Gases and Vapors

Health Practices Pamphlet No. 9

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This pamphlet is one of more than 150 Safe Practices and Health Practices Pamphlets. It is a compilation of experience in accident prevention from many sources. It should not be assumed, however, that it includes every acceptable procedure in the field covered. It must not be confused with American Standard safety codes; federal laws; insurance requirements; state laws, rules and regulations; and municipal ordinances. ***Additional copies of this pamphlet are available to members of the National Safety Council. Price: 25 cents per copy, less in quantities.***

1. Few persons give any thought to the air they breathe. As long as the mixture of gases we call air is odorless, tasteless, and at a reasonable temperature, its purity is accepted as a matter of course. Men in industry, even when in locations where air contamination is possible and probable, are just as prone to assume that the air which they are breathing is pure unless some stimulus, such as an unusual odor or taste, serves as an unmistakable warning.

2. The problem of vapor and gaseous contaminants in air has greatly increased in industry during the past decade. The discovery of new chemical compounds, the development of new processes, and the general speeding up of industry, have greatly increased the possibility of air contamination even where sincere attempts have been made to control such hazards through the introduction of local exhaust and general ventilation systems. The use of enclosed processes, the application of exhaust equipment to remove gases at their sources, and the careful control of chemical processes, undoubtedly tend to lower the danger of air contamination. However, the possibility is always present and must be guarded against by constant vigilance on the part of the safety engineer. Repeated air tests in every stage of the working process, together with regular inspection and maintenance of equipment and careful engineering control of all processes, are necessary if air in industrial plants is to be kept free from gaseous or vapor contaminants.

3. So that the importance of a reasonably pure atmosphere will be more readily apparent, this pamphlet briefly discusses the physiology of breathing, the relation of the circulation of the blood to breathing, and the mechanism of the absorption of volatile substances from the air. Also, a classification of noxious gases and vapors, and instruments for detecting them, as well as a discussion of the prevention of poisoning, is included. A short description of first aid treatment for poisoning due to gases is also presented.

Mechanics of Breathing

4. Breathing is an involuntary muscular effort on which life depends. The amount of air breathed by an individual is dependent upon his state of bodily activity and varies between 6 and about 75 liters per minute, in general, and sometimes up to 150 liters per minute. The amount is principally determined by the number and depth of respirations per minute which, for the normal individual at rest, varies from 17 to 20 per minute. The amount of air breathed for various degrees of bodily activity is, for the particular individual, an exact quantity. Stated in other words, if the air is pure, as the exertion increases, so does the rate and depth of respiration (and necessarily the amount of air breathed), but always in approximately direct ratio to the degree of physical activity. In industrial hygiene work, 10 cubic meters of air is the amount considered to represent the daily volume of air breathed by one worker per eight-hour shift.

The Structure of the Lungs

5. It is neither possible nor desirable in a publication of this nature to dis-

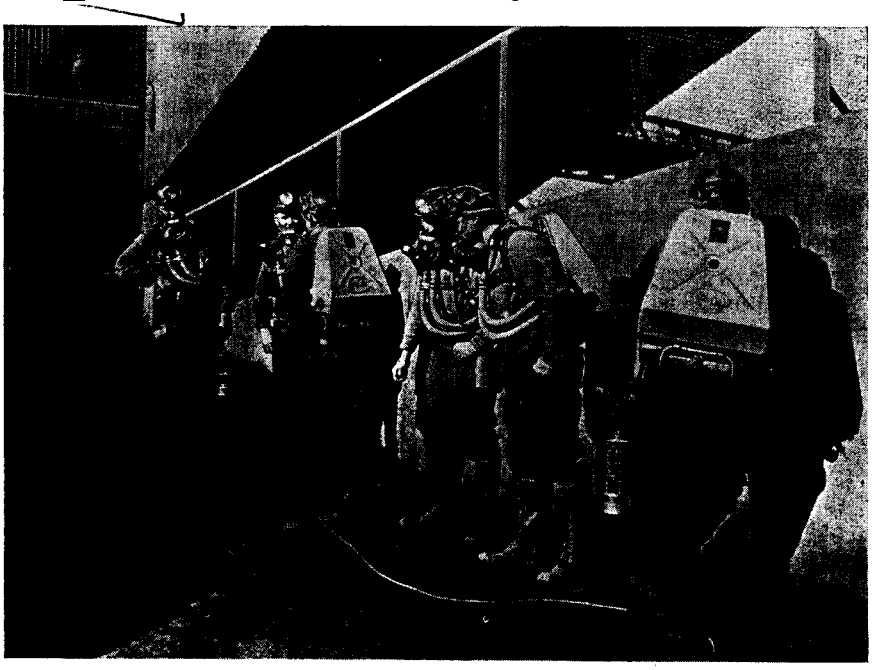

Figure 1. A mine rescue squad, equipped with McCaa two-hour oxygen breathing apparatus, awaits word to enter the mine. (See paragraph 60.)

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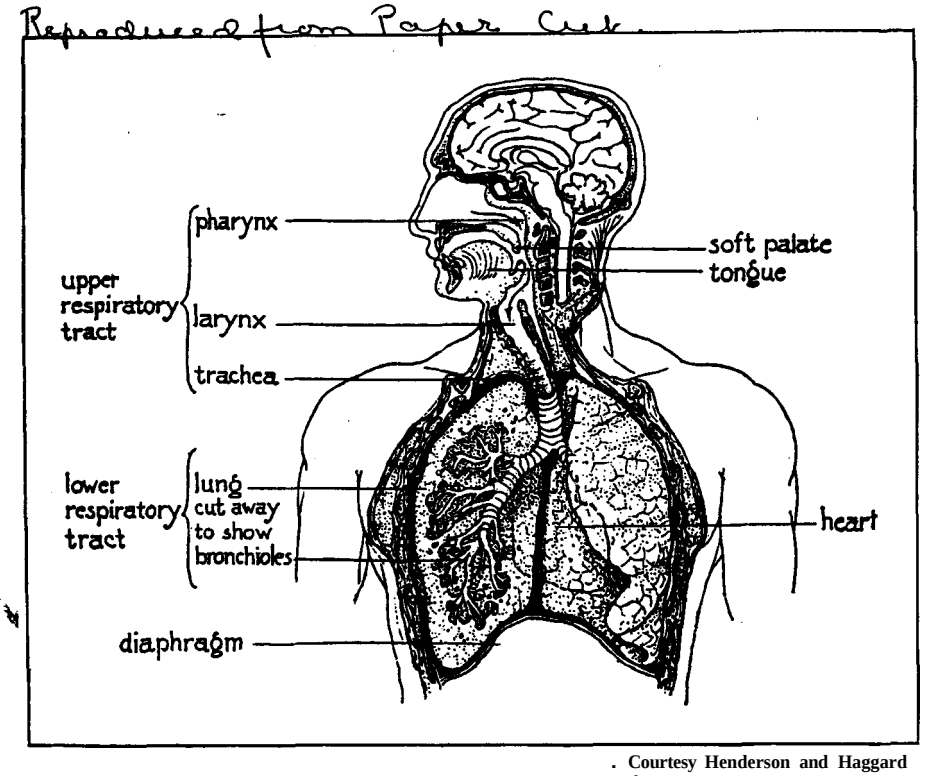

. Courtesy Henderson and Haggard

Figure 2. Diagram of the human breathing apparatus. (See paragraphs 5 to 8.)

cuss extensively the structure and action of the lungs. However, a general description and a brief discussion of the functions of the lungs will be helpful to the safety engineer. The lungs are two similar but asymmetrical masses of spongy tissue contained in an elastic sac in the chest cavity. The right lung is about 12 per cent larger than the left lung and has three divisions or lobes, whereas the left lung has only two divisions. The lungs communicate directly with the nose and mouth through the windpipe or trachea. *(See* Figure 2.)

6. Each lung has the appearance of a large sponge or of a large number of very small sacs or air cells. These are termed alveoli. These alveoli are the terminal elements of small air tubes called bronchioles. The bronchioles are the branching divisions of larger tubes called bronchi which lead to still larger tubes that also unite and open into the trachea or windpipe, which in turn opens into the larynx or voice box enclosing the vocal cords. The walls of the alveoli are almost completely filled with fine capillary blood vessels, and they are such that the oxygen from the air breathed into the lungs is easily absorbed by the blood. This makes it possible for the lungs to fulfill their function, that of inferchanging oxygen from the **air** breathed and carbon dioxide from the blood. It is interesting to note that the total surface of the alveoli is almost 1000 square feet in area. This fact helps to explain the quick absorption of gases, and why a small percentage **of** a toxic gas may **be** dangerous.

7. ***During breathing,*** air is brought into and discharged from the lungs due to the involuntary rhythmic contractions and expansions of the large muscles of the diaphragm and ribs. The lungs themselves are passive in operation. During this process, oxygen from the air passes through the walls of the alveoli into the blood. At the same time, the carbon dioxide, representing a product of metabolism in blood, passes through the walls of the alveoli to the air which is to be expired from the lungs. The nerves and muscles in the breathing mechanism are exactly the same **as** those for other voluntary muscular mechanisms of the body, but there is a certain involuntary element in breathing, which is relatively greater for this operation than for other muscular actions. The rhythm and alternating action of breathing are almost wholly involuntary.

8. Oxygen is a controlling factor in the adjustment of breathing volume (see paragraphs 9 and 10). Since each degree of bodily exertion requires, for a particular individual, a certain amount of oxygen, it can be readily seen that a sudden deficiency of oxygen would result in a more rapid respiration. persons in normal health adjust themselves automatically to their environment and breathe a sufficient volume **of** air to obtain the necessary quantity of oxygen vital for the efficient performance of bodily functions. While oxygen is a regulating factor in the frequency of respiration, it is not the only factor and, in fact, under ordinary conditions, because of the practically constant pressure of oxygen at lower altitudes, it takes but little part in the regulation of breathing.

Carbon dioxide and respiratory regulation

9. There is a nervous mechanism in the brain which is very sensitive to variations in the amount of carbon dioxide in the blood. An increase in the partial pressure of the carbon dioxide in the blood causes a corresponding increase in the depth of respiration, and conversely a decrease in the partial pressure will cause a proportional decrease in the volume of breathing. Even under very wide variations of bodily activity— this nervous mechanism functions perfectly in regulating the amount of air drawn into the lungs.

10. The distinction between oxygen and carbon dioxide as respiratory stimulants can be made clearer by a study of the following three examples:

a) **A** normal healthy man at rest is given a high concentration of oxygen to breathe instead of air. If the amount of oxygen he breathes, and the rate and volume of his breathing, are checked, practically no effect will be found. The man will feel no difference between the high concentration of oxygen and ordinary air which contains only 21 per cent of oxygen.

b) Using the same apparatus and methods of supplying air, plus a small quantity of carbon dioxide, it will be found that the volume of breathing will increase almost immediately. The depth of breathing, rather than the increase in number of respirations, will be the determining factor. If the air that is expired is analyzed, it will be found that the body is eliminating practically the same amount of carbon dioxide as under normal breathing conditions, although possibly a slightly greater quantity, be found due to the muscular exertion involved in the deeper breathing.

c) The subject voluntarily forces himself to breathe more deeply, but at about the **same rate** for a period of ½ minute,

using ordinary air. The lungs are thus over-ventilated, but owing to the nature of the combination of oxygen in the blood, no greater amount of oxygen will be absorbed. Carbon dioxide content in the blood, however, is temporarily decreased, and when the man stops his voluntary effort of breathing deeply, he will observe that there is a lack of desire to breathe, and in some extreme cases a complete cessation of respiration. This lack of desire is directly in proportion to the decrease of carbon dioxide in the blood.

11. Just as the amount of oxygen necessary to sustain the bodily activities varies with the degree of those activities, so, too, it is shown by Haldane and Priestly, the concentration of carbon dioxide in the blood is proportional to the needs of the blood for an increased supply of oxygen.

Respiratory Functions of the Blood

12. The blood is composed of a liquid-carrying medium called the plasma, a colorless to straw colored liquid in which are contained white corpuscles and red corpuscles. The white corpuscles have no place in the respiratory function, but red corpuscles, because of their hemoglobin content, or coloring matter, are extremely important. The hemoglobin gives the blood the ability to absorb oxygen and carry it from the lungs throughout the body where it is utilized. The blood also carries back to the lungs the carbon dioxide excreted by tissues.

13. The method by which this exchange occurs is unique. Blood picks up oxygen from the air in the lungs in proportion to the saturation of oxygen and carbon dioxide in the blood. Oxygen tension in blood returning to the lungs is about 35 mm. of mercury. Since the oxygen tension in the air in the lungs is about 100 mm., a rapid exchange takes place through the alveolar walls. In the case of carbon dioxide, the situation is reversed in that its tension in the blood is about 46 mm. of mercury, whereas the tension in the alveolar air is only about 40 mm. The carbon dioxide is originally picked up from the tissues by the blood at a vapor tension of about 60 mm. Thus, the movement of carbon dioxide from the tissues of the blood and to the air which is to be expired from the lungs is steady but somewhat slower than the transfer of oxygen from the air to the blood. Only a very small quantity of carbon dioxide combines directly with the blood hemoglobin; most of it is merely transported and held in the blood in the form of sodium bicarbonate, and to a lesser extent other alkaline bicarbonates, usually in solution in the fluid of the blood. Thus, the blood is enabled to transport large quantities of oxygen and carbon dioxide regardless of slight alterations in their partial pressures and also with a correspondingly small alteration of the balance of acid and alkaline elements within the blood stream.

14. Hemoglobin is considered to perform three functions:

a) It combines readily with the oxygen in the blood and also gives it up readily.

b) It provides an alkaline exchange with the plasma (blood fluid) which permits the formation of sodium bicarbonate (alkaline) for the purpose of transporting carbon dioxide.

c) It takes up and gives off alkali readily, thus preserving the acid alkaline balance of the blood within very narrow limits.

Absorption of Volatile Substances

15. Gases drawn into the lungs during respiration, unless they are of the simple asphyxiant or irritant type, do not exert any physiological action until they have been absorbed into the blood stream through the alveolar tissue. The nature and severity of the reaction which follows is dependent upon the concentration of the poisonous substance in the blood, the length of time which it remains in the blood, and the comparative toxicity of the material. In other words, the four factors which determine the effect of an inhaled poisonous gas or vapor upon the body are concentration, duration, toxicity, and individual susceptibility.

16. There are two classes of gases which exert an effect on the body after absorption into the blood stream: the reactive and the non-reactive. A reactive substance is one which is changed within the body and is eliminated in forms other than that in which it was absorbed. The poisonous action can be exerted either by the original substance or by the product of its decomposition. An example is ethyl alcohol, which exerts its action before decomposition has taken place, but which is eliminated from the body in other forms. Aniline is another example of a vapor which exerts its main action through the products of decomposition rather than as the original substance.

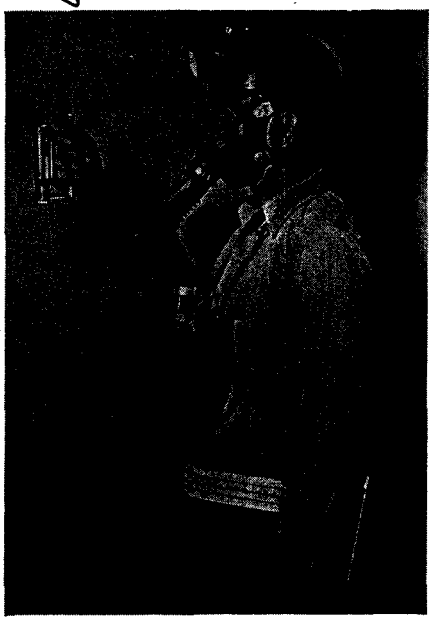

Figure 3. Coal miner equipped with All-service gas mask, making test with a carbon monoxide detector. *(See* paragraph *36.)*

17. A non-reactive substance is one which is not changed to any great extent within the body and is, therefore, eliminated in the same form in which it was absorbed Simple or uncombined aliphatic hydrocarbons (so-called "straight chain" series) such as methane, ethylene and acetylene are examples of non-reactive gases and vapors.

18. Certain of the irritating gases require considerable time for developing their entire effect on the lungs so that at first there is little or no irritation. Some hours later, after a period of but minor discomfort, if any, serious symptoms or death may occur. Nitrous fumes and phosgene are gases of this type. With methyl chloride, methyl bromide, and ortho tricresyl phosphate (reactive compounds), a longer latent period (sometimes several days) may follow exposure. This is because of the time necessary for these substances to change within the body to other compounds. In other cases, as with amido and nitro compounds of benzol and its homologues, the combination of another poison, such as alcohol, which may be drunk, produces serious symptoms.

19. The absorption of non-reactive vapors and gases depends upon the solubility of the substance in the body fluids, the rate of solution (absorption), the

Figure 4. Continuous combustible gas indicator and alarm. (See paragraphs 40-42.)

rate of lung ventilation (frequency and depth of respiration), and the rate of circulation of the blood. Changes in any one of these factors affect the ultimate action of a substance on the body.

20. Non-reactive gases and vapors are eliminated chiefly through the lungs. The urine and other excretions carry away relatively small amounts. The concentration of the gas dissolved in the urine corresponds to that in the blood passing through the kidneys at the moment the urine is secreted. The elimination through the lungs follows definite principles similar to those of absorption.

21. In general, the process concerned in the absorption of reactive gases is the same as for non-reactive gases. There is a difference in that the reaction and consequent destruction of the gas prevent the attainment of equilibrium which usually occurs from breathing non-reactive gases. The elimination of reactive substances is influenced by their alteration within the body, the amount of substance eliminated being less than the amount absorbed.

Definitions and Classifications

22. Henderson and Haggard, in their book, "Noxious Gases and the Principles of Respiration Influencing Their Action," from which much of the material in this Health Practices Pamphlet is taken, have classified gases and vapors as indicated in paragraph **24.** Before presenting this classification, it will be well to consider the definitions of the various air contaminants. The terms "gases," "vapors," "smoke," "fumes," and "mists" are frequently so loosely used that, for instance, the term "fume" might be used where a gas was under consideration.

Definitions

23. The following definitions have been found generally acceptable:

a) **A** *gas* is any aeriform fluid having neither independent shape nor volume, but which tends to expand indefinitely and which cannot be liquefied by pressure increase alone.

b) *Vapor.* **A** vapor is a substance which has neither independent shape nor volume, but which can be liquefied by pressure increase. From the standpoint of the safety engineer, there is little difference between a gas and a vapor. The definition of a vapor is that of a gas except that ***vapors*** *are generally thought of as related to a liquid.* For instance, the substance over a container of gasoline could be termed a gasoline vapor, but if the liquid gasoline entirely evaporated and the "vapor" were allowed to disperse or expand indefinitely, it would then be a gas or a mixture of gases. The same would hold true for liquefied petroleum gases such as butane. In a cylinder only partially filled with liquid butane, there would be butane vapor over the liquid, but if the valve in the cylinder were open and the butane under pressure allowed to expand into the atmosphere, then it would be butane gas since it has been allowed to expand indefinitely.

c) **A** *fume* is a solid formed by condensation from the vapor state. The particle sizes of fumes are usually below 1/25,000th of an inch (one micron). An example is the fume given off by lead burning. The particulate matter in fumes has a tendency to flocculate.

d) *Smoke* is generally considered to be a suspension of particulate matter with the individual particle size below 0.5 micron. Generally, it is of organic origin such as the smoke from burning coal, wood, paper, rags, bones, or oil.

e) *Mist or fog* is formed by the condensation of water vapor upon nuclei or, as in the case of acid, by the atomization of liquid. Particle sizes in mists are not definable since they may vary considerably depending upon conditions present.

Classification

24. Following is the classification of gases and vapors suggested by Henderson and Haggard in "Noxious Gases and the Principles of Respiration Influencing Their Action." (See bibliographic note.)

a) *Asphyxiants.* These do not directly injure the respiratory tract, but produce their effects by causing a condition of oxygen deficiency in the body tissues.

b) *Irritants.* These injure certain tissues of the respiratory tract causing inflamation of the respiratory passages and in some cases the lungs.

c) *Volatile* ***drugs*** *and drug-like substances.* This is the anesthetic group, and these substances have a drug-like action after they have been absorbed through the lungs.

d) *Inorganic and organometallic substances.* This group has a wide diversity of action. Some are essentially tissue poisons. The action of these compounds is observed only after absorption into the blood stream.

25. With these general headings in mind, it is now convenient to consider the sub-groups, naming the actual substances involved. In referring to this table, it must be remembered that certain substances will appear in more than one group. The reader should not be misled by the fact that certain substances are classed as irritants or as asphyxiants, when it is well known that in high concentrations they are deadly poison. For example, hydrocyanic acid and hydrogen sulphide, while classed as irritants, will, if present in sufficient concentrations, kill so quickly that the lesser irritation will not have time to take effect. Benzene is listed as an anesthetic gas, but if exposed to a low concentration (over 100 parts per million) is long continued, or if short exposure to a high concentration takes place, poisoning will result. Methyl chloride and methyl bromide, while listed as anesthetic, are serious nerve poisons if exposure is great enough. The table should be used always with the knowledge that the maximum allowable concentration should never be exceeded for industrial exposure for any of the substances covered, if poisoning is to be avoided. (The following tabulation is based on a table from "Noxious Gases Listed According to Their Chemical Composition and Classified According to Their Action," taken from the reference quoted in paragraph 24. For a complete discussion of this tabulation the reference text should be consulted.)

Group 1—Asphyxiants

Sub-Group (a) Simple Asphyxiants: Nitrogen, hydrogen, helium, methane, ethane, propane. nitrous oxide, ethylene, acetylene.

Sub-Group (b) Chemical Asphyxiants: Carbon monoxide,
Cyanogen compounds, the most important of which are: cyanogen. hydrocyanic acid, acetonitrile, propionitrile. methyl isonitrile, ethyl isonitrile, benzonitrile, cyanogen chloride.

Group 2—Irritants

Sub-Group (a) Including gases which art primarily upon the upper respiratory tract:

Ammonia gas, hydrochloric acid gas,

sulphuric acid gas, hydrofluoric acid gas, formaldehyde.

Sub-Group (b) Including those gases which act upon the upper respiratory tract and also spread their action to the deeper structures :

Sulphur dioxide, chlorine, bromine, iodine, acrolein, hydrogen sulphide (dimethyl sulphate).

Sub-Group (c) Including those gases which act primarily upon the lungs and only to a lesser extent upon the upper respiratory tract :

Nitrogen oxides, ozone, phosgene, phosphorous trichloride and pentachloride, arsenic trichloride.

Sub-Group (d) Those gases which are not altered or destroyed by contact with the tissues of the respiratory tract. These are essentially the hydrocarbons and consist mainly of the aliphatic hydrocarbons, their alcohols, ethers and halogen substitution products. These will be mentioned in detail in the next main group.

Group 3

Volatile Drugs and Drug-like Substances (Anesthetics)

Sub-Group (a) Anesthetic Gases without usual serious after-effects. (However, poisoning may occur.)

1. Hydrocarbons — Paraffin Series : gasoline, naphtha, benzine.
2. Hydrocarbons — Olefine Series : ethylene, propylene, butylene, amylene, hexylene, heptylene.
3. Hydrocarbons — Acetylene Series : acetylene, allylene, crotonylene.
4. Ethers: methyl ether, ethyl ether, propyl ether.
5. Aldehydes : formaldehyde, acetaldehyde, proaldehyde, bultadehyde, acraldehyde.
6. Ketones: dimethyl ketone (acetone), methylethyl ketone, diethyl ketone.
7. Esters of Organic Acids: methyl formate, methyl acetate, methyl butanate, ethyl formate, ethyl acetate, ethyl butanate, propyl acetate, butyl acetate, amyl acetate.

Sub-Group (b) Halogen Derivatives of the Hydrocarbons. Anesthetics injuring chiefly the visceral organs.

1. Halogen Compounds of Methyl: methyl chloride, methyl bromide, methyl iodide, methylene dichloride, trichloromethane, tetrachloromethane.
2. Halogen Compounds of Ethyl and Higher Hydrocarbons : ethyl chloride, ethyl bromide, ethyl iodide, dichloroethylene, ethylene dichloride, trichloroethylene, trichloroethane, perchloroethylene, tetrachloroethane, pentachloroethane.

Sub-Group (c) Hydrocarbons, Aromatic Series, injuring chiefly the blood-forming system.

1. Light oil or coal tar naphtha, the principal constituents being benzene, xylene, toluene, pyridine and thiophene.
2. Middle oil, consisting mainly of naphthalene and phenol.
3. Heavy oil, consisting of phenol, cresol and anthracene.
4. Anthracene oil, consisting of anthracene, phenanthrene and various solid hydrocarbons, that is, in the cooled state.
5. Pitch, which remains in the still. (Light, middle, heavy and anthracene oils and pitch are not sufficiently volatile under ordinary conditions to cause poisoning from the inhalation of vapors.)

Sub-Group (d) Compounds injuring chiefly the nervous system.

1. Alcohols: methyl, ethyl, propyl, butyl, amyl.
2. Carbon Disulphide.
3. Thiophene.

Sub-Group (e) Organic Nitrogen Compounds, acting upon the blood and circulation.

1. Substances which have predominating action of a "nitrite effect"; in general, these are the alkyl nitrites and the alkyl-nitro substitution products and are represented by ethyl nitrite, amyl nitrite, nitro ethane, etc.
2. Substances whose predominating action is the conversion of oxyhemoglobin to methemoglobin. This class is represented by the amine compounds and the aromatic nitro substitution products, such as

   Nitrobenzene
   Aniline
   Toluidine
   Methyl aniline
   Dimethylaniline

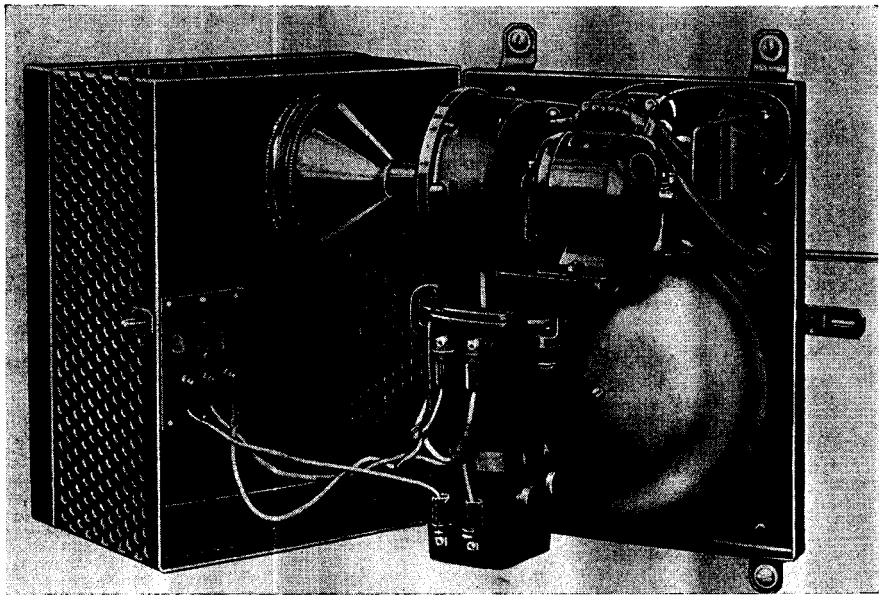

Figure *5.* Carbon monoxide alarm. (See paragraph *42.)*

Figure *6.* Miner wearing safety hat, goggles, safety shoes, and emergency self-rescue mask. He is using a flame safety lamp. (See paragraphs 49 and *59.)*

Figure 7. Testing for methane in a bituminous coal **mine.** (See paragraphs 49 and *50.)*

Group 4

***Inorganic and Organometallic* Gases** *and Vapors*

Sub-Group (a) Protoplasmic Poisons. Mercury and phosphorous.

Sub-Group (b) Organometallic Compounds. These are represented by: Diethyl arsine, cacodyl, cacodyl oxide, diethyl mercury, tetraethyl lead, nickel carbonyl.

Sub-Group *(c)* Inorganic Hydro Compounds: Hydrogen arsenide, hydrogen phosphyde (phosphene), hydrogen sulphide, arsine.

Effects **of** Exposure

26. In order to prevent poisoning by gases and vapors, it is necessary to know the maximum allowable concentrations of these gases and vapors that will permit men to work safely. These maximum allowable concentrations are taken from the code of the American Standards Association, and where that body has not yet approved maximum allowable concentrations for certain substances, from the sources indicated. (See Table 1.)

Modern Instruments of *Gas* and Vapor Detection

27. Where it is *suspected* that an atmosphere contaminant is present in industry, one of four conditions may exist: the air may be pure with no contaminant present; there may be an oxygen deficiency; a toxic gas may be present; or a flammable gas may be present. It is quite possible, too, that the gas present may be both toxic and flammable. Where this is the case, care should be taken that the testing is done for the particular hazard under consideration, since *usually* flammable vapor testers do not give readings low enough to indicate the presence **of** dangerous quantities of all toxic gases. However, there are instruments available which are modifications of the flammable vapor detector which give scale readings of toxic substances at lower than flammable levels. It must be remembered, too, that unless the instruments are specifically designed for the purpose, they do not indicate the specific gas present, but merely the concentration of some flammable gas.

28. Mention should be made of the primitive methods of gas detection formerly used in this country and still used to some extent in Europe. Small birds or animals were employed for the purpose of showing the presence of a toxic gas or an oxygen deficiency. Sparrows, canaries or mice were kept caged in the mines near the working parties where they could be conveniently observed. Since the birds and mice were more quickly affected by toxic gases or oxygen deficiency, any noticeable effect on them served as warning to the men. In this country, however, modern instru-

Table I

Maximum Allowable Concentrations

GASES AND VAPORS	P.P.M.
Ammonia (4) (5)	100
Amyl acetate (4) (5)	400
Aniline (1) (4) (5) (6)	5
Arsine (4) (5)	1
Azides (Lead & Sodium)	
Benzol (Benzene) (1) (2) (3) (5) (6) (8) (a)	100
Butanol (1) (5)	100
Butyl acetate (1) (4) (5)	400
Carbon disulfide (8) (b)	20
Carbon dioxide (2) (5)	5550
Carbon monoxide (1) (2) (3) (4) (5) (6) (7) (8) (c)	100
Carbon tetrachloride (2) (3) (4) (5) (6) (8) (d)	100
Chlorine (1) (3) (4) (5)	1
Chloroform (5)	100
Dichlor benzene (1)(4) (5)	75
Dichlor ethyl ether (4) (5)	15
Ether (4) (5)	400
Ethyl alcohol (5)	250
Ethyl bromide (5)	1700
Ethyl chloride (2) (5)	20000
Ethylene dichloride (4) (5)	100
Ethylene glycol monomethyl ether (6)	30
Formaldehyde (1) (3) (4) (5)	20
Gasoline (1) (3) (4) (5) (6)	1000
Hydrochloric acid (1) (2) (3) (4) (5)	10
Hydrogen cyanide (1) (3)(4) (5)	20
Hydrogen fluoride (1) (2) (3) (4) (5) (6)	3
Hydrogen sulfide (1) (4) (5) (6) (8) (e)	20
Methanol (2) (4)	100
Methyl acetate (5)	50
Methyl bromide (5)	500
Methyl chloride (2)	500
Monochlor benzene (1) (4) (5)	75
Naphtha (Petroleum) (5)	5000
Nitric acid (6)	10
Nitrobenzene (1) (5)	1
Nitrogen oxides (1) (4) (5) (6)	10
Ozone (1)(4) (5)	1
Phosgene (1) (2) (3) (5)	1
Phosphine (1) (4) (5)	2
Phosphorous trichloride (2) (5)	0.7
Sulfur dioxide (2) (3) (4) (5) (6)	10
Tetrachlorethane (8) (f)	20
Tetrachlorethylene (1) (4) (5) (6)	200
Toluol (1) (4) (5)	200
Trichlorethylene (4) (5)	200
Turpentine (1)(4)	200
Xylol. (1) (4)	200

FUMES, METALLIC COMPOUNDS (Mg.M³)	Mg/10M³
Arsenic trioxide (6)	5
Cadmium (8) (g)	1
Chlorediphenyl (4) (5)	10
Chromic acid (1)(2) (3) (4) (5) (6)	1
Chromium compounds (8) (h)	1
Lead (1) (2) (3) (4) (5) (6) (7)	1.5
Manganese (8) (i)	60
Mercury (8) (j)	1
Pentachlornaphthalene (4) (5) (6)	5
Trichlornaphthalene (4) (5)	50
Zinc oxide fume (4) (5)	150

NOTES

1. Standard of Wisconsin Industrial Commission
2. Standard of U. S. Public Health Service
3. Standard of Connecticut State Department of Health
4. Standard of Massachusetts Department
5. Standard of California Industrial Accident Commission
6. Standard *of* Illinois State Department of Labor
7. Standard **of** New **York** State Department of Labor
8. American Standard Allowable Concentration (See notes below.)
   (a) ***Benzol (Benzene).*** Exposure not over 8 hours daily at this Concentration.
   (b) ***Carbon disulphide.*** Exposure not over 8 hours daily at this concentration.
   (c) ***Carbon monoxide.*** 100 p.p.m. for exposure not exceeding 8 hours daily and 400 p.p.m. for exposure not over one hour.
   (d) ***Carbon tetrachloride.*** (Proposed) 100 p.p.m. for exposure not exceeding 8 hours daily and 155 p.p.m. **for** exposure not over one and one-half hours.
   (e) ***Hydrogen sulphide.*** Exposure not over 8 hours daily at this concentration
   (f) (Proposed)
   (g) *Cadmium A erican Defense Emergency d.* (Proposed)
   (h) *Chromium C mpounds* (Proposed)
   (i) *Manganese. American Defense Emerge y St d* (se
   (j) *Mercury.* (Proposed) Exposu c not over 8 hours i t this Concentration.

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ments have largely displaced this method of gas detection. It is said that cases have been reported where men were found "gassed" while the warning birds or animals remained unaffected.

Oxygen deficiency testing

29. One of the best field devices for detecting an oxygen deficiency is the flame safety lamp. There are laboratory methods which can be used, but these are not applicable to field work. Before the advent of the modern flame safety lamps, candles or lanterns were used as oxygen deficiency indicators. Where there was too little oxygen in the air to support the combustion of either the candle or the lamp, the flame would go out. This occurred usually where the amount of oxygen present did not exceed 16 to 17 per cent.

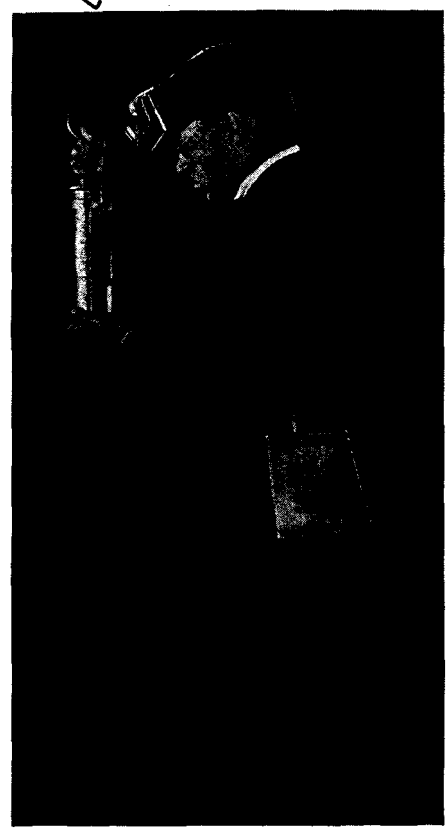
30. The danger of this method of detecting oxygen deficiencies is evident when it is considered that in many mines flammable vapors may be present which could be ignited by the open flame. Flame safety lamps should always be used since the flame is protected with a wire gauze that will prevent ignition of exterior atmospheres. The flame safety lamp should be used only by men thoroughly trained in its use and who understand its limitations, construction, and proper maintenance.

31. Certain gases, such as hydrogen and air mixtures, acetylene and air mixtures, and some other air and gas mixtures met with in industry, may ignite even where the flame safety lamp is used. To avoid this, a special oxygen deficiency testing lamp has been designed. A sample of the atmosphere to be tested is aspirated into the lamp by means of a rubber bulb and a hose. This makes it possible to keep the lamp outside the dangerous area and still test the oxygen content of suspected air. (See also paragraph 49.)

32. The flame of the safety lamp will be extinguished where the concentration of oxygen in the atmosphere is 16 per cent or lower. This allows a margin of safety of about 2 per cent for an individual in the atmosphere, since it is only when the oxygen in air falls to 14 per cent that a man is in danger. Where there are certain flammable vapors present, the flame of the lamp may not be extinguished until the oxygen falls to about 13 per cent. Even at this point, however, there is no real danger to human life if the persons exposed leave the area quickly.

33. Atmospheres deficient in oxygen can occur in many situations, such as in sewers, street manholes, mines, tanks, or any confined or closed space. Wherever there is doubt as to whether or not there is sufficient oxygen to support life, an air test should always be made before employees are permitted to enter.

34. A description of the behavior of the flames of flame safety lamps in mine atmospheres deficient in oxygen is given in United States Bureau of Mines Bulletin R.I. 3327. In this bulletin it is stated that when a flame safety lamp is brought into an atmosphere deficient in oxygen, it will rise (a phenomenon sometimes called "search for oxygen"), then the flame changes color and becomes lower. If no methane is present, the flame decreases below the original height. If methane is present, the resultant flame height may be above, equal to, or below the original flame height, depending upon the relative quantity of methane and oxygen present. Oxygen deficiency is indicated in other ways than by changes of the flame height. A normal flame, in an atmosphere of normal air and no combustibles present, gradually reddens as oxygen decreases, then starts to leave the wick; that is, the part of the flame near the wick loses its color and appears to have a colored tip of flame detached from the wick. A one per cent oxygen deficiency causes perceptible change in color of the flame toward the red. A two per cent deficiency causes unmistakable reddening, especially at the edges. With a three per cent deficiency, the flame just above the wick tube is non-luminous and appears to be detached from the wick. A further decrease in osygen content increases the apparent detachment of the flame, and the top or luminous part becomes smaller and redder at the edges until an eight per cent deficiency of oxygen and a four and one-half per cent of methane is reached, when the flame is extinguished. The flame will be extinguished when the oxygen content in the air falls below 13 per cent, no matter how high a percentage of methane is present. When a flame safety lamp is brought into an atmosphere that is explosive, the flame is extinguished suddenly, with definite popping sounds within the lamp; thus, such a lamp may be used as an indicator of explosive atmospheres in the hands of a person experienced in their use. (See paragraph 30.) Those desiring further information on flame characteristics of safety lamps in atmospheres deficient in oxygen should refer to the publication mentioned above.



Courtesy U. S. Bureau of Mines

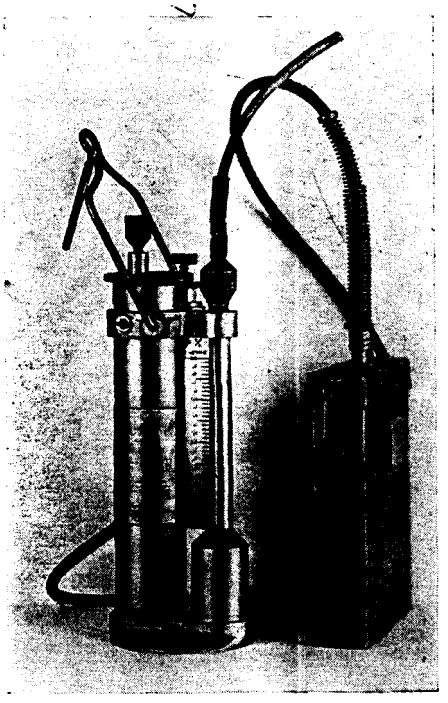
Figure 8. Man wearing Burrell methane indicator. (See paragraph 50.)

Detecting Carbon Monoxide

35. There are several means by which carbon monoxide can be detected either in the laboratory, the plant, or in field work. This is fortunate since carbon monoxide is colorless, odorless and tasteless, creating a great need for accurate indicating instruments that can be used by laymen.

"Hoolamite" carbon monoxide detector

36. This detector consists of a metal barrel filled with activated charcoal to remove interfering gases, through which the sample of the atmosphere to be tested is drawn by a rubber aspirator bulb. It is applicable for detecting car-



Courtesy U. S. Bureau of Mines

Figure 9. Burrell gas indicator. (See paragraph 50.)

bon monoxide in atmospheres that contain 0.1 per cent to 1.0 per cent. The sample is discharged from the bulb through a glass tube which contains the Hoolamite. A color scale which indicates concentrations of carbon monoxide from 0.05 to 1.0 per cent is attached to the detector along the Hoolamite tube. After the bulb is squeezed ten times, the resulting green color is compared with the permanent colors in the comparison tube, and the percentage of carbon monoxide is thus estimated. If the device is properly used, it will detect from 0.07 to 0.10 per cent (700 to 1000 parts per million) of carbon monoxide in the air. (See Figure 3.)

Palladium chloride detector

37. Another device now in general use was designed primarily for detecting the presence of carbon monoxide in street manholes, sewers, transformer vaults, pipe tunnels, and other underground spaces. A palladium chloride solution is sealed in a glass tube. A color comparison chart accompanies each tube. When it is desired to use the ampule, the glass is crushed; this saturates the cotton with the palladium chloride, and the ampule is exposed in the atmosphere to be tested for from 10 to 20 minutes, with the longer time preferable. When carbon monoxide is present, the color of the cotton changes from brownish yellow to black, and this change is compared with the comparison chart. A fairly accurate indication of the amount of carbon monoxide present can be obtained in this manner, for on the comparison chart the minimum indication is one part per 10,000 (100 parts per million) and the maximum is ten parts per 10,000 (1000 parts per million) of carbon monoxide in air by volume.

38. Allowance must be made when these indicators are used in low temperatures because at zero degrees Fahrenheit the resulting color changes will not be indicative of the amount of carbon monoxide shown by the color scale. For best results, they should not be used in temperatures below 32 degrees Fahrenheit. Where gases such as hydrogen, hydrogen sulphide, ethylene, or gasoline vapor are present, these ampules are not dependable since they, too, change the color of the palladium chloride. However, where these gases are present in quantities sufficient to change the color of the cotton, there is a dangerous concentration and the area should be avoided until adequate ventilation has been assured. The presence of hydrogen sulphide or ammonia may affect the results when using a palladium chloride detector. The test has about the same sensitivity for hydrogen sulphide as for carbon monoxide, while the presence of ammonia will not permit the use of the test. If hydrogen sulphide and carbon monoxide are present together, however, the results will tend to be higher; hence, the need for ventilation or protection would be apparent. Too, since ammonia is easily detectable by odor in concentration of 100 parts per million, the need is evident for ventilation and personal protection before men can be exposed. The detector is also useful for indicating gasoline fumes, hydrogen and ethylene in explosive and toxic concentrations.

"Hopcalite" carbon monoxide indicator

39. A carbon monoxide indicator is available which operates on the principle of oxidation or measuring the heat liberated by burning carbon monoxide in air to carbon dioxide. Burning is accomplished by passing air through an oxidizing agent or catalyst called "Hopcalite," and the increase in temperature is measured by a series of thermocouples which are attached to an electric meter on which the scale is calibrated in the percentage of carbon monoxide.

40. These portable indicators are valuable for use in motor vehicles, airplanes, garages, or industrial atmospheres. They will measure concentrations from 0.01 to 0.15 per cent by volume. All carbon monoxide indicators should be standardized regularly, using the I_2O_5 method. (A description of this method will be furnished on request). (See Figure 4.)

41. In construction, the instrument consists of a small motor directly connected to a pump which draws a continuous sample through a flow meter, a drying material, and the Hopcalite and thermocouples. There is a standard model available which measures quantities from 0 to 0.15 per cent and a special model with two scale ranges, one reading from 0 to 0.1 per cent, and the other from 0 to 0.01 per cent. The indicators are said to have an error of only 5 per cent, which is not important. The reading of the instrument may be affected by the presence of a high concentration of carbon dioxide, or hydrogen, if either is present. Here, again, as in the case of any unknown atmosphere, high readings mean ventilation before men are exposed. The instrument should be regularly calibrated.

Carbon monoxide alarm

42. Another device which is similar in construction to the carbon monoxide indicator is termed the carbon monoxide alarm. Here, the scales are replaced by a sensitive electrical relay which causes a warning signal to be given when the concentration of carbon monoxide in the atmosphere reaches a predetermined level. Where it is desired to have continuous testing done in garages or industrial atmospheres, this type of warning is especially valuable. (See Figure 5.)

Carbon monoxide recorders

43. In some cases, it is desirable to keep a record of the concentration of carbon monoxide in the workroom air, or in other locations such as in the cabs of motor vehicles or in tunnels. Instruments are available with a clock-work mechanism which give a continuous record of the concentration of carbon monoxide on a chart. These charts can be used as permanent records. Recording instruments are said to be accurate to within one part of carbon monoxide to one million parts of air by volume.

Detecting Other Gases

Hydrogen sulphide

44. An instrument similar to the Hoolamite detector may be used for detecting hydrogen sulphide in the air. It consists of a glass tube containing a white granular chemical through which the air is drawn by means of a rubber aspirator bulb. Where hydrogen sulphide is present, it reacts with the chemical, producing a stain varying from brown to black, which is compared with the color comparison chart mounted alongside the glass tube. The concentration is determined by the length of the stain as compared to the scale, which has a range from 0 to **0.04** per cent. These detectors will indicate the presence of 25 parts per million of hydrogen sulphide. Where smaller quantities of hydrogen sulphide are present, and it is necessary to detect them, then other and more complicated methods must be used. Test papers on which two drops of a palladium chloride solution are placed may also be used. Further information on the use of test papers and the preparation of the reagents will be furnished on request to the National Safety Council. Test papers may also be used for the detection of other gases covered in this pamphlet. (See Industrial Safety Series Pamphlet No. Chem-**4,** "Safety in Rayon Manufacture.")

Hydrocyanic **gas**

45. An instrument which is similar in construction and operation to that for hydrogen sulphide detection is used for the detection of hydrocyanic acid **gas.** The chemical through which the air is drawn is different from that used with the hydrogen sulphide detector. The hydrocyanic acid gas detector will show hydrogen cyanide in air from **0.005** per cent to 0.10 per cent **(50** to 1000 parts per million) by volume. In using these detectors, it is important that the tubes of chemicals be used within six months after they are purchased. (For additional information on hydrocyanic acid gas testing, giving other testing methods and safety precautions, see Industrial Safety Series Pamphlet No. Chem-6, "Cyanide Compounds." In this pamphlet, test paper methods for the detection of hydrocyanic acid gas are covered.)

Portable gas interferometer

46. The interferometer is used to determine the presence and quantitative amounts of certain gases and solvent vapors in air. Its principle of operation takes advantage of the difference in light refraction for air contaminated with gas and pure air under the same conditions of temperature, pressure and humidity. The cost of this instrument is quite high, and as far as is known, it is not manufactured in this country at this time. However, these instruments are effective and quite accurate quantitatively for a single gas (no quantitative measurement can be made for a mixture of gases). It is believed that they will take their rightful place in the field of industrial hygiene when they can be manufactured in this country at a reasonable cost.

Halide detectors

47. The halide detectors are used mainly for detecting leaks in refrigeration systems where some form of chlorinated hydrocarbon is used as the refrigerant. The detector consists of a small torch which can burn a fuel, such as alcohol, giving a nearly colorless flame. Illuminating gas may be used where it is available. The torch is equipped with an exploring hose which is moved about the area of the suspected leak, and where even the slightest trace of chlorinated hydrocarbon gas or vapor is present, it burns with a brilliant green flame when sucked through the tube. Color charts for quantitizing the tests have been developed by the California Occupational Disease Bureau. These torches are specially constructed with copper filaments in the flame area, since the test is based on the reaction of heated copper with chlorine. This is not a quantitative test (except where the chart is 'used), but the green flame is indicative of the presence of chlorinated hydrocarbon vapors which give the necessary warning for needed precautions. The lamps should not be used in the presence of a flammable gas or vapor. (See paragraph 30 for precautions.)

48. Methods for the detection of other gases and vapors, such as carbon disulphide and mercury are discussed in Industrial Safety Series Pamphlet No. Chem-4, "Rayon," and Industrial Data Sheet No. D-Chem. **17,** "Mercury." See also, Industrial Hygiene Foundation of America, Inc., Preventive Engineering Series Bulletin No. 2, Part 8, "Routine Sampling for Control of Atmospheric Impurities"; "Some Methods for the Detection and Estimation of Poisonous Gases and Vapors in the Air" by A, S. Zhitkova, translated by Joseph B. Ficklin, published by Service to Industry, Box 133, West Hartford, Connecticut; "Manual of Industrial Health Hazards" by Joseph B. Ficklin, published by the same company. If information is desired on the detection of a specific gas, it will be furnished on request to the National Safety Council.

Figure 10. Testing with a combustible gas indicator aboard a tanker. See paragraphs 51 to 53.)

Combustible Gases

Flame safety lamp

49. The flame safety lamp was developed originally for giving safe light in atmospheres where flammable vapors and gases were present. In addition to being used as an indicator of oxygen deficiency, it is also used for detecting flammable concentrations of methane in air. The presence of methane is shown by the formation of a blue cone or cap on the flame of the safety lamp when the flame is low. (See paragraph 34.) When the flame is high, the blue cap is elongated considerably. This

blue cap will be difficult to see unless the test is made in a darkened space. Here, again, caution should be used in testing unknown atmospheres, since if acetylene or hydrogen is present, trouble may be experienced, because such gases will ignite through the screen on the safety lamp. Where the air contaminant is unknown, the modified flame safety lamp with an aspirator line should be used. (See Figures 6 and 7.)

Methane detector

50. Several types of methane detectors are commercially available. However, the type most widely used, and finding its principal application in mines where methane is a common air contaminant, employs the principle of the change in resistance of a heated electric filament in the presence of a flammable gas, the change in the resistance varying in direct proportion to the amount of gas present from 0 to the lower flammable limit of the gas. The Wheatstone bridge is used to measure the change in resistance, and the scale is calibrated in percentage of the lower explosive limit to show the amount of methane present. The United States Bureau of Mines issues approval on methane detectors of this type which give indications from as low as 0.25 per cent methane by volume, and they recommend, too, that the upper limit on the indicators be at least 4 per cent by volume. (See Figures 7, 8 and 9.)

Combustible gas indicators

51. The principal function of these indicators is to show the percentage of combustible gas present in atmospheres being tested. They are not primarily intended to indicate the presence of toxic gases, but, since the majority of combustible gases are toxic to a greater or less degree, an instrument that shows their presence in sufficient volume to be a fire or explosion hazard indicates also that a toxic concentration is present. Indicators of special design are available and may be used for accurate determination of both toxic and flammable concentration. (See Figure 10.)

52. Combustible gas indicators have been used for detecting and indicating combustible gases and vapors in oil refineries, in sewers and manholes and in many other locations where the presence of gas is suspected. The principle of operation in most of these indicators is to pass the air under test over a wire which is heated to a temperature that will ignite the gas present. At the same time, the change in resistance of the wire produced by the increase of temperature from this ignition is measured. The Wheatstone bridge principle is again employed and, since the increase in resistance will be proportional to the amount of flammable vapors present in the sample, the scale of the instrument is calibrated to give direct readings in percentage of the lower explosive limit. Most of them, of course, are designed for use in concentrations below the lower flammable limits of the gases to be tested, although they can be used to show whether a concentration of a flammable vapor is within the lower and upper limits or over the upper limit.

53. For greatest accuracy, these instruments must be calibrated against the gases which are to be tested. General purpose instruments are available that will show with a fair degree of accuracy the percentage of any flammable vapor that may be present in air being tested if the amount is below the flammable limit. Instruments of this type are available that will show toxic concentrations of gases, such as carbon monoxide and hydrogen sulphide, and oxygen deficiency, as well as the concentration of combustible gases that may be present. Pocket-size indicators are also on the market, and these are found to be a great convenience to the safety engineer in making field tests. Combustible gas indicators of the type described in the above paragraph will not indicate the amount of a flammable gas present if there is an oxygen deficiency, or if there is a concentration of the gas in the atmosphere above the upper flammable limit. In the latter case, a dilution valve must be used to get readings. (Names of manufacturers of any of the instruments and devices discussed in this section of the pamphlet will be furnished by the National Safety Council on request.)

Prevention of Poisoning

54. In addition to knowing the physiological effects of the various atmospheric contaminants, it is necessary, for purposes of prevention, that the safety engineer and supervisor have a thorough knowledge of the hazards of the particular operation which is being conducted. To know that certain gases or vapors given off by a process will cause bodily harm is not enough, but in addition, ways and means by which these contaminants might be put into the air must be known and guarded against.

55. The best method of preventing cases of poisoning by noxious gases and vapors in industry is to avoid, as far as possible, processes which will cause their evolution. Non-toxic and non-flammable materials should be substituted for dangerous materials whenever this can practicably be done. In addition to using less toxic or less flammable substances, it is also possible to control emission of gasses into the air by controlling the temperatures of the bath, the surface area exposed, cross drafts that interfere with ventilation, and similar conditions. The discharge of gases from the building, by the exhaust and ventilating systems, should be carefully studied so that there is no possibility of their being drawn back into the building.

56. Where it is possible, processes involving the use of materials which will cause the evolution of harmful gases and vapors, should be completely enclosed so that there is no possibility of harmful substances escaping into the general workroom air. This may be found practicable even in the case of the so-called nuisance gases, which are only mild irritants and which exercise no permanent deleterious effects upon the body, since it is evident that if working conditions are held to a high level of comfort, particularly as respects breathing, more efficient production is the likely result.

57. In every case, local exhaust ventilation should be applied to remove harmful gases and vapors at their source. This local exhaust should, if necessary, be supplemented with a general ventilation system that will provide a sufficient number of air changes that the allowable concentration of such harmful gases and vapors as are encountered will never be exceeded. Standards of ventilation as set by state departments of labor, or other governing bodies, should be adhered to except where the requirements of the American Standards Association are more stringent. For additional information on exhaust and ventilating systems, see Safe Practices

Pamphlets No. 32, "Exhaust Systems,'' and No. 37, "Industrial Ventilation,''

58. The same procedure should be followed in the case of tanks, transformer vaults and manholes where tests show toxic or flammable gases are present, or where there is an oxygen deficiency. Portable ventilating apparatus in the form of electric or gasoline engine driven blowers which force air through a canvas tube, may be used for ventilation. Where this is not practicable, men can be supplied with United States Bureau of Mines approved supplied air respirators for protection against toxic fumes. However, ventilation is preferable.

59. Personal protective equipment should be supplied for employees wherever its use is indicated and wherever it is found impracticable or impossible either to enclose operations or to supply adequate local exhaust and ventilating equipment. In general, personal protective equipment for harmful gases and vapors should be used only in emergencies where process enclosures or exhaust and ventilating systems have failed. This should not be interpreted to mean that personal protective appliances are ineffective or inefficient, since such is not the case. However, it is difficult to get workers to use such equipment, and many of them prefer minor inconveniences in the way of breathing low concentrations of irritants to wearing the proper mask or respirator. (See Figure 6.)

60. There are a number of types of personal protective equipment available for use with gases and vapors. These include self-contained oxygen breathing apparatus, canister type gas masks, supplied air respirators (hose masks and blowers), and air line respirators (respirators supplied by compressed air lines through reducing valves and air cleaners). In every case where such personal protective equipment is used, it should be of a type approved by the United States Bureau of Mines. In each case, too, care should be used in selecting the particular protective equipment which is to be used. For instance, it would be impracticable to use a self-contained oxygen breathing apparatus in locations where there was no chance of a large quantity of gas or vapor being suddenly released. While this protection would be effective, the comparative cost would be prohibitive.

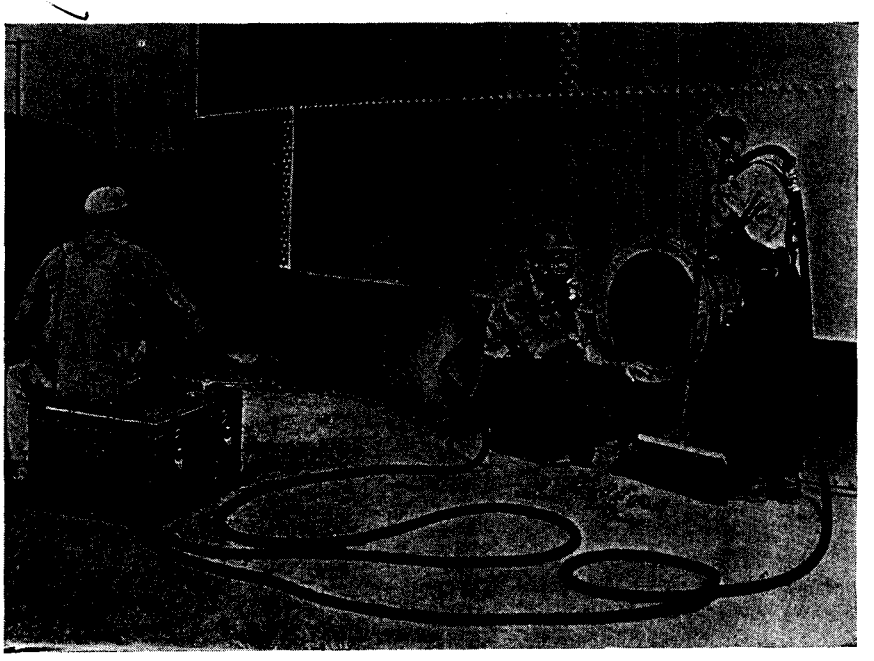


Figure 11. Using combination hose masks for the dangerous job of entering fume-laden tanks, during repair and maintenance operations. (See paragraph 60.)

A canister type mask would probably be selected and would prove effective for most exposures like those where the amount of toxic gas present in the air would not reach a concentration greater than two per cent, ***and where there is no oxygen deficiency.*** (See Figures 1 and 11.)

61. Men using such personal protective equipment must be thoroughly trained in its use and limitations, since using the wrong mask or using it in too high a concentration of a gas, or in a location where an oxygen deficiency exists, might lead to serious injury. (For additional information on respiratory protective equipment, see Safe Practices Pamphlet No. 64, "Respiratory Protective Equipment.") It is also necessary, where personal protective equipment is used, that a regular inspection and maintenance system be put into effect so the equipment can be kept in first class condition at all times. The canisters on masks should be changed in accordance with the instructions of the manufacturers. The canisters on masks are designed to give protection for a stated length of time in concentrations of gas not exceeding two per cent. Should the concentration of gas be greater, the length of time the mask will protect will, in general, be less, Where the exposure is in gases that can be smelled, ample warning of the impending failure of the canister will be given by a very slight but noticeable odor of the gas, coming through the respirator. High concentrations of carbon monoxide will affect the carbon monoxide canister mask by causing the canister and the incoming stream of air to heat. Where either of such conditions occurs, the individual wearing the mask should leave the exposure at once.

62. Even with completely enclosed processes, adequate local exhaust and general ventilation systems, and all necessary respiratory protective equipment, accidents may occur unless employees are completely educated in the exact safe method by which their duties are to be performed. Employees should be so trained that any deviation from the process as outlined in the specifications would be almost impossible.

63. Regular inspection and maintenance systems designed to keep all apparatus and equipment in first class condition should be in force. Any defects found in equipment should be repaired at once. (See also Industrial Data Sheet No. D-Gen. 16, "Cleaning and Sterilizing Goggles and Respiratory Equipment.")

64. Pre-employment and periodic physical examinations of employees exposed to noxious gases and vapors are an important element in the prevention of poisoning. Pre-employment examinations will bring to light existing diseases that might be aggravated by exposure to even minor concentrations of certain

noxious gases. The re-examination may bring to light early symptoms of poisoning before serious harm has been done.

65. The prevention of explosions from accumulations of flammable gases or vapors is discussed at length in Safe Practices Pamphlet No. 34, "Industrial Explosion Hazards (Gases, Vapors and Flammable Liquids)." This subject will not be considered in this pamphlet.

First Aid Treatment

66. Generally, the methods of treatment for persons exposed to poisonous gases or vapors include the following:

a) Removal of **the injured person to pure air.**
b) **Artificial respiration.**
c) **Use of inhalator if available.**
d) **First aid treatment for shock, treatment of lacerations, abrasions, burns, of other injuries.**
e) **Qualified medical aid.**

67. In rescuing any person from an atmosphere contaminated by a harmful gas or from an atmosphere in which an oxygen deficiency exists, the rescuer should take care to provide himself with the necessary personal protective equipment, including respiratory protective equipment, a life belt and a life line, the free end of which is in the hands of another person who remains outside the danger zone. Where processes are conducted in which such exposures may occur, certain of the plant employees should be trained in the proper method of rescuing persons who may be exposed. Only those qualified, *and no others,* should be permitted to attempt rescue work and, also, a rescue should never be attempted by one person alone; help should always be secured first. The United States Bureau of Mines approved type gas masks, self-contained oxygen breathing apparatus, or other approved respiratory protective equipment should be provided by the management, and the employees should be trained in its use.

68. In moving an injured person to pure air, care should be taken that he is not exposed to wide variations of temperature. Pure air does not necessarily, mean cold air. What should be done *at once* is to get the individual from the contaminated air to pure air as quickly as possible, and in the meantime keep him as warm as possible.

69. The Schafer prone pressure method of artificial respiration should be started *at Once* if the victim is not breathing. It may be necessary, at the same time, to administer a mixture of oxygen or a mixture of oxygen and carbon dioxide while artificial respiration is being given. In many cases, the use of an inhalator employing this mixture, along with prone pressure resuscitation, speeds the recovery of the victim and possibly aids in preventing subsequent ill effects. Stimulants or liquids of any kind should never be given a person who is unconscious, even though breathing has started. (The Schafer prone pressure method of artificial respiration is fully explained in the American Red Cross First Aid Textbook, the United States Bureau of Mines First Aid Handbook, as well as in the National Safety Council booklet "First Aid Reminders.")

70. All employees in a plant where there is a possibility of exposure to harmful gases should be trained in administering artificial respiration. Their ability in applying artificial respiration should be tested at least four times a year.

71. In addition to being trained in rescue work and administering artificial respiration, men should be trained to give first aid, through participation in one of the American Red Cross standard first aid classes or one of the courses offered by the United States Bureau of Mines. In many companies, at least one man in each department per shift is trained in first aid work, and in a constantly increasing number of companies all employees, at their own request, are being so trained.

72. In all cases of injury to the body, including poisoning by gases or vapors, shock exists in greater or lesser degree. Chilling, according to medical authorities, is also: likely to occur, and its treatment is the same as that for shock. The victim, while lying down, should be kept warm by being wrapped in blankets, old coats, burlap bags, newspapers, or any other medium that is available. If the victim is conscious, light stimulants such as tea or coffee may be given. Alcohol in any form should not be used. The victim's hands, feet and lower limbs may be massaged briskly, toward the heart, to improve circulation. Hot water bottles, if available, or warm stones may be used against the feet and legs to keep the victim warm. In using these, the person giving the first aid should always test them on the inner side of his forearm to make certain they are not too hot.

73. When a victim regains consciousness after having been gassed, he should be kept in a supine position. There is great danger that the heart will be over-strained if the victim is allowed to get up and move around or even sit up. He should be carefully restrained from any physical activity until the doctor arrives. When the doctor arrives, all responsibility for subsequent treatment of the victim will devolve upon him.

Bibliographic Note

The National Safety Council is deeply grateful *to* Yandell Henderson and Howard W. Haggard for permission to use in this pamphlet material published in the following reference:

Henderson, Y. and Haggard, H. W., "Noxious Gases," New York, Chemical Catalog Company, Inc. **(Reinhold Publishing Corp.), 1942.**

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