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CURRENT SAFETY TOPICS Volume 5

CHEMICAL INDUSTRIES

Transactions of the

45th National Safety Congress

(October 21-25, 1957, Chicago, Ill.)

NATIONAL SAFETY COUNCIL

425 N. MICHIGAN AVENUE, CHICAGO 11, ILLINOIS

CONTENTS

LEARNING TO LIVE . . .

Learning to live—safely—was the drawing card which brought more than 13,000 men and women from the United States and 27 other countries to Chicago for the 45th National Safety Congress. These people gathered to exchange the latest ideas in safe attitudes, safe methods and safe equipment. Through speeches, panel discussions and symposiums, they acquired new ideas for helping others—and themselves—to live, work, and play safely.

This was the reason the National Safety Council was organized less than half a century ago, a time when man's thoughts barely kept pace with the industrial revolution. Since then, man has introduced an atomic age which is bringing the continents closer and has made the earth a smaller world. And now man anticipates inter-space travel!

Through science and technology, man is progressing to increasing speeds in travel and production, and increasing dangers—new dangers never before encountered. These, in addition to the everyday hazards of life, occupied the thoughts of the safety people at the Congress.

To encourage more widespread knowledge of the various fields of safety, the National Safety Council publishes the Current Safety Topics—30 volumes of condensations of Congress speeches and exchanges of ideas. Each volume is a handy reference to different phases of accident prevention. The complete set of volumes are listed on the back page of each volume.

Since the proceedings have been edited and condensed for reference purposes, the complete original manuscripts with any charts or illustrations used, are available in the National Safety Council files. Views expressed at the Congress or in any volume of Current Safety Topics are those of the Congress participants, and not necessarily those of the National Safety Council.

THE CHEMICAL SECTION

This volume is a record of the sessions held at the 1957 National Safety Congress by the Chemical Section. The conduct of these Congress sessions each year is only one of the many cooperative activities which the Chemical Section carries on in behalf of its members, and for the benefit of accident prevention work in the chemical industry generally. The section gives guidance in the preparation of a great variety of technical and educational material useful in the day-to-day safety programs of chemical companies.

The activities of the section are under the direction of its executive committee, the members of which are listed at the close of this volume.

mists, fumes, dusts. Also asphyxiation, irritation of lungs—acute (edema, pneumonitis), irritation of lungs—chronic, pneumoconiosis, fibrosis, emphysema, and granuloma (Be). In addition cancer of lung, deposition—radition within lung and hilar lymph nodes; specific carcinogenic agents are hazards. Ingestion of chemicals, following upper-respiratory trapping of dusts, following contamination of hands and handling things that go into mouth and following contamination of food stored in work rooms—eaten in dirty lunch rooms are potential dangers.

(2) nature of hazard—aspect of absorption—systemic effects such as: acute intoxication, percutaneous, respiratory, alimentary absorption (often two or all three combined); chronic intoxication—remote enzymatic or metabolic effects and organic damage; or remote radiation effects following absorption and distribution of radioactive materials in body—example—bone and marrow, following absorption, distribution and metabolism of specific carcinogins—example—bladder tumor.

RECOGNITION AND IDENTIFICATION OF HAZARDS

1. Toxicologic investigation (in laboratory) (stepwise with progress of research and development in industry)
   (a) screening—preliminary choice or elimination of materials under consideration—
   —immediate toxicity—indicative of type of control measures based on portal of entry (type and point of application of preventive procedure) (degree of precision required in protection, i. e. extent of apparent danger) (medical criteria—type of anticipated-injury or disease)
   (b) Comprehensive—(adapted to the problems to be met)
   —manufacturing hazards
   —hazards of transportation and use as raw materials by others
   —hazards of consumer of final product
   —cumulative effects if any
   —metabolic fate in body—remote effects—long-term—chronic—injurious effects
   —diagnostic and prognostic procedures based on results of investigation
2. Toxicologic investigation—(in plant) clinical investigation of personnel
   —basis of all specifications for safe environment
   —sometimes the only basis for recognition of hazard, e. g. beryllium, occupational cancer

CONTROL OF HAZARDS

1. Medical measures of control—environmental—(operations, plant conditions and (how men work)
   —clinical examination—all types.
   —policing the plant—(clinical findings and tests on personnel)
   —identification and quantitation of responses to observed exposure—within physiological (tolerable) limits—beyond physiological limits
   —warning of need for further protection
   —disposition of personnel with respect to exposure restriction of time (*duration*) of exposure—removal from exposure —temporary or permanent
   —personal protective equipment (choice and supervision, physiological criteria) adequacy of equipment employed—adequacy of its maintenance—adequacy of its use
   —education, group meetings, written instructions, hygienic manual, combined with operating manual
   —reports to engineering personnel (in both operations and industrial hygiene) and to management
2. Engineering measures of control
   —designing and applying measures of control—physical devices for protection against chemicals—plant design—operations design—ventilating design
   —policing the plant (environmental monitoring) inspection—critique of maintenance operations—analysis of materials —air analyses.
   —personal protective equipment (choice and supervision—engineering criteria)
   —reports to medical personnel, and management (directly or through physician)

3. Administrative measures of control
   —appropriate organization of hygienic facility in relation to operations
   —appropriate budgetary provision for hygienic effort

Adequate control depends upon the complete understanding of the hazard through physiologic and toxicologic research.

In addition, satisfactory team work includes:

1. Physician (including nurse and technicians) measures applied to personnel measures to be applied to environment (hygienic specifications)
2. Engineer (including chemist, physicist and technicians) measures to be applied to environment (hygienic technologic applications)
3. Management
   proper organization
   proper financial implementation▲

LIVING IN THE AIR WE BREATHE

by H. H. FAWCETT

safety director, research laboratory, General Electric co., Schenectady, N. Y.

Living in the air we breathe has been a problem since God created man from dust and then breathed into him the breath of life! But even today, the vital role of breathing in our daily life has not been completely appreciated. This paper reviews briefly (1) air contaminants, and (2) commercially available respiratory protective devices, with emphasis on their limitations, and on the training and maintenance necessary for safe and effective use.

Each of us is a creature of habits, but none of our habits is more vital to life than is breathing. So automatic and effortless is this habit that we give almost no thought to our respiration, although most of us cannot live without air for more than five minutes. From the second of our birth when we descend from in utero (where the oxygen partial pressure corresponds to 33,000 feet altitude) into a world with a mixture of gases called air, we must breathe several quarts of air each minute so our body cells can exist, grow, and perform their functions.

For an average lifetime of 70 years, we may breathe in excess of a half billion times. By contrast, we consume "three square meals" and "six glasses of water" daily. Our air requirements which we obtain virtually without effort are of greater significance by any standards than water, food, clothing, and shelter, which demand much "day-by-day" thought and deliberate action to obtain.

We live at the bottom of an ocean of air called the atmosphere, a name given to a mixture of several gases which consist mainly of four-fifths nitrogen and one-fifth oxygen. Virtually limitless in volume and mass as we view it from the ground, it thins out into space. Half of its density is under 18,000 feet. In a multitude of ways the air assists all living things to exist.

FUNCTIONS OF AIR

Besides providing oxygen for breathing-oxygen which lungs transfer to the blood—air conveys both sound and light, absorbs heat, enables fires to burn, propels boats, turns windmills, makes possible air brakes, vacuum cleaners, and other useful machines. Air in motion forms winds which modify climate, equalize heat and cold, and distribute rainfall. Rivers high in the air, such as the jet stream, greatly influence weather and are an increasingly important factor as airplanes travel at higher altitudes. The ancient Greeks ranked air with earth, fire and water as one of the four fundamental elements.

Since each of us has been breathing several times each minute from our birth, respiratory protection and devices to aid or supplement breathing might seem unnecessary. If pure air were truly ubiquitous, and no harmful gases, vapors or dusts existed, breathing problems would be confined to underwater or to travel in high altitudes. Unfortunately, pure air is a relatively rare commodity, and is much harder to obtain pure than many chemical elements and compounds.

Some variations of the air are caused by natural forces (such as moisture from rain or dust from winds on dry earth), while some are due to man (such as combustion products, unburned or incompletely burned fuels, solvents, vapors, dusts, fumes, inert and toxic gases). When these variations are small, we say that the air is "pure," but when the variations, either alone or in combination, exceed our ability to adapt to them, or our ability to tolerate them, we say the air is "bad."

AIR POLLUTION

No simple yardstick has yet been devised to tell us when air ceases to be "pure," although numerous air pollution studies are underway, and threshold limit values (maximum allowable concentrations for industrial exposures) are available as a guide. We have just begun to realize that air pollution control may be even more important than stream pollution control. When extreme conditions exist, as in London, Meuse, Donora or Los Angeles, we know that human life is more difficult than other times when smog is not present.

On a minor scale, every year a serious problem exists from dust or pollen (such as rose fever, hay fever, or ragweed fever) for allergic persons, and we have found that respirators are frequently considered a a welcome supplement to medication for the relief of such conditions.

Most breathing air supply problems can be controlled with adequate ventilation. If air could be properly treated to remove *particulate matter, noxious vapors, and toxic gases, heated or cooled, and then distributed as required, breathing can be reduced to a minor problem insofar as purity of air is concerned. Unfortunately, adequate ventila-*tion and air treatment is sometimes impossible or impractical where emergency action must be taken to preserve life and property.

Therefore, we must provide man with respiratory protection if we expect him to survive. A glance at the case histories of incidents collected at random from many sources and appended to this paper shows that respiratory problems have occurred in many diverse activities. Specialized knowledge and action in advance is essential if such injuries are to be prevented.

It is sometimes glamorous or unusual incidents which produce serious results; failure of a pressure system in an airplane at high altitudes will cause blackouts in seconds; above 43,000 feet, even breathing pure oxygen is not adequate— a pressure suit or a pressurized cabin is essential. On the other hand, no less serious are the problems when commonplace materials, such as a few sausages overheating and burning on a frying pan on a kitchen range produced sufficient smoke and toxic gases to overcome the occupants; firemen required respiratory protective apparatus to effect a rescue of the unconscious victims.

Gases and smokes resulting from fires have been studied for years, and excellent reports are available, but it is impossible to predict what gases may be encountered or in what concentrations in a given fire. A large number of different flammable chemical compositions or chemical combinations that change with heat, such as plastics, fabrics, insulation, refrigerants, solvents, paints, insecticides and building materials, play important roles in our daily lives.

VARIETY OF GASES IN FIRES

In addition to carbon monoxide, carbon dioxide, and water (present in nearly all fires), one may expect ammonia from burning wool, cyanogen from burning silk, acrolein from burning fats, sulfur-containing gases from burning rubber and leather, and chlorine-containing gases from burning or smouldering chlorinated plastics. From piled newspapers smouldering in limited oxygen, 41 per cent of the total gases given off was *found to be carbon monoxide, and 43 per cent was carbon dioxide.*

A pile of newspapers in a large open hallway would give an entirely different concentration of carbon monoxide and carbon dioxide within the breathing zone than the same pile burning in a small enclosed basement. Determinations ranging from two per cent to four per cent carbon monoxide have been made using recognized CO detectors in the smoke of building fires in the same room in which firemen were engaged in extinguishment, by a medical doctor

wearing self-contained breathing apparatus. A vigorous movement is now underway to encourage fire and other rescue services to use adequate respiratory protection more effectively.

AIR CONTAMINANTS

The conventional classification of air contaminants follows:

A. Aerosols (dispersoids) (particulate contaminants)—dusts, fumes and mists.

A better classification of aerosols is based on physiological effects:

A. Nuisance and Inert: produce no known injuries: calcium carbonate, magnesium carbonate, gypsum

B. Inert pulmonary reactions: produce non-specific pulmonary reactions: silicates, carbon, aluminum

C. Minimal pulmonary fibrosis-producing barium compounds, tin, iron oxides

D. Extensive pulmonary fibrous-producing silica, asbestos

E. Chemical Irritants: produce inflammation or ulceration alkaline reactions: acids, fluorides, chromates

F. Toxic systemic poisons: produce pathological reactions: lead, manganese, antimony, arsenic (not more toxic than Pb), arsenates, organic-phosphates, *cadmium, radioactive, beryllium (more toxic than lead)*

G. Allergic manifestations: produce allergic reactions: pollens.

H. Fever-producing reaction: action unknown or allergen: metal fumes, certain textile dust, (hemp, cotton, jute, bagasse)

A. *AEROSOLS*

Formerly called dispersoids or particulate *contaminants, these are substances present in the air as minute particles (such as dusts), as fumes (such as metal fumes), or as mists (such as chromic-acid mists). In grouping these together, it is recognized that they* may be physically filtered, screened, or adsorbed from the air with properly designed filters. Aerosols may range in size from 150 microns to a thousandth of a micron in size (1 micron equals 39.37 millionths of an inch or 1 x 10-4 centimeter). Many dusts are also fire and explosion hazards.

Pneumonokonioses (Greek for lung dust) or pneumoconioses are a group of lung conditions which result from the inhalation of dust. Silicosis is one of the most common types of pneumoconiosis, and is caused by the inhalation of "free" or "uncombined" silica, such as quartz, *opal flint and crystobalite.* Many other dusts may produce lung involvement such as absestos, talc, the silicates, carbon, iron and barium.

Other dusts cause chemical irritation, such as the acids, alkali substances, fluorides and chromates. Allergic reactions may be caused by common dusts such as pollens, synthetic resins, plastics, felt, fur, gums, spices, tobacco, paper, rubber, wood, starch, flour, and wool. The Bureau of Mines groups all the above dusts as "Pneumoconiosis-Producing and Nuisance Dusts."

TOXIC DUSTS

Another classification of dusts refers to "Toxic Dusts." Some have a lower threshold limit or maximum allowable concentration than does lead, although the Bureau of Mines classification uses lead as a reference. Among aerosols more toxic than lead are: cadmium oxide fume, chromic acid and chromates, mercury, mercury (organic), yellow phosphorus, picric acid, selenium, tellurium, calcium arsenate.

Respirators approved for all the above dusts (both toxic and pneumoconiosis-producing and nuisance dusts) are called "dust" respirators. A few substances, such as beryllium and radioactive substances, are not currently covered by Bureau of Mines schedules.

"Fumes" include aerosols formed by the condensation of vapors from heated metals. Melting, cutting, and welding of zinc, lead, cadmium and other metals produce such fumes.

"Mists" and "Sprays" include liquid droplets formed when liquids are carried into the air or are formed by a reaction with the moisture in the air. An interesting example is 0.3 parts per million sulfur dioxide, with sunlight, forms 20,000 particles per c.c. of sulfuric acid mist.

The availability of filters with pore sizes from 10 millimicrons (approximately the size of the polio virus) to five microns (the size of common contaminants in liquids) has greatly improved and speeded up analyses of aerosols such as acid mists, metal fumes, smokes, and radioactivity.

In recent years, study and measurements of even smaller particles in air than previously observed, known as condensation nuclei, have contributed greatly to our understanding of the nature and number of particles in air. The particles in the air on which water will condense are called condensation nuclei; under natural conditions only the larger particles are so effective. When the air is sufficiently super-saturated apparently any particle will serve as a condensation center.

Particles from such diverse substances as platinum, silver, stearic acid, glycerin and lubricating oil will all form droplets at a sufficiently high supersaturation of water vapor. Practical methods are now available to measure the number of particles in an aerosol in free air. A wider use of the technique already available for size and numbers of an aerosol would not only throw light on some of the problems of air pollution but would certainly lead to further improvements in our knowledge of aerosols.

Respirators for insecticides are tested and listed by the U. S. Department of Agriculture.

B. *GASES AND VAPORS*

In this major group may be included most of the air contaminants which are not classified as aerosols.

1. *Irritant gases* are those which produce inflammation of tissue, such as the skin, the eyes, and the respiratory tract membranes. They are divided into two general groups:

a. action is limited to irration (such as hydrogen choride)

b. action extends to systemic effect (such as oxides of nitrogen)

Some of these gases and vapors have pronounced odors, but the nose cannot be depended upon as a reliable method of estimating concentrations.

2. *Asphyxiants* are substances which deprive the body tissues of oxygen, causing hypoxia (oxygen starvation). Two general methods of action are known: *simple* asphyxiants (such as nitrogen, hydrogen, helium, and methane), which dilute or replace the oxygen partial pressure in air; and chemical asphyxiants (such as carbon monoxide, hydrogen cyanide, hydrogen sulfide, acetonitrile, aromatic nitro and amino compounds like aniline, nitrobenzene and derivatives), which combine with the hemoglobin of the blood to prevent oxygen-carbon dioxide exchange.

The insidious nature of the action of the simple asphyxiants, and the speed with which they can act, is still not widely appreciated; whereas most people have a healthy respect for the chemical asphyxiants. Under proper medical supervision, pure nitrogen may be breathed for several seconds and this technique has been used clinically by Himwich and others. However, nitrogen and the other *simple asphyxiants* give almost no warning between the time breathing air is replaced with the asphyxiant and unconsciousness overtakes the subject.

PHYSICAL REACTIONS

A loss of mental facilities begins within a few seconds, and unconsciousness may occur shortly after with no warning. The brain is the first organ of the body to be affected seriously by oxygen want, and the subject "blacks out" quickly. Mention is made of this little-appreciated phenomenon not only because asphyxiants can be released in a room or tank with inadequate warning from the action of a fixed carbon dioxide fire extinguishing system, from a large spill of liquid nitrogen, from a leaking gas system, from an inert-gas producer, or from a leaking cylinder, but also because airline-*supplied respirators*, hoods and suits are frequently attached to a plant air supply with little appreciation of the hazard.

For example, at the Acids and Heavy Chemicals sub-section meeting, Chemical section, National Safety Council, October 25, 1956, no company present reported use of a special air system for respiratory equipment. If a cross-connection should occur anywhere in the air system which would permit an asphyxiant, toxic, or flammable gas to enter the air used for breathing, the results can easily and rapidly be fatal.

Oxygen, used indiscriminately, may also be a hazard, since serious fires have been reported where oxygen, either from a cylinder or an airline, or a leaking hose or pipe, was used for breathing purposes in an airline respirator or hood where welding or other flames were involved. Only a completely separate air supply, supplied by a compressor which cannot evolve carbon monoxide, carbon dioxide, oil mist or other unwanted impurities or from cylinders of tested known purity should be used for airline respirators, hoods or suits. In any event, regardless of supply, the system should include pressure relief valves, filters and absorbents as recommended.

2. *Anaesthetics* are gases and vapors whose action is primarily by inducing the symptoms of anaesthesia when inhaled in sufficient quantities. These include the substances which come to mind when the word "anaesthetics" is mentioned, such as the ethers, chloroform, methyl chloroform (1,1,1-trichloroethane), trichloroethylene, ethylene oxide and nitrous oxide (laughing gas), as well as hydrocarbons, aldehydes, ketones, other halogenated hydrocarbons, the aromatic hydrocarbons, alcohols, esters, and carbon disulfide.

DECOMPOSITION OCCURS

In addition to the physiological action of these materials alone and in combination, decomposition products are produced in a fire or when they are otherwise subjected to heat. Even relatively harmless substances such as the Freons and the Genetrons, (widely used as non-flammable refrigerants of low toxicity, as replacements for ammonia, sulfur and ethane), will evolve toxic decomposition products if they are heated above their decomposition temperatures. This has occurred where Freons and Genetrons were used as cleaning solvents.

Metal parts, after cleaning, were heated above the safe limits in order to dry and flash off the remaining solvent. Several persons were hospitalized with pulmonary congestion. Trichloroethylene degreasers, properly installed, maintained and operated, are safe, yet the failure or misuse of these vapor degreasers has created serious hazards including both fires and toxicity.

Mass hysteria and unconsciousness due to the little-appreciated anaesthetic action of the trichloroethylene has occurred in seconds; in one incident 72 persons were overcome, and in another, 26. Fortunately, all recovered after removal to fresh air and oxygen inhalation. The hazards of carbon tetrachloride mixtures in fire fighting and in other applications are well documented.

4. *Substances producing other effects*— This classification includes several substances whose action differ from previously-mentioned substances. Included in this group are mercury, white phosphorus, tetraethyl-lead, nickel carbonyl, arsine, the boron hydrides, phosphine, hydrogen sulfide, and the widely-publicized military "nerve gases." The initial action of these gases and vapors is primarily on the nervous system, with respiratory arrest following.

CONTAMINANTS COMBINE

If the above classifications appear complicated, it must be remembered that these air contaminants seldom occur alone, and that even less is known about the combined action of two or more substances, especially if they are in different groups, than of the individual substances. Even if particles in the air are non-toxic in themselves, they are known to act as carriers of condensable toxic vapors—formaldehyde can have its toxicity increased five times by the presence of an aerosol.

It is little wonder, then, that respiratory protection can become a highly complicated subject, and that the practical application of respirators, gas masks, and self-contained breathing apparatus (all with their limitations), even by persons thoroughly trained in their use, is not cut-and-dried or foolproof.

Relatively untrained persons in an emergency situation, are in especially vulnerable positions. Many of the case histories attached to this paper clearly point to the need for more widespread appreciation of the nature of the hazard, as well as of the limits of the various respiratory protective equipment used.

RESPIRATORY PROTECTIVE DEVICES

A. *AIR-PURIFYING RESPIRATORS*

The fundamental limitations of any air purifying device are that the air must be within the limits for which the respirator was designed (for example, the oxygen content must be more than 16 per cent); the particular unit will only protect against the specific substance or combinations for which it was designed, (for example, aerosol [dispersoid] [filter type] respirators will give no protection against gases and vapors); and the canister or filter must be maintained in proper working condition (on a properly maintained facepiece that fits snugly enough to exclude leakage).

Aerosol (filter type) respirators require frequent changes in filters when breathing resistance becomes uncomfortable when used where excessive dust or fumes are involved. Chemical cartridge respirators will safely protect only against the specific vapors and gases in non-emergency situations where no more than 0.1 per cent is encountered.

Extremely toxic materials, such as acrolein, acrylonitrile, aniline, dimethylaniline, arsine, bromine, carbon disulfide, carbon monoxide, dimethylsulfate, hydrogen cyanide, hydrogen fluoride, hydrogen selenide, hydrogen sulfide, iodine, methyl bromide, methyl chloride, nickel and iron carbonyl, nitrobenzene, nitroglycerine, nitromethane, oxides of nitrogen, ozone, phosgene, phosphine, phosphorus, trichloride, stibine, sulfur chloride, the boron hydrides and others are too toxic even in low concentrations for reliance to be placed on simple cartridge type respirators.

NOT FOR ODORLESS GASES

Chemical cartridge respirators should not be used against gases which are odorless or whose odor threshold is high, since the only warning of failure of the respirator or of concentrations which are above the ability of the respirator is odor. Methyl chloride is an example of such a gas whose warning properties are too slight for practical purposes. Substances which are highly irritating to the eyes, such as sulfur dioxide, require eye protection (such as a gastight goggle, an air-supplied hood, or a full-facepiece).

Several lacrimatory (tear-producing) substances, such as benzyl chloride, are in the same classification, and a respirator alone is clearly inadequate. Some substances, such as carbon monoxide, cannot be stopped by a chemical cartridge (except by the Hopcalite in the Type N universal gas mask and in the miner's pocket self-rescuer). Ammonia cartridge respirators will protect against ammonia up to 1,000 p.p.m., while eye irritation from ammonia begins at about 700 p.p.m.

Mercury cartridge respirators are effective against concentrations of mercury vapor normally encountered at ambient temperatures, but service life is proportionately reduced where higher concentrations of mercury from elevated temperatures and pressures are present. (There is no Bureau of Mines approval schedule for mercury respirators). Combination cartridges have the limitation of a shorter service life when used with one particular type of hazard than the equivalent specific single-purpose canister would have for the same hazard.

FACEPIECE TYPES

Normally, respirators use a "half-mask" facepiece, covering the nose and mouth, while gas masks use both full-masks and full facepieces. (Only full facepieces on gas masks are approved by the Bureau of Mines). Recently, the "self-rescue" or "pocket" respirator, normally used with a cartridge containing Hopcalite with a dryer and designed for escape from mines, has been extended into other cartridges.

The mouthpiece of this style respirator is held tightly by the front teeth of the wearer, and the breathing is accomplished through the mouth. A nose clamp blocks off the openings of the nostrils, and prevents irritation of the membranes of the nose. A neckband permits the respirator to be worn ready for instant use. Twelve different filter cartridges will fit the basic holder and mouthpiece.

Industrial canister-type gas masks, with canisters designed for specific substances or combinations, have the same limitations in general as chemical cartridge respirators, except they are effective in concentrations of any specific gas or members of the same group of gases for which they are designed of not more than two per cent in air or a two per cent total for a mixture of gases for which the canister is designed.

The ammonia canister is approved for three per cent ammonia. For shorter periods of time, industrial canister-type gas masks can be used in higher concentrations, but the time of service life will be reduced. Depending on the size of the canister, and the service for which it was designed, the service time varies.

Protection for a combination of various gases, such as acid gases, organic vapors, and ammonia can all be obtained in one canister, but the service life of such a combination is shorter in the combined canister when used with one specific substance, than is the life of an equivalent canister

designed for specific substance alone. The only warning that a canister or cartridge is "exhausted" is the detection of odor of vapor or gas passing through the canister or cartridge.

Persons who need corrective lenses in order to work properly when wearing the respiratory protection, especially full facepieces, may find of interest two methods of incorporating lenses inside a facepiece. One method consists of wire frames which fit around the circumference of the sight lenses, and hold a 50-mm round prescription lens.

PRESCRIPTIONS IN FACEPIECES

A second method consists of a center post built inside the mask, onto which can be attached 40mm rimless glasses. Such arrangements seldom allow perfect alignment of the prescription lenses to the viewer's eyes, but with adjustment, a sufficiently accurate fitting can be achieved for most purposes for reasonably long periods of time.

The type N universal gas mask canister is constructed of several layers including activated carbon (to remove organic vapors), soda lime (to remove acid gases and carbon dioxide), copper sulfate (to protect against ammonia gas), silica gel and other dryers (to remove moisture both before and after the Hopcalite), and Hopcalite itself (a mixture of metallic oxides which catalyzes the conversion of carbon monoxide to carbon dioxide), plus a filter for smokes.

This canister can be used as protection against smoke and gases which do not exceed two per cent by volume total, where adequate amounts of oxygen are present. Sixteen per cent oxygen is cited as the practical minimum, but life is not actually in danger until about 14 per cent or less oxygen is present. A timer is used to count the number of inhalations, and indicates about two hours total use.

DISPOSE OF CANISTERS

A canister should be discarded at least as soon as the timer indicates the pointer has completed one revolution, if not sooner. One authority recommends that universal canisters be weighed immediately on receipt from the manufacturer, and that they be discarded as soon as they have gained 45 grams. This 45 grams limit was imposed since it represents the limit of the dryers to keep the Hopcalite dry, and also to prevent excessive breathing resistance from developing as the dryer becomes moist.

The shelf-life of the universal canister, once the canister has been attached to the facepiece is one year, if stored with the bottom seal in place, even though the mask has not been used. If stored with both top and bottom seals unopened, as received from the manufacturer, the shelf-life is considered by some to be four, and by others, five years.

With an respirator or gas mask, the problem of proper fitting of the facepiece is critical. In addition to the time honored technique of holding the hand over the opening in the bottom of the canister while inhaling gently to see that the facepiece will collapse on the face, another technique recently suggested by the A.E.C. is to use isoamyl acetate.

Since isoamyl acetate (which smells similar to bananas) can be detected in a concentration of as low as one part per million, a small leak will be detected if the acetate is placed on cotton and the cotton passed slowly around the edges of the mask without touching either the wearer's face or the mask. If the wearer can detect the odor, a leak is indicated and the mask should be further adjusted until the odor can no longer be detected.

CIVIL DEFENSE MASKS

As part of its chemical warfare defense program, the Federal Civil Defense Administration is stockpiling a mask designated as CD V-800 organizational mask for use by civil defense personnel. The canister on this chin-style mask is the same as used in the U. S. Army Assault Mask. This mask is reported to give "excellent protection against CW (Chemical Warfare) and BW (Biological Warfare) agents, as well as against the inhalation of radiological particles, or CBR (chemical, biological and radiological)".

Designed to be used in conjunction with a detection kit, CD V-810, which will detect and distinguish between the nerve gases and the mustard gases, the V-800 mask is a specific mask for war gases (including nerve gases) and will not protect against carbon monoxide, ammonia and other gases. The Army Chemical Corps recently announced a new E-13 mask for troops. It is designed to give the soldier complete protection against the inhalation of war gases, germ warfare agents and airborne radioactive fallout particles, but does not protect against direct radiation.

The new mask does not have the protruding canister used in current masks. This was made possible through development by the Chemical Corps of a new light-weight, pliable gas-aerosol filter material. Pads of this material are enclosed within cavities molded into the rubber facepiece of the mask. Lower breathing resistance, superior vision, better speech transmission, and greater comfort are claimed.

It should be noted that the CD V-800, the existing and the new Army gas masks should be used for purposes for which they were designed only. After both World War I and II, several instances were reported where "surplus" Army masks were used for protection against gases for which they were not designed, with serious consequences. It is important that gas masks are not misused.

B. *AIR-SUPPLIED RESPIRATORS*

Since the simplest solution to all respiratory problems is to supply pure air to the breather, the use of an air supply from some remote source where the air is not contaminated is both simple and logical. For many applications, air-supplied equipment has real advantages, but this equipment is subject to definite limitations. The simplest type is the Bureau of Mines Type B hose mask, which is a facepiece to which is attached a hose without a blower which must extend to a respirable source of air. This mask depends on the breathing action of the wearer to move the air. For this reason, a maximum hose length of 75 feet has been established for the hose mask without blower.

Low pressure blowers, operated either by hand or by power (power blowers do not carry Bureau of Mines approval) are used to supply Bureau of Mines Type A hose masks up to 150 feet. All hoses should originate at the blower.

A respirable source of air must be assured, and a safety man must be present at the blower at all times. Fouling of the hose may cut off the air supply, and the exit route must be the same as the entrance route. These hose masks can be used safely only if the above precautions are observed.

Airline-supplied Bureau of Mines Type C respirators are divided into two classes: (a) the continuous flow type and (b) the demand or intermittant demand flow type; (a) is usually used with a powered compressor or blower, while (b) is usually used with breathing air supplied from cylinders. The use of such equipment in atmospheres immediately hazardous to life is not recommended since failure of the air supply or fouling of the hose would be serious, and further, it is absolutely necessary to have respirable air of unquestioned quality.

We have previously noted the hazard of using a plant air supply for air-supplied breathing equipment. It is recommended that a separate air system be used exclusively for breathing air. Depending on the pressure available and the diameter of the hose, there is a limit to the length of hose which is practical.

Wherever possible, such systems should be piped as close to the outlet as possible, so possibility of fouling of the hose and cutting off the air supply will be minimized. Exit from areas where air-line respirators are used must, of course, be the same as the route in. If a compressor or tank supply is used, sufficient pressure relief control must be available to protect the wearer against pressure in excess of that prescribed for the equipment.

AIR-INFLATED SUITS

Air helmets, air hoods, and air-supplied suits have the same general limitations as for air-line respirators. An interesting development in this field is the use of air-inflated suits for protection of the whole body against hazardous materials.

In one form, the large impervious plastic tunnel or pipe allows a man to work in one room while using air from another—the slight air pressure supplied giving both breathing air and inflation (or body) to the suit. The front of the suit is tailored into a facepiece, and arms with gloves are attached. Mobility is reported good within the obvious limits imposed by the length of the tunnel attached.

In another form, a complete suit with built-in arms and legs is supplied with air for inflation and a hood, also air supplied, is used for head, face and respiratory protection. Depending on the particular fabric, plastic, or composition used in its construction, this suit allows work inside tanks, reaction vessels and other confined space which still contain a hazardous atmosphere.

Properly used, together with safeguards to insure that the wearer's air supply and life-line are always in proper position and working order, this suit has increased safety and decreased operating costs in maintenance work inside tanks containing materials which are corrosive or are easily absorbed through the skin such as aromatic amino and nitro compounds. The same limitations noted above for air-line respirators should be noted.

Regardless of the type "respirator" used, a definite program of control is necessary to insure the device is used properly, is properly maintained, and that it is doing what is expected of it. After the Canadian Chalk River atomic reactor incident, respirators were used to prevent inhalation of radioactive contaminants. This program was successful only after a respirator official was appointed to control the use and maintenance of respirators, regular urine-samples were analyzed to show definitely the degree of absorption, and an improved respirator was made available.

C. *SELF-CONTAINED BREATHING APPARATUS*

Self-contained breathing apparatus supply complete respiratory protection in any concentration of toxic gases and under any oxygen deficient atmosphere. However, certain gases and vapor will cause systemic poisoning by skin absorption. Although a small group, these exceptions are highly important, including hydrogen cyanide, nitro and amino aromatic compounds, ethylene imine, phenols and a few others. These gases and vapors require complete skin protection of an impervious type in addition to respiratory protection.

EARLY REBREATHING APPARATUS

The early self-contained rebreathing apparatus, which was imported from Europe, had serious deficiencies. Loss of life was reported by users in this country; 19 accidents are reported involving 26 facilities between 1911 and 1940, due partly to equipment failure and partly to improper use. Where life-lines and standby rescue squads were employed, the apparatus was generally satisfactory in the hands of well-trained users.

The first self-contained breathing apparatus to be approved by the U. S. Bureau of Mines was of the two-hour rebreathing type.

The oxygen rebreathing type apparatus is relatively heavy (39# for the two-hour type) and is bulky. Most self-contained (closed circuit) oxygen breathing apparatus in use today require mouth breathing with a nose clip, but a full facepiece has recently been approved. Careful training is required in use and in maintenance of this apparatus. A minimum of 20 hours initial training is recommended by the Bureau of Mines.

RESTRICTS MOVEMENT

Demand-type air and demand-type oxygen breathing apparatus is available in half-hour, quarter-hour and 7½ minute ratings. Only the half-hour demand apparatus is Bureau of Mines approved; the Bureau has no approval schedule at present for any self-contained apparatus of less than a half-hour. Although the schedule of work on which the Bureau's half-hour rating is exhausting, large men under extreme stress have exhausted a half-hour (40 cu. ft.) cylinder in significantly less than a half-hour.

Differing only in whether it is supplied with compressed oxygen or compressed air, the apparatus weighs nearly 30 pounds for the half-hour type, with the large cylinder (40 cubic feet) on the back. It is relatively awkward to put on and it restricts action in confined spaces. With practice, it may be put on and into operation from a mounted backboard in less than 20 seconds.

The back position of the cylinder makes it difficult to crawl under equipment. Climbing in and out of small openings, such as manholes, requires care when wearing this type apparatus. Operation of a motor vehicle is awkward when wearing a cylinder on the back. (15-minute and 7½-minute demand apparatus use smaller cylinders slung on the side of the wearer, which overcomes this objection to some extent.)

The purity of the air or oxygen with which the cylinder has been charged should always be questioned since other gases such as nitrogen, acetylene and carbon dioxide and gas mixtures other than air have actually been found in "breathing air" cylinders. Errors in compressed air used for breathing may be rapidly fatal, and every newly-filled cylinder should be checked to insure it actually contains "breathing air," regardless of the source of supply.

Unless the user has his own compressor producing air of an unquestioned purity, no cylinder should be put on a demand breathing apparatus or air-supplied respirator, hood or suit until the contents have been checked for purity. The Orsat gas analyzer or the Beckman paramagnetic oxygen analyzer are often used in analyzing oxygen percentage while carbon monoxide may be checked with the National Bureau of Standards colormetric tester available from two manufacturers.

High pressure cylinders may leak and frequent inspection is necessary to insure that the air or oxygen is actually available for use in an emergency. High pressure valve, gauge, and demand regulator must be maintained in top operating condition by inspection and a regular preventative maintenance schedule as recommended by the manufacturer.

ATMOSPHERE CUTS SERVICE

If demand-type apparatus is worn in environments where pressure above one atmosphere is present (as in caissons or tunnels under higher than atmospheric pressure), the service time is reduced as the pressure increases. This is also true of underwater use of the regular demand-type apparatus; a special adaption is available for underwater swimming. Other peculiar effects have been reported when demand and closed circuit oxygen breathing apparatus was worn under pressure.

The use of oxygen in atmospheres above two atmospheres absolute pressure should be avoided since oxygen produces a toxic effect under such conditions. For periods up to 12 hours at normal atmosphere pressures, however, oxygen may be used without apparent ill effects by healthy persons—persons in questionable physical condition should *not* wear *any* emergency breathing equipment, but should remain away from contaminated air and underwater.

When the supply of air or oxygen has been depleted, the supply in the demand type apparatus cuts off abruptly, and the facepiece must be removed immediately or asphyxia can occur. One British half-hour breathing apparatus has available as optional equipment an automatic warning whistle (Pat. No. 644105) which will start to blow when the cylinder pressure falls to 300 pound/square inch, to aid in warning the wearer to return to fresh air at once.

The seal around the facepiece must be absolutely gas-tight in a toxic atmosphere since in the demand-type apparatus the facepiece is under slight negative pressure momentarily during the beginning of the inspiration phase of the cycle. A recent revision by one manufacturer eliminates this negative pressure part of the cycle. Another novel feature of another demand mask (54 cubic feet of air or oxygen divided between two 26 cubic foot cylinders for balance) is a plug-in attachment carried with the mask for administering resuscitation to an overcome person on-the-spot while still in a toxic atmosphere.

In the above discussions, no mention has been made of the fire and explosion hazard of air which is richer than 21 per cent in oxygen, or of pure oxygen itself. Certainly air should not be replaced with oxygen, either in a breathing apparatus, in a ventilation technique, or for any other purpose, without full consideration of the increased potential hazards from fire, as the oxygen concentration increases above the 21 per cent oxygen content of air. A flammable vapor-oxygen mixture requires only about one thousandth the energy to ignite it as does a corresponding flammable vapor-air mixture.

The resulting fire or explosion is many times more violent. Failure to appreciate these facts (which have been published and well documented for years) has cost many lives. For this reason, it is as important to analyze a suspected atmosphere for oxygen concentration as for flammable vapors and gases, and for toxic gases. By using either the time-honored mine safety lamp as an oxygen indicator, or the more recently available Beckman paramagnetic oxygen analyzer, it is possible to obtain fast and sufficiently accurate oxygen analyses for practical purposes.

Combine such oxygen analysis (which will reflect inert gases or oxygen deficient atmospheres as well as excessively high oxygen concentrations) with a check for flammable vapors and gases (using one of the many instruments commercially available), and a check for whatever toxic gas is suspected (for CO, for example, the National Bureau of Standards glass tubes containing palladium chloride which changes color with CO). To ignore any one of these fundamentals is to run risk of trouble.

SAFE 45 MINUTES

The self-contained oxygen-generating breathing apparatus is approved by the Bureau of Mines, and is rated for 45 minutes. Some of the models produced for the military are not Bureau of Mines approved, however. The weight of 14#, carried on the chest and stomach, gives it a decided advantage both in weight and convenience over the demand-type apparatus, although the chest position creates limitations in use under some conditions.

The highly exothermic reaction which generates oxygen from the potassium superoxide (K_2O_4) evolves significant heat, which might serve as an auto-ignition source to carbon-disulfide or nickel carbonyl vapors under extreme conditions. This temperature of the canister surface may reach 250°F, and is equivalent to the hazard presented by unshielded incandescent lamps, *hot plates and steam pipes in such an* atmosphere.

When worn in hot areas, or while working hard in the heat, the oxygen generated may occupy a volume which requires "dumping" of surplus oxygen to maintain comfort. The apparatus requires care in starting, especially in sub-freezing temperatures—for this reason it is considered good practice that both the apparatus and the canisters be stored inside or in a heated truck cab or automobile, and that the apparatus be thoroughly started above freezing temperatures, if possible.

Unless the sub-freezing starting is thorough, the wearer may be aware of insufficient oxygen during the first few minutes, by a feeling of "light headedness" and difficulty in coordination. If such a condition is noted, he should return to fresh air, deflate the bags and re-start the apparatus, until the breathing rate and the generating rate balance before re-entry.

In inserting the canister in the canister holder (canister is stored separately), care must be exercised to avoid cuts from the torn top seal when removing it, and the canister brought securely into place after it has been punctured by the sharp point designed into the apparatus for that purpose. The facepiece should not be donned until the canister is completely seated. A fresh canister should always be used in any emergency.

Once opened, a canister will continue to evolve oxygen even when removed from the apparatus and re-capped. To enter a hazardous atmosphere with a used canister is a highly dangerous practice—a fresh canister must be employed to insure safety. In view of the relatively high cost of these canisters, the temptation to re-use canisters is great, but should be avoided, and canisters promptly disposed of to insure the safety of the next user.

DON'T RE-USE CANISTERS

The disposal of the self-contained oxygen-generating canisters must be performed according to the instructions. Oil, grease, gasoline, or other flammable or combustible liquids must be kept from the canister mouth, or an explosion will occur. Only clean water in large quantities should be used to destroy a canister. The canisters should be promptly disposed of, and not be left sitting around where they could contact combustibles.

For reasons noted under discussion of demand-type breathing apparatus, the self-contained oxygen-generating apparatus should not be worn under pressures greater than two atmospheres absolute.

Smaller Self-Contained Breathing and Oxygen Inhalation Devices

U. S. Bureau of Mines approval for self-contained breathing apparatus currently makes no provision for apparatus rated for less than 30 minutes. In emergencies where a smaller, less cumbersome device with a shorter life would give adequate protection, the only available devices until recently were regular demand masks with smaller cylinders for 20, 15, and 7½ minutes service, using the same facepiece, reducers and regulators as on the larger approved devices.

Recognizing that many (perhaps most) breathing emergencies can be brought under control in 10 minutes, and that the first 130cc of expired air contains relatively little CO_2, there is now available a lightweight device in which oxygen from small cylinders, supplemented by the first 100cc of the previous exhaled breath, is used for breathing at a rate of seven liters per minute. The device is still too new for extensive field experience, but represents a novel and new approach to the weight, bulk and cost of presently approved equipment.

Another recent development is a small portable anaesthesia and oxygen breathing device which is designed for use by medical personnel primarily, but which has obvious application as a "self-rescuer" for escaping toxic atmospheres. The device consists of a face piece with pressure limiting valve, an aluminum central body, a soda lime canister in volumes of 100cc to 500cc, two aluminum cylinders, each containing three liters of oxygen, and a six liter rubber rebreathing bag.

Using the device for escape, it is claimed a young male adult walking three mph can travel safely for 1100 yards using a 200cc soda lime canister, and 1800 yards using a 500cc canister. Since the complete unit weighs less than two pounds, and the oxygen cylinders are pocket-size, the device may rightly be called pocket-size, and, in the hands of trained personnel, should be useful for self-rescue oxygen inhalation or resuscitation.

Maintenance, Training and Medical Precautions

In discussing respiratory protection, we have shown the importance of breathing "good" air, briefly reviewed the major air contaminants, and discussed briefly apparatus available. We have stressed the limitations of each type, rather than the advantages, since we believe that limitations were not as widely appreciated as advantages. The ideal breathing apparatus has yet to be developed. We have tried to create the impression that a thorough knowledge of the particular apparatus used is essential for its safe use under various conditions.

Maintenance of the apparatus in first-class condition so it is immediately ready for use at any time is likewise important. Metal parts of apparatus will wear, tarnish or corrode; rubber parts will slowly "age." Facepieces will take a "set" and must be discarded. Cylinders, regulators and valves on demand-type apparatus must be checked frequently for leaks; canisters on industrial or universal service masks or chemical cartridge respirators must be replaced.

Washing the facepiece with an antiseptic solution or soap, rinsing in clear water, and drying will assure that sanitation and cleanliness is not neglected. This also prolongs the useful life of the facepieces. Proper storage conditions and frequent checking for deterioration are as important with respiratory protective equipment as with fire extinguishers, parachutes and life-lines.

TRAINING DEFICIENT

Training is the third, and perhaps most important leg of the triangle of respiratory safety. There is serious deficiency in this phase of the respiratory program. Putting on a device for a few minutes once a year is not adequate training. The U. S. Bureau of Mines Health and Safety Activities, through its district and sub-district offices, conducts training courses in first-aid, and also in the use of various emergency breathing apparatus.

The course can be modified to meet special needs on request. Addresses of offices which offer these courses may be obtained by contacting the Health and Safety Division of the Bureau of Mines, 4800 Forbes St., Pittsburgh 13, Pa. This service of the Bureau is available to the mineral and allied industries, as well as to governmental agencies. The Bureau has at each of its Health and Safety field offices throughout the country mine-rescue equipment, and will make it available to trained personnel in any emergency.

During training, breathing apparatus should be worn for relatively long periods, in dark and confined spaces, climbing hills or stairs, duplicating all manual labor expected, and in smoke-filled atmospheres by hand-carried lights while performing work. Smoke generators are available, which will quickly fill a room, a basement, a tunnel or a small building with a smoke that is realistic, but which is relatively harmless and can be ventilated out without any damage.

The "buddy" system and team drill should be practiced, as in a real emergency. The use of life lines should be a part of this training, and should be a standard part of any underground, tank or smoky operation.

Signals as used by mine rescue teams based on OATH (O=OK=1 pull; A=advance=2 pulls; T-take-up=3 pulls; H=help=4 pulls) should be employed and stand-by men, ready to enter the area for rescue, should always be on hand.

Hand-carried short-wave two-way radios may also prove useful for communication between base and field party. When used in atmospheres which may contain flammable vapors or gases, any electrical devices should have a "permissible" rating by the Bureau of Mines for the gases or vapors involved.

PHYSICAL EXAMS LACKING

The need for proper physical examinations for persons wearing emergency equipment has not always been appreciated in the past. A regular program of physical checkups with particular attention to the respiratory and circulatory system as well as general physical condition probably would have prevented some cases where inhalation of a smoke combined with physical exertion with or without respiratory protection, has produced serious illness.

Pulse rates before, during and after exercise, general physical condition, moderate weight, good eyesight and proper teeth alinement (where mouthpiece breathing is involved) are considered vital to pre-training by the Bureau of Mines instructors. A practice of not permitting persons to return unprotected to smoke or fumes after they have been overcome and revived, would help prevent more serious inhalation effects.

Such restraining action may require physical force to implement it in practice, since a patient who is partially recovered from fume or smoke inhalation may display highly irregular behavior. One recommendation is that persons sufficiently exposed to smoke and carbon monoxide to require treatment should not return to active duty in less than four to six hours, while those who have been rendered semiconscious or unconscious should rest 24 to 48 hours.

Properly maintained breathing apparatus, used with full appreciation of its limitations, by healthy persons, properly and adequately trained, will eliminate most "fume" disabilities in the future. However, the ideal breathing apparatus for all applications has not been developed, and may not be developed until there is sufficient demand for it.

CASE HISTORIES

AMMONIA

The incident in question took place in Singapore, Malaya, during the early days of the war 1942, just prior to the fall of the city to the Japanese.

Our ship was tied alongside the docks, having just completed a mission. The city was under air attack continually, so that we maintained a full scale Battle Watch, ready for any emergency. It was after one of these raids that a strong odor of ammonia was observed on our ship; our blower ventilating system was picking it up. Investigation by our shore patrol informed us that a large cold storage plant had been hit and that the local fire department was attempting to rescue several members who were trapped inside the buildings.

Our fire and rescue section was dispatched to the scene at once; we were equipped for such work with demand-type breathing apparatus, with proper protective equipment and safety lines. Upon arrival we were briefed as to the plant layout and the possible location of 10 men inside the building with a British type canister mask for protection. We entered the area working in pairs, and during the next 20 minutes removed 10 firemen, who had been well trained by the best of British methods, but unfortunately ill equipped for such violent conditions.

When found, all men were unconscious and upon removal from the building were rushed to the hospital, oxygen being administered enroute by a fine Australian medical team. Of the 10 men rescued, six died from the effects of ammonia inhalation, four men recovered completely.

During the entire operation none of our team experienced any breathing difficulty; the teaching of damage control, fire and rescue work by Naval standards are very good. Their careful selection of reliable equipment has been the result of careful research and experience.

NITROGEN IN AIR-LINE RESPIRATOR

Employees in an area were required to use air-line respirators as a precaution against inhalation of radioactive particles. The air line was also used to provide instrument air.

FILMS

1. *Mechanisms of Breathing* (EBF) 612.2-1, Pennsylvania State University, Audio-Visual Aids Library, State College, Pa. or Encyc. Brit. Films, Inc. 1150 Wilmette Ave., Wilmette, Ill., (16mm sound, 11 min).
2. *Oxygen*, 16mm sound, 10 min., B&W and color, Coronet Films, Coronet Bldg. Chicago 1, Ill.
3. *The Air We Breathe*, 16mm sound, 26 min., B&W; Mine Safety Appliance Co., 5-45 49th Ave., Long Island City, N. Y. or local sales office.
4. *The City That Disappears* (Los Angeles), 16mm sound, color, 30 min., (Stanford Research Institute, Menlo Park, Calif.
5. *A Report on Smog*, 16mm sound, color, 20 min. (same source as 4).
6. *You Bet Your Life*, 25 min., 16mm sound B&W, available same source as 3.
7. *Use of Oxygen in Aviation*, TF1-4595, 22 min., 16mm sound, color, same source as 8.
8. *Oxygen, In-Flight Requirements*, TF-1-5038A, 25 min., 16mm sound, color, Air Force Training Films, Eastern Film Exchange, 1356 Film Library Flight (APCS) (MATS), Marietta Air Force Station, Marietta, Pa.
9. *Oxygen-In-Flight Equipment*, TF 1-5038B, 30 min., 16mm sound color, same source as 8.
10. *The Physiology of Anoxia*, 30 min., 16mm sound, B&W, same source as 11.
11. *The Breath of Life*, 10 min., 16mm sound color, H. J. Polk, Oxygen Therapy Dept., Linde Air Prod. Div., U.C.&C., 30 E. 42nd St., New York 17, N. Y.
12. *Safe and Efficient Oxygen Therapy*, 20 min., 16mm sound color, avail. same source as 11.
13. *Nitrogen Inhalation Therapy*, 10 min., 16mm silent color, Dr. H. E. Himwich, Galesburg State Research Hospital, Galesburg, Ill.
14. *Solvey Chlorine Emergency Devices*, 16mm silent color, 40 min., Research Dept., Solvey Process Div., Allied Chem. & Dye Corp., Solvey, N. Y. or local Solvey sales branch off.
15. *Use of the Air-Chem Suit*, 16mm sound, 30 min. color, Cost Reduction Section, Chamber Works, Organic Chemicals Dept., E. I. DuPont deNemours & Co., Inc. (Penns Grove, N. J.) avail. both with magnetic sound tract & regular optical sound tract.
16. *Breathing Apparatus*, Fire Dept. Training Film, 16mm sound B&W, 30 min., Public Relations sect. Los Angeles Fire Dept., Los Angeles, Calif., also avail. as Navy Train. Film
17. *Breath of Life*, 16mm sound, color, 10 min., Scott Avia. Corp., Lancaster, N. Y.
18. *No. 2 Training Film*, 16 sound B&W, 20 min., Scott distributors.
19. *Damage Control, Oxygen Breathing Apparatus*, MN-6931A, 16mm sound, B&W, 22 min., Navy Train. Film, U. S. Naval Train. Aids Center, E. Coast, 207 W. 24th St., N. Y. 11, N. Y.
20. *Rescue Companies*, 16mm sound 30 min., by Warwick & Tompkin, Public Relations section, Los Angeles Fire Dept., Los Angeles, Calif.
21. *Nerve Gas Casualties & Their Treatment*, 16mm sound color, 30 min., State CD Offices, or thru the Federal CD Admin., Battle Creek, Mich. on Fed. contributions prog. or thru W. B. Jacques, E. R. Squibb & Co., 745-5th Ave., New York, N. Y.
22. *Gas Obstacle Course*, TF-14440, 16mm sound, B&W, 19 min., 1943 (Air Force) same source as 8.
23. *The Effects of Weather on the Travel of Smoke & Gas Clouds*, TF-1-4666, 16mm sound, B&W, 21 min., 1949, avail. same as 6.

A regular compressor and a standby compressor were provided on the air line. Over a week-end, both compressors were out of service, so bottled nitrogen was manifolded into the line by a temporary jumper connection to maintain instrument air pressure. An employee, aware of the circumstances, was told to wear a filter-type mask. By habit, however, he entered the area and was found dead several minutes later due to nitrogen inhalation in the air-line respirator he had worn instead of the filter-type mask.

Breathing air systems, using an approved compressor or tank system, should be closely supervised and used only for breathing. Employees whose work takes them out of contact (visual or audiable) with others should be closely supervised. Human error caused this fatality.

CARBON TETRACHLORIDE AGAIN

Bunker C oil leaks had sprayed oil over the walls and ceiling of a small boiler room. Fearing the fire hazard which might result from using kerosene on the electrical equipment, the plant engineer had four men use a bucket of carbon tetrachloride with a long-handled brush.

Respirators of the proper type were provided and worn, but due to a missing part and poor fitting on one mask, one of the men became ill and was hospitalized three weeks with typical carbon tetrachloride poisoning symptoms.

A properly adjusted respirator, a less toxic solvent (such as 1,1,1-trichloroethane), and ventilation—any combination of these measures would have prevented this injury. It was also noted that the injured man occasionally consumed alcoholic beverages—a contra-indicated action in solvent areas.

PHOSGENE

A chemist suffered a major injury when phosgene gas containing dissolved HCl escaped from a cylinder too fast for the capacity of the hood. The chemist was wearing a Type N universal canister mask, but he noticed that his eyes were irritated when he took the mask off moments later in the fresh air.

Two men who worked alongside him were wearing air-line respirators and did not smell phosgene nor notice any eye or throat irritation. The chemist was hospitalized for 10 days from a toxic exposure to phosgene fumes, and was absent from work for about one month. The two other men suffered no ill effects whatsoever.

NO RESPIRATORY PROTECTION

A chemist was decomposing a reaction mixture containing phosphorous oxychloride in a hood by pouring it over ice onto a four-liter beaker. While his back was turned, the reaction became violent and the mixture overflowed onto the hood floor. A small amount also spilled onto the laboratory floor, since he did not have a catchpan under the beaker.

He directed his laboratory assistant to leave the room promptly, but stayed behind to throw some ice on the spill on the floor and open windows. He re-entered the laboratory after 10 minutes, when the fumes had subsided considerably, and cleaned the spilled material off the floor. This required 10 minutes, during which period he inhaled some of the fumes, chiefly HCl. He did not use any respiratory protection, although it was available.

He did not notice any ill effects that day, other than eye and throat irritation, but he was hospitalized on the following day for bronchial and pulmonary congestion. He was in the hospital for four days.

* * *

A vertical catalyst bed was being rodded out to remove solids. Dust and fumes from the solids being discharged at the bottom of the reactor were sufficient to cause coughing and discomfort to the operator, although spot ventilation was being used at the top of the column.

The operator continued to work out his shift, but that night he had an attack of nausea and vomiting, accompanied by persistent coughing. Following a recurrence of the original attack, he was admitted to a hospital for four days.

An air line respirator was readily available, although the magnitude of the dust hazard was not fully appreciated at the time.

* * *

During the operation of a small scale reactor housed in a barricade, it was necessary to enter the barricaded area and withdraw condensate every half-hour. This removal consisted of opening a valve at the bottom of a condenser to check for and remove any unconverted by-products. In performing this operation it was necessary to discharge some vapors to insure complete withdrawal of the condensate.

The injured had been doing this during his shift without using the air-line respirator which was prescribed protection equipment for this operation. In addition to this exposure, he had entered the barricade during the early part of the shift to make minor repairs to a leaky blower.

The injured worked for several days with no apparent ill effects. While at home he developed a fever and shortness of breath which was subsequently diagnosed as acute bronchial asthma. He was home for three days.

In this case, the injured failed to obey written and verbal instructions to wear an air-line respirator, and the injured's shift leader failed to enforce this rule. Since then, all operators in this group have been reinstructed in the necessity for observing regulations regarding barricade entry, and have been informed that repeated violation of safety regulations may constitute grounds for dismissal.

WRONG TYPE MASK

An employee washing out a chlorine tank car passed out due to insufficient oxygen. A fellow employee put on a Type N universal canister gas mask and entered the car for rescue purposes. He, too, passed out and it was necessary to use self-contained breathing apparatus to rescue both. Fortunately, both men recovered.

* * *

Fire was located in a drying-storage room of steel construction, measuring 8 feet x 50 feet x 30 feet closed by an asbestos curtain at one end. There was no possibility of ventilating. The room was located on the sixth floor of a factory and contained a large quantity of "wood flour" (pulverized saw dust), used in casting ornaments, contained in 100# bags. Fire was started by an electric motor in the rear-most portion of the room.

The fire had smoldered for some time and this room was heavily loaded with smoke, and obviously a high CO and CO_2 content. Alarm was sounded when the heat finally built up enough to activate a sprinkler head, which transmitted an A. D. T. alarm. Since very little smoke was visible external to the drying room (which was held at approx. 150°F) the first firemen went in without any protection. They were quickly overcome.

Members of the rescue company followed closely behind using Type N universal canister masks. These functioned well on the sixth floor outside the drying room, but inside, one of these five men was overcome. The other four heeded the warning sign of "overbreathing" and retreated to fresh air before being overcome. These same men returned to the room after donning self-contained breathing apparatus. In all, 30 men were overcome in this multiple alarm fire—multiple only because all men from the first companies were overcome. All the firemen recovered.

NO RESPIRATORY PROTECTION

A chemist was preparing to use hydrogen sulfide for a determination and when the valve was opened, a leak developed because a washer did not seat properly.

Before the employee could close the valve, the hydrogen sulfide was ignited by the flame from a bunsen burner located in the same hood. In an attempt to close valve, the employee re-entered the room, without wearing protective equipment, was overcome, and struck his head on the edge of a bench as he fell to the floor. He was rescued by another employee who was wearing a demand self-contained breathing apparatus. He was hospitalized for three months and as a result of this incident lost his sense of smell.

ANOTHER SOLVENT INCIDENT

Two electricians, journeyman and apprentice, were working in a concrete pit—four by six foot top opening and standing on the bottom, the ground level was in the proximity of their eyes, nose and mouth. Repair of the small motor involved using a solvent an inhibited grade of 1,1,1-trichloroethane. Approximately 10 minutes after entering the pit, the one electrician appeared to be swaying, somewhat in a stupor and somewhat incoherent. A combination of lifting and pushing forced the man out of the pit. The other electrician used the ladder in leaving the pit.

A few minutes exposure to fresh air and the "overcome" electrician stood up and walked to the dispensary. Examination revealed him to be coherent and no signs of narcosis. He rested for about half an hour and returned to his job—by this time the job in the pit was completed.

A few pertinent facts are in order: solvent was not spilled on the floor of the pit, the "overcome" electrician had returned to work that morning after being off for several days due to a bronchial inflammation, and the other electrician never demonstrated or mentioned any ill effects.

INERT GAS IN TANK CAR

A tank cleaner entered a tank car (which had previously contained caustic soda) and started to wash it down with a hose with the bottom outlet open. After failing to reappear in a normal time, investigation revealed the man lying in the bottom of the car. Upon removal and attempts at resuscitation, it was determined that he had died as a result of weak alkali solution having been taken into the respiratory tract.

This is strong evidence that the inert gas used to unload the car was a byproduct of chemical operations, low in oxygen and could have contained carbon dioxide, carbon monoxide, nitrogen and other constituents. Upon checking the air oxygen and 2000 ppm of reducing gases which would commonly be reported as carbon monoxide.

Inasmuch as the official coroner's report stated that the man fell to the bottom of the car apparently due to heat exhaustion, there was no significant publicity concerning this incident. Corrective measures have been taken to avoid any recurrence.

TANK JOB CLAIMS LIFE

A maintenance mechanic lost his life, and his assistant narrowly escaped in tank incident.

Repair work had been scheduled inside the tank to begin after lunch, and two men assigned to the job. The mechanic decided to look over the job about 11:30 a.m. and went into the tank after sending his helper for certain supplies. The inert gas (which contained essentially nitrogen with small percentages of CO and CO_2) supply to the tank had not been shut off, since the mechanic had not informed anyone of his entry. The mechanic was quickly overcome.

His helper returned a few minutes later, shouted for help, then went into the tank to aid the first man who was unconscious. Before help arrived, the helper was also overcome, but both men were promptly removed to fresh air. The helper was successfully revived, but the mechanic could not be brought back to life.

Failure to follow established tank-entry procedures was the reason given for this fatality.

INERT GAS

Two men entered a kettle to repair an agitator, which is normally a two day job. On the first day nothing unusual happened. On the second day the men went into the kettle, worked for an hour, and came up for a coffee break. When they re-entered kettle, they began to feel weak. They were actually too weak to climb out of the manhole after 15 minutes, but finally crawled out. They came to as they stepped out into the air.

After investigation, it was discovered that one of the men had opened an inert gas line instead of an air line. Close to the top of the kettle was a section for a hose line to be piped to outside the building. The hose was only half-way down into the kettle. The inert gas was heavier than air, when they bent over to pick up tools, they would get inert gas until they eventually were made ill.

* * *

An engineer went down to inspect a kettle. He began to feel sick and came out. Upon investigation later they found the kettle had been "blown-out" with enert gas and did not follow through by removing the gas with proper air ventilation. (The engineer recovered immediately upon leaving the kettle)

* * *

A man went into a non-enameled kettle. The complete kettle was blanked off with exception of entrance. The kettle had been "blown-out" with inert gas. He was overcome. It was necessary to resuscitate the man quite a while before he recovered.

ILLUMINATING GAS IN TRENCH

Two men were working in a series of three by seven by seven foot trenches dug along a 75-foot length of a street. While tapping a high pressure illuminating gas main to install a jumper line into a low pressure main, a drill slipped and opened a valve in the tapping machine. Gas was released into the trench.

One man immediately left the trench, but the other was overcome. A laborer standing on the bank observed this, and immediately descended into the trench. He tied a rope around the waist of the unconscious man before he, too, was overcome. Meanwhile the foreman of the job put on an air-line respirator and went into the trench to close the valve. By the time the two unconscious men were brought to the surface by the foreman, one was sufficiently ill that inhalators could not revive the laborer even after a half-hour of resuscitation. The other unconscious man was revived.

The final score: three men treated at hospital for gas inhalation while one man was dead on arrival.

MASK IMPROPERLY ADJUSTED

A near fatality occurred when an operator went to tighten a chlorine line in the Waste Treatment Plant and the line disintegrated, thus exposing him to a full blast of chlorine. He had his face mask on, but due to maladjustment, he was hospitalized for twenty-four hours.

NARROW ESCAPE

A plant protection officer entered manhole to inspect water valves, collapsed after about three minutes, was unconscious for three and one-half hours, revived by artificial respiration. If there had not been another officer watching and a truck with a rope on it nearby, this would likely have been a fatality. A six inch artificial gas main 30 feet away had broken and the gas had seeped into the hold. No respirator was worn.

METHYL CHLORIDE

A leak developed in the methyl chloride compressor which was being used to transfer methyl chloride from the drier through a tank to storage. The leak was first discovered by a foreman who had heard the compressor pounding and who entered the area to investigate.

Two men inhaled excessive quantities of methyl chloride. An operator entered the area with a filter type respirator, but left when he detected methyl chloride through his respirator. Shortly afterward he was observed staggering and shouting outside. He was wearing a dust respirator. Both men were given oxygen and sent to the dispensary. Each of the men had a pale white complexion with a bright red overtone.

An examination of the compressor after the incident showed a crack along the base of the compressor housing. This was caused by liquid methyl chloride in the compressor.

The tank had been full for three days and had been frosted over, indicating the presence of liquid.

The incident was caused by attempting to transfer through the full tank.

OXYGEN WASN'T THERE!

During degreasing operations involving the use of Freon-113 (Trifluorotrichloroethane), it appears that one operator fell into the tank while attempting to disengage the basket. The other operator, without calling for help, immediately entered the tank to go to his assistance. Both men lost their lives due to suffocation in the oxygen-deficient atmosphere.

In fire safety, we have long hammered at the point of calling assistance before tackling any fire alone. The same point should be reiterated again and again in training personnel where the hazards of suffocation or entrapment exist. In many large chemical plants, personnel are often widely spaced and telephones are not always readily available at all locations. In practically all plants, however, a fire alarm box is located quite conveniently to all operating stations. Pulling the fire alarm box summons trained assistance and supervision in a matter of seconds. Where feasible, employees should be trained to use the fire alarm box instinctively to summon assistance before attempting on their own.

In any case where hazard evaluation discloses the possibility of suffocation or entrapment, personnel should be thoroughly trained to overcome the instinctive reaction to go immediately to the victim's assistance and to summon help first by the fastest available means.

HYDROGEN SULFIDE!

One man suffocated and two escaped death when exposed to H_2S.

This accident was caused when a precipitation tank overflowed and spilled acid-

bearing liquor on the floor. The liquor drained into a sump near the leach station and was then pumped into a reserve holding tank. Later, pipes from a reserve sulfide holding tank were disconnected, allowing the contents to drain on the floor.

The sulfide, during clean-up was washed into the sump and then pumped into the same reserved holding tank. An immediate reaction generated large quantities of H_2S, filling the area surrounding the tank. Unaware of this, three employees entered the area.

The first employee collapsed just as he passed the tank. The remaining two men walked a few feet further; one collapsed and the other reached a window and called for help. Other members arrived and gave artificial respiration while the ambulance was summoned. On arrival at the hospital, the first employee was pronounced dead.

Processing plants and laboratories in the program contain the elements to produce not only gases like H_2S but disastrous fires and explosions as well. These can occur from an uncontrolled chemical process reaction or, as in this case, from improper mixture of two chemicals. Infrequently, storage of incompatible chemicals can be separated physically for safety, which was done here afterward. More reliably, however, the employees should be instructed fully in the adverse effects of chemical combinations possible in the operation.

ALIPHATIC HYDROCARBONS

A pipe-fitter, aged 26, was gassed by aliphatic hydrocarbon fumes in a pit 20 feet by 10 feet by 6 feet deep in an oil refinery while he and another man were inserting a blank in a pipeline which had been shut off. Both men were wearing breathing apparatus supplies with air from a hand-pump, a Y piece being used to supply the two sets of apparatus from a single pump.

While working in the pit, the pipe fitter, who was apprehensive and difficult to reassure, was seen to remove his mask. The safety attendant, who, with the foreman, was watching from ground level, replaced the mask and assured him that it was working properly. When the joint was opened, some liquid escaped owing to residual pressure, and the pipefitter endeavored to come away, but was persuaded to return.

Later, when he again attempted to leave the pit, his airline caught on the bottom of the handrail and impeded his exit. This caused him to panic and he took off his mask. The foreman and the safety attendant running to his assistance, pulled him to safety as he collapsed. His workmate continued to work in the pit without any trouble.

After being given artificial respiration and an injection of coramine, the pipe-fitter was removed to hospital where he recovered. The apparatus which he had been wearing was subsequently found to be in good order, but it was unwise to compel him to work under circumstances of which he was obviously afraid.

AMMONIA

One afternoon, while the engine-room foreman of an ice-cream factory was standing near an oil separating unit, there was a report and ammonia liquid and gas issued from the sump. It was later found that the rubber seal between the sighting glass housing and the sump had "blown." The engine room was immediately evacuated, the foreman taking with him a canister respirator from a rack.

The fire brigade was called and warning given to all employees in the factory. As the concentration of gas was too high for the canister respirator, the foreman was unable to re-enter the engine room to reach the ammonia isolating valve. The gas spread rapidly through the factory area and many of the 100 employees, most of them women, were affected.

There was some degree of panic and some women were rescued from the canteen by firemen. Sixteen women employees and two firemen were admitted to hospital but only three persons were detained overnight. Seven of the women were sufficiently affected to require notification. Occupants of houses within a radius of 50 yards of the factory were also affected. The firm had already been advised to provide self-contained breathing apparatus and they were again advised to keep apparatus of this kind outside the engine room as well as the canister respirators.

TWO FATAL ACCIDENTS WITH BENZENE VAPOR

In one accident a laborer, aged 23, was fatally gassed and an ambulance room attendant and a fireman were also gassed while attempting to rescue him. The foreman had given instructions for four of a series of 16 benzol tanks to be cleaned after they had been steamed out, tested and declared free from gas. While the laborer with his workmate was preparing to start work on a tank which had been steamed out, he enquired about another tank which had not been steamed and was told they were not instructed to clean that tank.

When the workmate returned after fetching a respirator and a lifeline he saw that a ladder and hose pipe had been lowered into the unsteamed tank and that the laborer had unaccountably entered without a lifeline or respirator. After shouting for help he attempted to enter the tank, at the bottom of which there was about 12 inches of liquid, but was forced to come out because of the fumes.

During the rescue operations a fireman, who in his hurry entered the tank without a mask, was gassed, as was the ambulance room attendant who had donned a fresh-air mask and a lifeline but dislodged his face mask while in the tanks and lost consciousness. The laborer was given artificial respiration and oxygen but failed to recover.

The other fatal case was a benzol house attendant aged 47, who was found lying prone and unconscious on the floor, which was saturated with benzol. He was immediately dragged into the open air and artificial respiration was started at once, this being continued with the aid of a rocking stretcher, oxygen also being given. Despite this treatment, he was found to be dead on arrival in hospital.

When the distillation temperature had been reached it was the attendant's duty to reduce the steam sufficiently to allow distillation to proceed in the normal manner. If this was not done, the crude motor spirit would boil rapidly and would eventually overflow on to the floor. After the accident, the plant was found to be in order, and it was assumed that the accident was due to the use of too much steam.

CARBON DISULPHIDE

Following the discovery of a leak at a rotary valve on an electric arc furnace used for the preparation of carbon bisulphide, the manager decided that breathing apparatus was necessary while repairs were being effected and he issued a permit-to-work certificate accordingly. Without being instructed to do so, a laborer climbed up a ladder to the top of the furnace.

He was not wearing breathing apparatus and, being overcome by escaping gas, he fell to the ground about 10 feet below. After recovering consciousness he was able to walk to the ambulance room.

FOUR CASES OF CHLORINE POISONING

In four cases in which only slight exposure to chorine gas occurred, the effects were stated to have been aggravated by the existence of a previous chest condition. One of these cases was a plant operator who inhaled a whiff of chlorine when adding hydrochloric acid to a reaction vessel under negative pressure, after having put in a slurry of sodium chlorite. The doctor who treated him in hospital considered that the inhalation of a small amount of chlorine had "triggered off" an acute attack in a man subject to asthma.

A process operator, aged 32, whose exposure to chlorine from a leak in a plant for the chlorination of dimethylacetal was slight, suffered from cough, breathlessness and pain in the chest. The chest physician, who found a lesion in the left upper zone and kept him under observation at rest at home to assess the activity of the tuberculosis lesion, thought the infection was a factor greater than chlorine exposure in this case. A night watchman, aged 58, said to have had a previous chest condition, suffered from a sensation of choking, cough and respiratory tightness following a slight leak of chlorine from a control valve.

The fourth case in this group was a fitter, aged 57, who, with other men was cleaning an air-cooler plant from which some water containing four p.p.m. of chlorine was leaking. The other men were unaffected by the small amount of chlorine, but the fitter, who was stated to be a heavy smoker, which caused him to cough continuously, became unconscious and suffered from lachrymation and cough.

IMPROPER VENTILATION

A laboratory technician was cleaning a vessel with a mixture of hydrochloric and nitric acids. The work was being done at a sink in front of an open window. How-

ever, there was not sufficient ventilation to prevent the worker from inhaling fumes to make him sick to his stomach. The proper type Canister Respirator was available on the lower floor but the person was not familiar with its use.

NO RESPIRATORY PROTECTION

Several specific instances are known where personnel should have worn protective equipment and did not although it was available and the specific personnel were familiar with use. For the most part these instances involved professional grade personnel of the "difficult personality" category engaged in Research and Development. Injuries were in all of these cases from volatile vesicants, and though injuries were serious enough to have resulted in lost time, there was, in fact, no lost time.

In one instance the employee was convinced to use recommended safety procedures by a combination of greatly increased supervisory pressure and alarmist industrial hygiene propaganda. In another instance such stresses produced no apparent effect.

RESPIRATORY PROBLEMS

We have had people injured while they were wearing respiratory equipment and also we have them injured by not wearing them even though they were available. Some of the latter are the "Smoke Eater" type who think they can get along without the stand-by equipment.

A basic problem with any respiratory protective equipment is knowing the limitations of a particular device. Actually, the popularity of the self-contained breathing apparatus can be attributed to the fact that *its limitations are far less than any of those that depend on chemicals for air purification.* In addition, the operator does not have to be concerned in knowing whether *there is sufficient oxygen in the air.*

In one particular process we were confronted with a number of stages in which reactants were more or less open to the atmosphere. In spite of a number of spot ventilators there was a prevalence of noxious odors, most free chlorine.

Chlorine is considered here for its nuisance and noxious characteristics rather than for its toxicity. Even small amounts have a definite odor and they usually cause an operator to get out of the contaminated area. This latter incidently provided cause for an additional problem and usually ended in a lost time injury. Many times the individual would go outside for fresh air where it was too cold for his condition. He would catch cold and would come near to developing into pneumonia.

During the time this particular process was being developed, operators got used to the chlorine type odor. At this same time the self-contained breathing apparatus was not the popular item it is today. A chemical cartridge respirator was what they generally carried draped about their neck. Probably many times the trouble was located and the mask removed after the contaminated area was under control without the operators' having an exposure.

A number of times though, the capacity of the cartridge was unknowingly depleted by prior uses. Then again, the general contamination would instill in the operator the idea that his mask was O.K. when it really wasn't. The operator would then prolong his trip beyond limits and have an exposure. To sum up then an operator:

a. would not know the conditions of his mask because he was generally conditioned to the contaminant.

b. would not know the remaining capacity of the mask.

c. would realize that the mask was not working but would remain in the area thinking he could get by or hold his breath a moment longer in order to complete the job.

The second part of the problem refers to the people that do not use the equipment that is available. These are the "Smoke Eaters" or the ones that think they can chance it. Even today with the self-contained breathing apparatus available, this practice continues. I witnessed an entry to a contaminated area (FH fog).

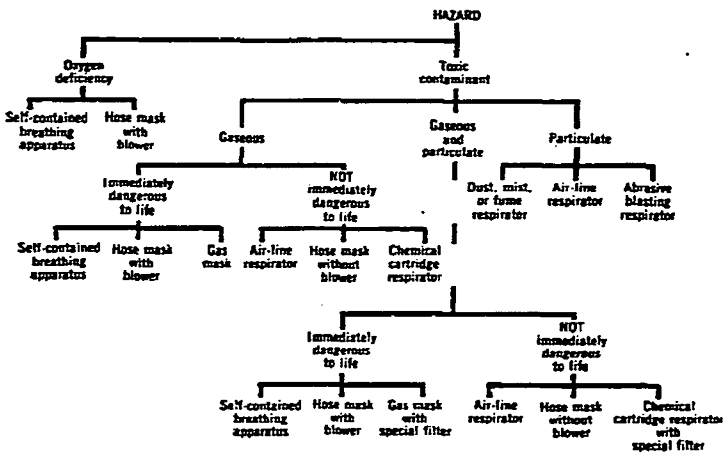
This particular entry was made for no good reason at all. Two men were putting their self-contained breathing apparatus on and this fellow decided to go in with a handkerchief over his nose. It turned out that the men wearing self-contained breathing apparatus made the necessary emergency shutdown, ventilators soon decontaminated the area, and normal entry could be made.

SOAP DUST

Our operation is essentially a soap manufacturing plant and the air in our factory is frequently contaminated with soap dust from detergents and dust arising from fine woodflour and cornmeal. We issue our employees a dust mask (not Bureau of Mines approved). The filter element consists of a honeycomb construction of whipped foam latex.

This device does a modest job of filtering, however, we have never been completely satisfied. Despite the fact that we have issued masks to all personnel about half of our personnel prefer to use an ordinary handkerchief wrapped about their face which appears to do a satisfactory job without the unpleasantness of the dust mask.▲

OUTLINE FOR SELECTING RESPIRATORY PROTECTIVE DEVICES



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LABORATORY AND PILOT PLANT SAFETY

(A Symposium)

LABORATORY BARRICADING OF HIGH PRESSURE AND EXTRA HAZARDOUS REACTIONS

by GODFREY J. MOLL

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Safety engineers are often called on to formulate or approve plans for laboratories in which high pressure or extra hazardous reactions will be safely operated. In these designs the protective shield or barricade is the only fixed piece of safety equipment which will remain operable 100 per cent of the time. Equipment, instrumentation, and safety devices are all apt to fail at any time regardless of maintenance and inspection. The judgement of the best-trained operating personnel need only be wrong once. The barricade may be considered as the primary safety device.

High pressure and extra hazardous research projects are being carried out in unbarricaded laboratories in many universities and at some industrial research centers in the United States. Workers at these installations will point with pride at their perfect safety record, but tomorrow might yield their first and last accident. The management of CIBA Pharmaceutical Products Inc. of Summit, N. J., has recognized the risk involved in not barricading high pressure reactions.

Our high pressure laboratory was constructed in a built-up area presenting the problem of not only protecting the operating personnel but also the personnel of adjacent buildings from the effects of missiles and shock waves. A suitable barricade was constructed of 16-inch reinforced concrete with a reflector wall of similar construction eight feet from the frangible wall. Further protection was provided by hanging one-half inch wire rope blast mats between the building and the reflector wall, which would operate on the ballistic pendulum theory in stopping missiles and dissipating shock waves. This is but one approach to the problem of barricading.

The question often arises as to what should be considered hazardous enough to warrant the expense of barricading. Some authors feel that when equipment is installed to handle inflammable materials at pressures greater than 500 psi the use of some form of barricade should be considered. When research at high gas pressures or work on known explosives is conducted the protection of personnel and other facilities with an adequate barricade must be considered.

In small-scale flow experiments where the amount of material in process is small, it is common to use pressures as high as several thousand pounds without special barricades. Once it has been decided to build a barricade there are still many questions to be answered. The two most important as far as the barricade is concerned are the materials of construction and their thickness.

MUST KNOW MISSILE

If we knew the velocity, weight and shape of the missile and the maximum force expected from an explosion, we could design a barricade using a minimum wall thickness. Barricades must be designed to prevent penetration by large missiles at low velocity, such as reactor heads, and also small missiles at high velocity, such as tubing, nuts or other small fittings. Penetration is dependent upon the velocity of the missile at impact, the physical properties of the missile, and the characteristic of the material used to construct the barrier.

The speed of sound has been suggested as a velocity, as most objects when propelled through air decrease in velocity to the speed of sound. If missiles of higher velocity are expected, the modified Petry equation for penetration can still be used to calculate a