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, tetraethyllead, 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