little of something may be all right whereas too much of it may be all wrong. It is not true that carbon dioxide remains non-toxic in high percentages. The best authorities are inclined to believe—they haven't quite checked it up but are still working on it—that around 20 to 30 per cent of carbon dioxide will produce an immediate narcosis, will put you out of business immediately and you will go down flat.

Of course, such a reaction is vitally important when you get into any enclosed space, because then you cannot get up and walk out, and I do not care whether it is an open pit or an enclosed tank. Men have been killed in open pits, only 6 or 8 feet deep, when they got down to that layer of carbon dioxide. It is 50 per cent heavier than air and it is likely to be colder than the air—and so it pockets. And this brings us immediately to our first demonstration.

(The Demonstration Apparatus consisted of a wooden framework in the shape of a vertical, cylindrical tank, 10 feet in diameter and 9 feet in height, the bottom end being solid and the top end having a central manhole opening with a ladder through it to permit entrance into the tank from the top. The cylindrical, vertical sides of the tank were covered with a semi-transparent cloth to permit the audience to see the interior of the tank. A controlled flood lighting of the interior was provided. Access to the top of the tank was by an exterior ladder at the rear of the tank. All characters in the demonstration acted in pantomime only.)

Now, as the curtain swings open, you will see what we call a tank. Again I must ask you to use your power of imagination. Of course, we could not set up a real tank because you do not have eyes that can see through boilerplate. Since what goes on inside of the tank is just as important as what goes on outside of the tank, we have made the front of it partly transparent and in addition for your further assistance I have in my hand a control device that allows me to flood the inside of the tank with light upon occasion. Just keep in mind that this light has nothing to do with the action in the tank itself but is merely for your assistance in seeing the action. We do not show the details of piping and valve connections through the tank but merely the top manhole opening, with a ladder stuck down through it to enter the tank.

(Summary of Act I: A tank used for a fermenting process and containing a residual layer of carbon dioxide is to be cleaned out. A helper arriving ahead of time drops his pipe into tank and enters tank to get it and is overcome. The safety man looks over the job, glances in tank, signals for help and hastily enters tank and is quickly overcome. The foreman and an assistant hastily arrive with gas mask and a life belt and line. Hastily donning gas mask and carrying life belt, the foreman enters tank, the assistant holding the life line. The foreman is overcome and the life belt is pulled out of the tank with no man fastened to it. The assistant puts on the belt, gives the life line to a fifth man who has arrived but the latter prevents him from entering the tank. Curtain, followed by chopping sound backstage.)

This is a cleaning job of a tank that had some fermenting process in it but the liquor has all been drained off. This first man arriving is a helper and he probably doesn't know what it is all about but anyhow he gets on the job ahead of time and I see why. He thinks he'll have time to light up his pipe. Perhaps he shouldn't be using matches around tanks but somebody must have told him that carbon dioxide is harmless—you can't start a fire with that—well, he hasn't gotten the pipe going yet. These pipe smokers smoke more matches than they do tobacco—oh, his shoe is unlaced so he puts down the pipe—wait a minute! he didn't apparently set it down in the right place—oh, he thinks it's fallen in the tank—now, you shouldn't go into the tank, you know that is against the rules—nobody should go in until the boss arrives, that isn't safe, suppose there's some gas down there—but he's bound to get his pipe before the boss arrives and finds it in the tank—look out! don't get your head down—maybe there's some gas—yes! there is! It's knocked him out!

This is the safety man who is going to look over the job to see that everything is done right—I hope he calls help when he sees that man in the tank—yes! he sees him—he's called help—why—he's going into the tank himself! A safety man ought to know better than that! He can't hold his breath long enough—he won't think about holding his breath—yes—he's going to get caught—there he goes! He's overcome too!

Well, there ought to be help arriving pretty soon now—ah! Here's the foreman with an assistant—he's got a life line too—but what else has he got—oh—he's got a canister gas mask—he's getting excited—he puts the mask on—that shouldn't be depended upon for any tank work unless you know what the concentration is—there he goes down—he's got the life belt with him—oh, the canister gas mask isn't any good, it's of no value against carbon dioxide gas or any other gas in high concentrations—he's overcome! The other man is going to pull him out—no! he doesn't pull him out—the belt comes out without any man in it!—

Here comes the other fellow—he has seen such accidents before—of course, the assistant wants to rescue them—he puts the belt on and he gives the rope to the other man—he tries to go down but the other man won't let him—no use killing any more people—*(Curtain closes.)*

You see there the very typical situation of everybody losing their—*(Sound of chopping backstage.)* That chopping of wood reminds me how they got those men out of the tank—no one else dared to go in, so when the Fire Department arrived they cut a hole through the side of the tank and dragged the men out, but it was too late to save their lives.

Now, these tank accidents are typically multiple death accidents—not only is the first victim lost but the rescuers themselves in their haste are frequently lost also; it is not merely one life, it is two lives, three lives, four lives, and even five lives.

The spontaneous action of almost everyone to rescue anyone they find in trouble is a very noble attribute but it merely builds up a catastrophe where this latent hazard of tank asphyxiation has not been anticipated by training men beforehand how to handle such emergencies intelligently. There is too much sheer indifference to this hazard—until it strikes like a bolt from a clear sky.

Now, please do not conclude that this pantomime of an accident has been exaggerated in its details. It has not, they actually occurred. We cannot predict what men will do in a panic. Even the sudden collapse is fact, not fiction. I was puzzled by this until recently because we all know that men can hold their breath under water and have no oxygen supply for a minute or more with no collapse. An expert in this technical question, however, recently gave the explanation of why the breathing of an atmosphere deficient in normal oxygen content is quite different from holding your breath and not breathing at all.

In normal respiration, the flow of oxygen is into the lungs, thence into the blood stream and thence into the vital tissues that control all of the muscular and nervous and mental processes, the lungs retaining a residual supply of oxygen even at the end of the expiration portion of the respiration cycle. The pulmonary blood stream continues to feed on this residual oxygen and the following inspiration portion of the cycle soon furnishes a new and ample supply of oxygen. With a deficiency of oxygen in the air itself, inhalation adds nothing to the lung supply while exhalation actually discharges the residual lung oxygen and the blood quickly drains its own supply back into the lungs whence it is exhaled. Thus all vital functions become rapidly paralyzed.

(Summary of Interlude Demonstrations: Entirely separate from the tank apparatus, small scale demonstrations are made: (a) Extinguishment of four candles in a tall glass jar by carbon dioxide generated by the warming of dry ice; (b) The explosion of a transparent bag into which 10 drops of flammable solvent are vaporized, mixed and ignited; (c) A strip of metal is painted with quick-drying paint and flames up upon ignition with a match.)

Now we have just a few brief demonstrations illustrating three principles involved in certain tank hazards. These candles burn brightly since currents of air feed them oxygen. Any flame or any fire needs a constant supply of atmospheric oxygen to continue living. If you reduce the percentage oxygen below normal more and more, the flame gets sickly and then dies just as humans do. You see dry ice being vaporized as it absorbs heat and its vapor is run through a tube down to the bottom of the jar, rising in a layer. One candle has died, two, three, all of them.

This asphyxiation of candle lights by dry ice is just the same as the killing of men in a fermenting vat you have just witnessed. This ice is only solidified carbon dioxide and you must handle it with care in any enclosed spaces even including open pits. Not long ago a steamship hold was being unloaded of perishable fruit refrigerated by dry ice. No odor, no color, no warning—and three stevedores went down and died as quickly as those candles.

The other two experiments illustrate principles involved in our next tank act. This transparent bag of normal air has only ten drops of flammable liquid evaporated into it, the vapor and air are mixed by gentle pressure on the sides of the bag and ignited with a spark plug. Only ten drops, only about 2 per cent of vapor, but what a snappy explosion.

Now imagine an enclosed or tank space of the same shape as this bag but ten times as long with the same proportion of flammable vapor—vapor from a leaky pipe connection, from entrained solvent in sludge in the bottom, from a half dried film being scraped from the sides, or from a quick-drying paint being applied. Imagine yourself in this tank with the ever-present chance of a spark. You would be in the vortex of a flame and a blow one thousand times as great. The answer is ample ventilation to keep below the 2 per cent of vapor content.

The last experiment is simple but pertinent. We brush this quick-drying paint along a narrow strip of metal and ignite it. See the quickly running flame, imagine it surrounding you in any enclosed space, imagine it even in your home on the kitchen floor. Such work should be done only under full ventilation and freedom from all sources of ignition.

(Summary of Act II: A tank that has been emptied and ventilated is about to be painted. A chemist makes tests of the tank air in succession with an oxygen deficiency indicator and a flammable gas indicator, using a sampling tube at various levels in the tank. Two painters have arrived and the chemist now O.K.s the tank for their entrance. Painters enter tank and proceed

with their work but are gradually overcome by the fumes from the paint. The chemist finally notes the trouble, signals for help and hastily enters the tank and is overcome. The foreman and his assistant hastily arrive, the latter carrying a lantern. With life belt on him, the assistant enters tank, still carrying lantern, the foreman holding the life line. There are several flashes as the lantern gets lower in the tank and finally the assistant falls overcome as flames burst out of the manhole. Curtain.)

Now, as the curtains part, you see another tank and I do not care what process or what contents this particular tank had been connected with. We know that it has been emptied but precautions are here being taken by a chemist to test out the air of the tank before any man enters it for any kind of work whatever. He is making two kinds of test; one for oxygen deficiency by means of a flame lamp that is properly protected from being an ignition source by use of metallic gauze surrounding it like the well-known Davy's Safety Lamp. He will make a second test, however, since a tank that has adequate oxygen in it for sustaining life may, at the same time, have flammable gases in it sufficient to cause an explosion like that we have just demonstrated with laboratory apparatus.

These other men we see coming onto the scene are obviously painters who are going to protect the inside of the tank against rusting by suitable waterproof paint. Apparently both tests are O. K. and the chemist authorizes the two painters to go into the tank and this precaution is a valuable initial step against unexpected contamination of any enclosed space.

The men now are at their job at the bottom of the tank and the chemist has finished his job but is just standing around because he hasn't anything else to do. Well, look at that man on the right—he has been painting with his nose pretty close to the paint and it seems to be affecting him! That must be a highly volatile paint—There! He's getting worse—he's fallen over unconscious! I hope the other man sees him—the chemist doesn't seem to pay any attention—the other man does see him! He gets excited and begins to breathe faster—he goes over, trying to save the other man, he finds he's getting too dizzy himself, he's reaching for the ladder—but the fumes are too strong and he falls over unconscious!

The chemist evidently hears some noise—he goes to the tank—now he's in great excitement! He calls for help from the plant—he shouldn't go into that tank when he sees the others overcome! He should wait until help arrives! No, in his excitement he thinks he can get in there and help them out! There he goes inside—I hope he keeps his head up high—the vapors are probably near the floor—he tries to lift a man—he's overcome too—down he goes!! They're all overcome! I hope the rescuers hurry up!

Here they come—they've got a life line—but what are they doing with a lantern? The foreman is sending the other man down to get them out and he needs a light to see but he shouldn't use a lantern in there—Hold that lantern high! Oh, he falls unconscious—the foreman tries to pull him out! The lantern has fallen over! The gas is ignited—see those flashes! *(Explosion followed by curtain.)*

That was the type of hazard where a tank was found by test to be safe to enter but the kind of operations to be performed in the tank were given no consideration at all. The men have fouled their own tank and made their own atmosphere unsafe. They used a quick-drying paint that had low flash point solvent in it and there was no controlled ventilation to minimize those contaminating and explosive fumes.

Evidently it is necessary to consider not only what has formerly been stored in the tank but also the exact repair operations to be done that may contaminate it. Even a tank that had never contained anything worse than water will become hazardous if certain operations are done upon it—such as a repainting job with highly volatile paint solvents, a prolonged job of arc or acetylene welding or cutting, leaks of gas from the surrounding earth for buried tanks, manholes, etc.

With so many types of enclosed spaces which men have to enter, we cannot prophesy what kinds of contamination might occur. There was a small steel compartment in a steamship that had been kept closed for many years. Nothing whatever had been in that enclosure, it had been merely sealed. Yet a man was sent into it and died immediately of oxygen want and the answer was that the mere rusting of the steel plate had robbed the atmosphere of its normal and vital 21 per cent of oxygen.

(Summary of Act III, Scene I: A man has entered a tank with a life line on him and two men guarding him from the top. For some reason he has been overcome and the men promptly bring him out of the tank, lay him face down and immediately apply prone-pressure artificial respiration, one man continuing this method steadily while the other calls for help. Shortly an inhalator is brought to the tank and is applied to the patient without interfering with the manual artificial respiration. Both operations continue steadily. Curtain.)

Now this time we are doing the job right. A man has entered a tank, and it was too gassy for some reason we need not concern ourselves with, but the important point is he did not enter the tank except with a life belt around him and a life line attached to the belt and held by two helpers at the manhole. They have just brought him out of the enclosure and will be able to save his life.

When a rescued man is not breathing, it is evident that artificial respiration must be given to him without the slightest delay. Therefore, he is placed immediately on the top of the tank, face down, with his head resting on one arm so as not to block his breathing. Quickly the mouth is opened to see that there are no obstructions in it, the operator straddles the patient with his knees just below the waist and presses forward on the small of the back to push the air out of the lungs. Then the operator swings back and takes his hands entirely off the body—note that particularly. The inspiration stroke is done by the body itself in its natural expansion after it has been pressed upon during the down stroke.

Everyone in any plant (and in fact in your homes and on vacation) should know how to apply this simple, direct, efficient, prone-pressure method of resuscitation. Note that the operator is not working too rapidly but slowly, like a person naturally breathes. Note he does not put the pressure on with any jerk but steadily and smoothly.

Now the inhalator is set up not to produce artificial respiration but only to supply a special atmosphere for breathing that will help in the resuscitation work. It provides a supply of oxygen stronger than air to inhale; 93 per cent oxygen and 7 per cent of carbon dioxide, our old acquaintance. Whenever the patient has been asphyxiated by some poison that attacks the blood like carbon monoxide or hydrogen sulphide, you need both prone pressure and the inhalant mixture working together.

(Summary of Act III, Scene II: A tank that is empty has to be entered for repair work. A chemist makes both tests for condition of air in tank. A mechanic sets up a low-pressure portable blower and inserts discharge end through manhole into lower part of tank. Two men place air-hose masks on themselves and a third man operates a hand-driven portable blower that feeds air to the hose masks. The chemist continues making tests. The two workmen in turn enter tank taking with them non-sparking tools and a vapor-proof standard extension lamp. All operations continue steadily. Curtain.)

Again we see the chemist making his two tests for explosive atmosphere in the tank and for oxygen want. Indeed, nowadays we no longer need a chemist for such tests; any intelligent man can make them, so much improved are the test instruments made by the manufacturers.

This tank job is a big one and needs every precaution. You will note the chemist continues his tests throughout the whole procedure. There is a second man now setting up a portable blower to keep the tank itself constantly ventilated. The two men who are to enter the tank first don hose masks that have air pumped to them by a hand-operated blower. The mask air protects against asphyxiation, the blower air protects against explosion. There are other precautions and checks.

Now they go down into the tank and are tended from above with life lines fastened to them. Life lines that men so often sneer at. Life lines nevertheless that so connect men in the outside free air with men in the enclosed foul air that, by this precaution alone, a substantial catastrophe can be reduced to a negligible momentary dizziness. The job is organized and safe so that men who go down to their work in tanks can come up and go down tomorrow.

ADJOURNMENT