SELF CONTAINED BREATHING APPARATUS

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Respiratory Protection

The lungs and respiratory tract are more vulnerable to injury than any other body part of a firefighter. Therefore, the protective breathing equipment should be considered the most important piece of safety equipment worn by firefighters. Special attention must be devoted to its use and maintenance. Failure to properly use this equipment may not only injure and incapacitate the wearer; it could also jeopardize the safety of civilians and fellow firefighters.

It is the policy of North Zone Fire Departments that all personnel working in Immediately Dangerous to Life and Health (IDLH) atmospheres will wear Self-Contained Breathing Apparatus (SCBA). Hazardous atmospheres include incidents where one or more of the following hazardous conditions are present:

a. Fire Environments e.g.
   - Elevated temperatures
   - Toxic gases
   - Smoke
   - High likelihood of flashover
   - Overhaul or salvage operations

b. Deficiency in oxygen

c. Known or suspected Hazardous Materials Incidents.

d. Confined spaces

Hazardous atmospheres are not limited to enclosed spaces but may include vehicle and dumpster fires. A dumpster fire behind a carpet company requires the same respiratory protection as a two-bedroom apartment fire. In addition, the breathing apparatus will also protect the face from burns and flying debris. Therefore, no firefighter shall be permitted to enter an IDLH without wearing a Self-Contained Breathing Apparatus (SCBA). Additionally, users of SCBA's entering such situations shall work in teams of two or more and remain in visual or voice contact with one another at all times. Radio communication does not satisfy OSHA or the department's communication requirement for entry team communication. The team entering the work environment shall maintain contact with the Rapid Intervention Crew (RIC) visually or by radio. The RIC would, in an emergency, be capable of performing the necessary rescue operation of the entry team.

RESPIRATORY HAZARDS

Oxygen Deficiency

The combustion process consumes oxygen while producing toxic gases that either physically displace oxygen or dilute its concentration. Normal air contains approximately 21% oxygen. At concentrations below 17%, bodily effects include increased respiratory rate and decreased coordination. The effects of oxygen concentrations below 12% include dizziness, headache, and rapid fatigue. Unconsciousness can result from exposure to oxygen concentrations below 9%, and death occurs within a few minutes from respiratory failure at concentrations below 6%.

Elevated Temperatures

Exposure to heated air can damage the respiratory tract, and if the air is moist, the damage can be much worse. Excessive heat, temperatures exceeding 120° F (49° C), taken quickly enough into the lungs can cause a serious decrease in blood pressure and failure of the circulatory system. Inhaling heated gases can cause edema (fluid collection) in the lungs, which can cause death from asphyxiation. The tissue damage from inhaling hot air is not immediately reversible by introducing fresh, cool air.

Smoke

Most of the smoke at a fire is a suspension of small particles of carbon and tar, but there is also some ordinary dust floating in a combination of heated gases. The particles provide a means for the condensation of some of the gaseous products of combustion, especially aldehydes and organic acids formed from carbon. Some of the suspended particles in smoke are merely irritating, but others may be lethal. The size of the particle will determine how deeply into the unprotected lungs they will be inhaled.

Fire-Related Toxic Gases

The firefighter should remember that a fire means exposure to a combination of the irritants and toxicants that cannot be predicted accurately before hand. In fact, the combination can have a synergistic effect in which the combined effect of two or more substances is more toxic or more irritating than the total effect would be if each were inhaled separately.

Inhaled toxic gases may have several harmful effects on the human body. Some of the gases have the potential to cause disease of the lung tissue and impair its function. Other gases pass into the bloodstream and to other parts of the body and impair the oxygen-carrying capacity of the red blood cells. The particular toxic gases given off at a fire vary according to four factors: the nature of the combustible, the rate of heating, the temperature of the evolved gases, and the oxygen concentration.

Carbon Monoxide

More fire deaths occur from carbon monoxide poisoning than from any of the other toxic products of combustion. Carbon monoxide (CO) is a colorless, odorless gas with a vapor density of .97. CO is present at every fire, especially those where poor ventilation and inefficient burning occur. A rule of thumb, although subject to much variation, is that darker smoke means higher carbon monoxide levels. Black smoke is high in particulate carbon and carbon monoxide because of incomplete combustion.

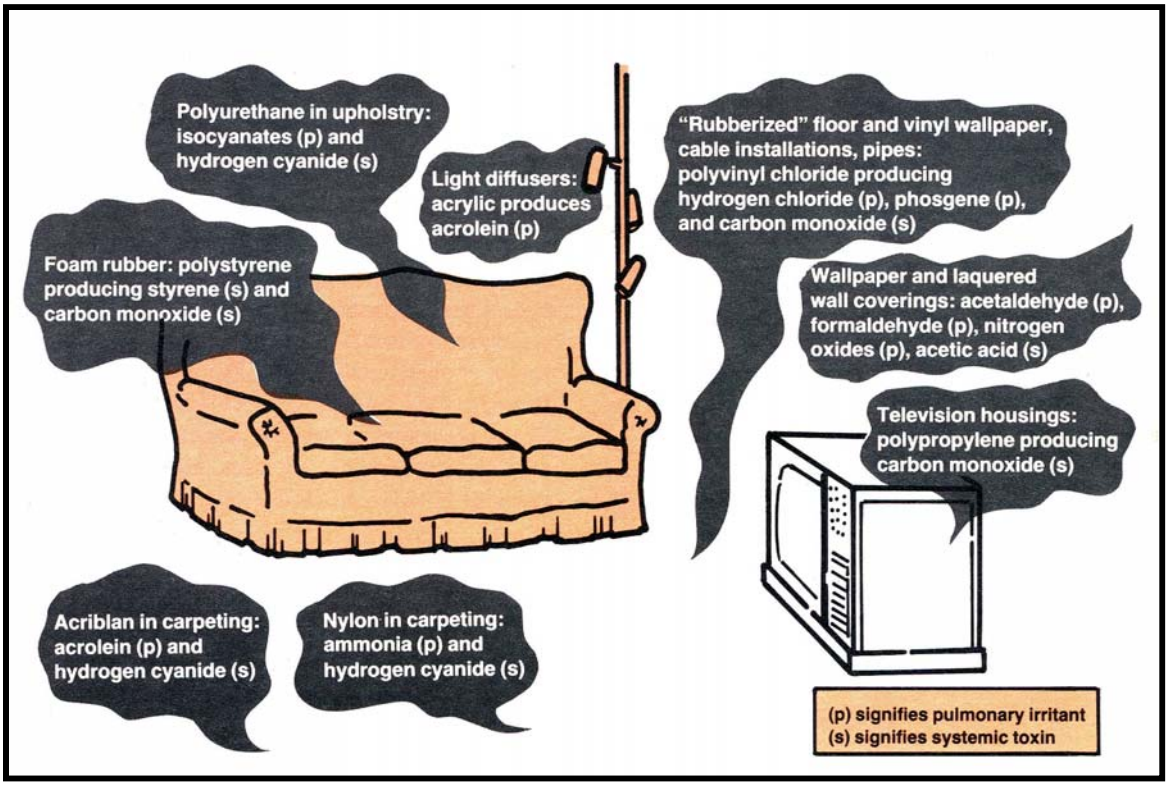

Figure 1

The blood's hemoglobin combines with and carries oxygen in a loose chemical combination called oxyhemoglobin. The most significant characteristic of carbon monoxide with oxyhemoglobin is that it combines with the blood's hemoglobin so readily that the available oxygen is excluded, forming carboxyhemoglobin (COH_b). In fact, carbon monoxide combines with hemoglobin about 200 times more readily than does oxygen. The carbon monoxide does not act on the body, but inhibits oxygen absorption in the blood and leads to eventual hypoxia of the brain and tissues, followed by death if the process is not reversed.

Concentrations of carbon monoxide in air above five hundredths of one percent (0.05 percent) can be dangerous. When the level is more than one percent, there is no sensory warning in time to allow escape. At lower levels, there is headache and dizziness before incapacitation, so sufficient warning is possible. The characteristic cherry red skin color of carbon monoxide poisoning is not always a reliable sign, particularly in long exposures to low concentrations.

Measurements of carbon monoxide concentrations in air are not the best way to predict rapid physiological effects, because the actual reaction is from the concentration of carboxyhemoglobin in the blood, causing oxygen starvation. High oxygen users such as the heart and brain are damaged early. The concentration of carbon monoxide within the blood will be greater when the concentration in air is greater. An individual's general physical condition, age, degree of physical activity, and length of exposure all affect the actual carboxyhemoglobin level in the blood.

Experiments have provided some comparison relating air and blood concentrations to carbon monoxide. A one- percent concentration of carbon monoxide in a room will cause a 50% level of carboxyhemoglobin in the bloodstream in two and one-half to seven minutes. A five- percent concentration can elevate the carboxyhemoglobin level to 50% in only 30 to 90 seconds. Because the newly formed carboxyhemoglobin may be traveling through the body, a person previously exposed to a high level of carbon monoxide may react later in a safer atmosphere. A person so exposed should not be allowed to use breathing apparatus or resume fire control activities until the danger of toxic reaction has passed. Even with protection a toxic condition could be endangering consciousness.

A hardworking firefighter may be incapacitated by a 1-% concentration of carbon monoxide. Normal breathing only slowly eliminates the stable combination of carbon monoxide with the blood. Administering pure oxygen is the most important element in first aid care. After an uneventful convalescence from a severe exposure, signs of nerve or brain injury may appear anytime within three weeks. Again, this is a reason why an overcome firefighter who quickly revives still should not be allowed to reenter a smoky atmosphere.

Carbon monoxide is measured in parts-per-million (PPM). The Industrial Scientific gas monitor carried on Truck 1 will be utilized to measure CO concentrations. An SCBA shall be worn when the monitor detects levels of CO at or above 25 PPM. The monitor will display both visual and audible warning signals when CO concentrations exceed the safe level of 25 PPM.

Hydrogen Chloride

Hydrogen chloride (HCl) is colorless but is easily detected by its pungent odor and intense irritation of the eyes and respiratory tract. Although not a general poison, hydrogen chloride causes swelling and obstruction of the upper respiratory tract. Breathing is labored and suffocation can result. This gas is more commonly present in fires because of the increase in plastics such as polyvinyl chloride (PVC) containing chlorine.

In addition to the usual presence of plastics in homes, firefighters can expect to encounter plastics containing chlorine in drug, toy, and general merchandise stores. The overhaul stage is especially dangerous because breathing apparatus is often removed, and toxic fumes linger in a room. Heated concrete can remain hot enough to decompose the plastics in telephone or electrical cables and release more hydrogen chloride.

The other gases given off when those plastics are heated are carbon monoxide and carbon dioxide. One investigator studying firefighters exposed to hydrogen chloride began his survey after a relatively small, smoky fire in an office photocopier killed one firefighter and sent others to the hospital. He discovered that hydrogen chloride acts as an irritant to the heart muscle and causes irregular rhythms.

Hydrogen Cyanide

Hydrogen cyanide (HCN) interferes with respiration at the cellular and tissue level. The proper exchange of oxygen and carbon dioxide is hampered, so hydrogen cyanide is classified as a chemical asphyxiate. The gas inhibits the enzymes by which the tissues take up and use oxygen. Hydrogen cyanide also may be absorbed through the skin.

Materials that give off hydrogen cyanide include wool, nylon, polyurethane foam, rubber, and paper. Unusually hazardous atmospheres might be found at fires in clothing stores or rug shops. Exposure to this colorless gas that has a noticeable almond odor might cause gasping respirations, muscle spasms, and increased heart rate, possibly up to 100 beats per minute. Collapse is often sudden. An atmosphere containing 135 parts per million (.0135 percent) is fatal within 30 minutes; a concentration of 270 PPM is fatal. Nearly all materials tested in an experiment with aircraft interior materials yielded some hydrogen cyanide.

Businesses with vermin problems sometimes use hydrogen cyanide as a fumigant. Owners should be instructed to notify the fire department whenever the building is being fumigated.

Cyanide asphyxia is one of the most rapid killers at a fire. Death is quick and painless, noted authorities say.

Carbon Dioxide

Carbon dioxide (CO_2) must be considered because it is an end product of the complete combustion of carboniferous materials. Carbon dioxide is nonflammable, colorless, and odorless. Freeburning fires should generally form more carbon dioxide than do smoldering fires. Normally its presence in air and its exchange from the bloodstream into the lungs stimulates the respiratory center of the brain. Air normally contains about 0.03% carbon dioxide. At a 5% concentration in air there is a marked increase in respiration, along with headache, dizziness, sweating, and mental excitement. Concentrations of 10 to 12% cause death within a few minutes from paralysis of the brain's respiratory center. Unfortunately, increased breathing increases the inhalation of other toxic gases. As the gas increases, the initially stimulated breathing rate becomes depressed before total paralysis takes place.

Firefighters should anticipate high carbon dioxide levels when a carbon dioxide total-flooding extinguishing system has been activated. These systems are designed to extinguish a fire by excluding the oxygen, and they will have the same effect on a firefighter. According to the American Conference of Industrial Hygienists, exposures for even a short time to carbon dioxide concentrations greater than 15,000 PPM should be avoided.

Nitrogen Oxides

There are two dangerous oxides of nitrogen: nitrogen dioxide and nitric oxide. Nitrogen dioxide is the most significant because nitric oxide readily converts to nitrogen dioxide in the presence of oxygen and moisture. Nitrogen dioxide is a pulmonary irritant that has a reddish brown color. When inhaled in sufficient concentrations it causes pulmonary edema that block the body's natural respiration processes and leads to death by suffocation.

Additionally, all oxides of nitrogen are soluble in water and react in the presence of oxygen to form nitric and nitrous acids. These acids are neutralized by the alkalis in the body tissues and form nitrites and nitrates. These substances chemically attach to the blood and can lead to collapse and coma. Nitrates and nitrites can also cause arterial dilation, variation in blood pressure, headaches, and dizziness. The effects of nitrites and nitrates are secondary to the irritant effects of nitrogen dioxide but can become important under certain circumstances and cause delayed physical reactions.

Nitrogen dioxide is an insidious gas because its irritating effects in the nose and throat can be tolerated even though a lethal dose is being inhaled. Therefore, its hazardous effects from its pulmonary irritation action or chemical reaction may not become apparent for several hours after exposure.

Phosgene

Phosgene ($COCl_2$) is a colorless, tasteless gas with a disagreeable odor. It may be produced when refrigerants, such as freon, contact flame. It is a strong lung irritant, the full poisonous effect of which is not evident for several hours after exposure. The musty-hay odor of phosgene is perceptible at 6 PPM, although lesser amounts cause coughing and eye irritation.

Twenty-five PPM is deadly. When phosgene contacts water it decomposes into hydrochloric acid. Since the lungs and bronchial tubes are always moist, phosgene gas will form hydrochloric acid in the lungs when inhaled.

TOXIC ATMOSPHERES NOT ASSOCIATED WITH FIRE

Hazardous atmospheres can be found in numerous situations in which fire is not involved. Many industrial processes use extremely dangerous chemicals to make ordinary items. For example, quantities of carbon dioxide would be stored at a facility where wood alcohol, ethylene, dry ice, or carbonated soft drinks are manufactured. Any other specific chemical could be traced to numerous wide-ranging common products.

Many refrigerants are toxic and may be accidentally released, causing a rescue situation to which firefighters may be called. Ammonia and sulfur dioxide are two dangerous refrigerants that irritate the respiratory tract and eyes. Sulfur dioxide reacts with moisture in the lungs to form sulfuric acid. Other gases also form strong acids or alkalis on the delicate surfaces of the alveoli.

Chlorine gas leaks obviously can be encountered at manufacturing plants or at swimming pools. At either place incapacitating concentrations of chlorine can be found. Chlorine is also used in manufacturing plastics, foam, rubber, and synthetic textiles, and is commonly found at water and sewage treatment plants.

Sometimes the leak is not at the manufacturing plant but during transportation of the chemical. Train derailments have resulted in container failures, exposing the public to toxic chemicals and gases. The large quantities involved can travel long distances.

Rescues in sewers, caves, trenches, storage tanks, tank cars, bins, silos, manholes, pits, and other confined places require the use of self-contained breathing apparatus because some toxic gas is usually present or there is an oxygen deficiency to cause a rescue need in the first place. Harmful gases in large tanks during cleaning or repairs have also overcome workers. Unfortunately, personnel attempting a rescue while unprotected often have also been overcome. In addition, the atmosphere in many of these areas is oxygen deficient and will not support life even though there may be no toxic gas.

The smallest town, even without a chemical processing plant or without any manufacturing plant using dangerous chemicals, is susceptible to hazardous conditions from accidents involving dangerous chemicals in transit by rail or truck. Many of the chemicals are especially damaging when inhaled. The need to properly use self-contained breathing apparatus is just as important in these situations even when there is no fire.

Breathing Apparatus History

One of the earliest recorded respirators for fire fighting was developed and tested in France in 1825. It was known as “Apparatus Aldini”, a thick mask of asbestos worn over the head trapped a small amount of air for breathing. Another mask made of woven iron was placed over the asbestos mask for protection. Hoods, known as “smoke respirators”, placed over the head were also being developed at the same time.

For years the fire service has adopted various types of breathing apparatus (BAs). Filter canister BAs developed in the late 1800s used materials such as activated charcoal and water to filter out certain gases and particulate matter. Self-contained, closed circuit BAs develop in the early 1900s used exhaled air to generate oxygen. The system was “closed” because it did not vent the users exhaled air to the outside atmosphere. Neither filter canister nor closed circuit BAs are currently approved for fire department use.

A third type of BA, the open circuit, is in use today. This type of BA uses an external air supply and exhausts exhaled air to the outside atmosphere. Scott Aviation began development of an SCBA toward the end of World War II based on their experience in aircrews operating at extreme altitudes. There are two types of open circuit Bas, demand and pressure-demand. Demand units provide air only with each inhalation. Pressure-demand, now referred to as positive pressure, units provide a slight positive pressure to the mask at all times, in addition to supplying air on inhalation. This slight positive pressure helps keep contaminates out of the mask. Supplied Air Respirators and SCBAs are the only respirators approved by Occupational Safety and Health Administration for fire service use in an Immediately Dangerous to Life or Health (IDLH) atmosphere. Even at incidents where they are not required, it may still be beneficial to use an SCBA.

All personnel shall understand how to operate their fire department’s SCBA’s. The following topics that the wearer must be familiar with include ; donning and doffing the SCBA, emergency operations, maintenance, testing procedures, cleaning procedures, component specifications, proper operation of air compressors, as well as the proper application and maintenance of the Personal Alarm Safety System (PASS) device.