## TABLE 1

### TYPICAL CONFINED SPACES

Barges
Boilers
Caissons
Caves
Cisterns
Closed tanks
Degreasers
Digestors
Diked areas
Equipment housings
Floating roof-storage tanks
Furnaces
Grain elevators
Hoppers
Kilns and similar structures
Manholes
Open-topped spaces more than 4 feet deep
Open-topped tanks
Ovens
Pipelines and similar structures
Pits
Pumping or lift stations
Railroad tank cars
Septic tanks
Sewers
Shafts
Ships' holds
Silos
Stacks
Steam condensers
Storage bins
Storm drains
Tank trailers
Tanklike compartments
Trenches
Tubs
Tunnels (subway, vehicle)
Underground utility vaults
Vats
Ventilation/exhaust ducts
Vessels

## TABLE 2

### HAZARDS IN CONFINED SPACES

- Bad atmospheres
- Electrical devices (may cause electrocution)
- Environmental conditions (excessive heat, cold, noise, dust or vibration)
- Excessive depths, heights, widths and lengths
- Falling objects
- Harmful contents/materials (germs, toxic substances, bacteria, radiation, steam, spiders and snakes)
- Lack of effective communication
- Limited egress/entry
- Limited interior workspace
- Limited visibility
- Mechanical equipment (may cause entrapment)
- Personnel failures (heart attacks, heat exhaustion, claustrophobia)
- Protruding or sharp objects
- Unsecured lids/covers
- Unstable or loose material (may cause engulfment)
- Wet/slippery surfaces

year in relation to occupational confined space incidents.[1]

One reason for the high incidence of accidents and deaths is that confined spaces do not always give the outward appearance of being a major threat to workers or rescuers who enter them. In fact, the National Institute for Occupational Safety and Health (NIOSH) has found that approximately 60 percent of all fatalities associated with confined spaces involve would-be rescuers.[4] And most such incidents occur because workers or rescuers either are unaware of confined space hazards or simply neglect to follow established safety procedures.[3] This indicates that untrained or poorly trained rescuers constitute an especially important group at risk.[5]

### Atmospheric Hazards

Although there are many hazards associated with entering and working in confined spaces, the major cause of morbidity and mortality in confined space entry is entering a space that has a bad atmosphere (see Table 2).[4] In fact, atmospheric hazards account for approximately two-thirds of all deaths and injuries in confined spaces.[6]

OSHA classifies atmospheric hazards as being either asphyxiating, flammable/explosive or toxic according to their differing reactions and effects. It is important to point out, however, that some chemical substances present multiple atmospheric hazards depending on their concentration.

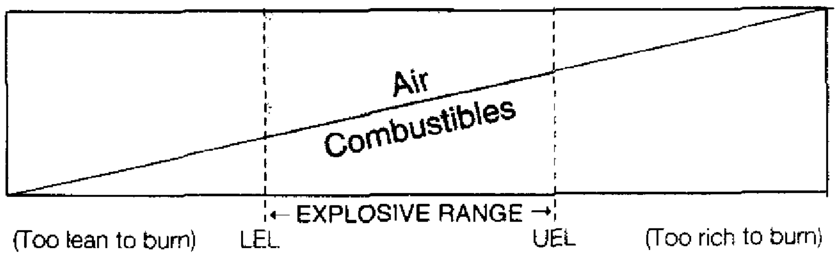
Methane, for example, is an odorless, non-toxic substance that is harmless at some concentrations. In larger concentrations, however, it can displace all or part of the atmosphere in a confined space. With only 10-percent displacement, methane produces an atmosphere that is adequate for respiration but that can explode violently. With 90-percent displacement, methane will not burn or explode, but it will asphyxiate an unprotected person, such as the two victims in the opening scenario, in approximately five minutes.[5]

*Asphyxiating atmosphere*—Asphyxiation is the leading cause of death in confined spaces.[6] Asphyxia is a condition in which respiratory function is severely impaired or suspended because of interference with the body's pulmonary and cellular respiration. An asphyxiant is any substance that can cause asphyxia by its action either on the body or in the breathing atmosphere.[7]

Asphyxiants are categorized as being either simple or systemic. Simple asphyxiants are gases or vapors that can displace available oxygen

FIGURE 1

**EXPLOSIVE RANGE OF SUBSTANCES IN AIR**




from a breathing atmosphere, usually in an enclosed space. Propane, methane, hydrogen and helium are a few examples of simple asphyxiants.

In contrast, a systemic asphyxiant exerts its effects if it is absorbed into the body either by ingestion or inhalation or through the skin. Systemic asphyxiants either inhibit cellular oxygen utilization—such as occurs with cyanide, cyanogens and hydrogen sulfide—or decrease the oxygen-transporting capability of the blood—as seen with methemoglobin inducers and carbon monoxide.[7]

OSHA uses the term "asphyxiating atmosphere" when referring to an atmosphere that contains less than 19.5 percent oxygen, a concentration that is insufficient to supply a person's respiratory needs when performing physical labor. Such atmospheres contain no toxic materials and are sometimes referred to as oxygen-deficient atmospheres.[5]

A confined space can become oxygen-deficient when oxygen is consumed or displaced. Oxygen consumption often results from work that involves any burning, such as welding, cutting, heating and brazing. This can also involve natural reactions, such as *fermentation* and decomposition of organic materials. Carbon dioxide, a byproduct of fermentation, is often encountered in industries that specialize in brewing of waste-water.[8]

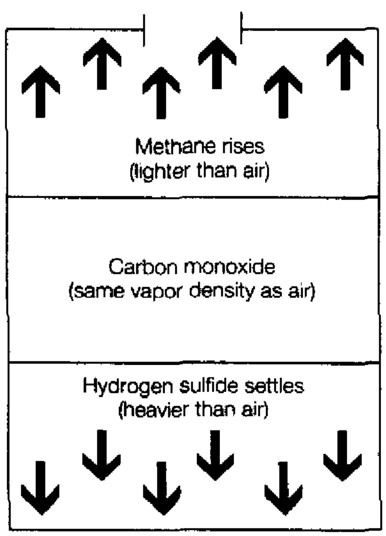
Oxygen consumption can also occur when too many workers are inside a confined space that has inadequate fresh-air ventilation. Consumption also occurs when oxygen is consumed by a chemical reaction, such as rusting, inside the confined space. Oxygen also may be absorbed by the confined space or by materials stored in the space, such as carbon/charcoal. Damp activated carbon absorbs oxygen and has been known to decrease the oxygen level from 21 percent to 4 percent in a closed vessel.[9]

Oxygen displacement results when other gases, such as argon, nitrogen, carbon monoxide or hydrogen sulfide, which may result from the chemical reaction, are present in concentrations that either change the concentration of oxygen or completely displace it. Carbon dioxide, which exists naturally in sewers, storage bins, wells, tunnels, wine vats and grain elevators, can also displace oxygen or change its concentration. Aside from the natural development of these gases or their use in the chemical process, certain gases are also used as *inerting* agents to displace flammable substances and retard *pyrophoric* reactions.

Although these gases are frequently referred to as non-toxic and inert, they are responsible for many deaths in confined space incidents. Since they are colorless and odorless, their displacement of oxygen poses an immediate threat to health unless appropriate oxygen measurements and ventilation are adequately performed prior to entering the space.[9]

FIGURE 2

**VAPOR DESTINY AND GAS MOVEMENT**




## GLOSSARY

**Desorption**—the removal of an absorbed substance from a space.

**Fermentation**—any of a group of chemical reactions induced by living or non-living ferments that split complex organic compounds into relative simple substances.

**Hemoglobin**—an iron-containing compound found within red blood cells. It is responsible for the transport and delivery of oxygen to the blood cells.

**Hypoxic**—relating to a state in which insufficient oxygen is available to meet the requirements of the cells.

**Inerting**—the replacement of one gas or substance with another.

**Olfactory**—referring to the sense of smell.

**Pyrophoric**—spontaneously igniting in air.

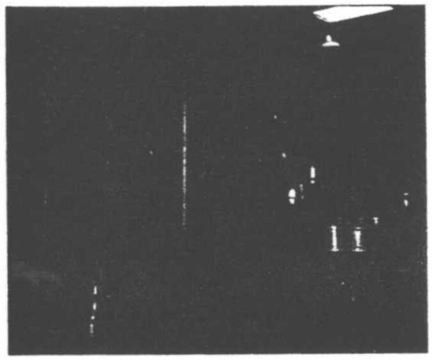
**Vapor density (VD)**—the weight of a given volume of vapor or gas compared to the weight of an equal volume of dry air.

**Confined space access may be so limited that air bottles must be passed separately.**

Although any atmosphere containing less than the normal 21-percent concentration of oxygen should be considered oxygen-deficient, the body can tolerate slight deviation from this concentration (see Table 3). It is when a person enters an asphyxiating atmosphere and becomes *hypoxic* that physical signs and symptoms develop.

Common signs and symptoms of hypoxia include increased respiratory rate, tachycardia, cyanosis, changes in levels of consciousness, seizures, nausea, vomiting, disorientation, hallucinations and coma.

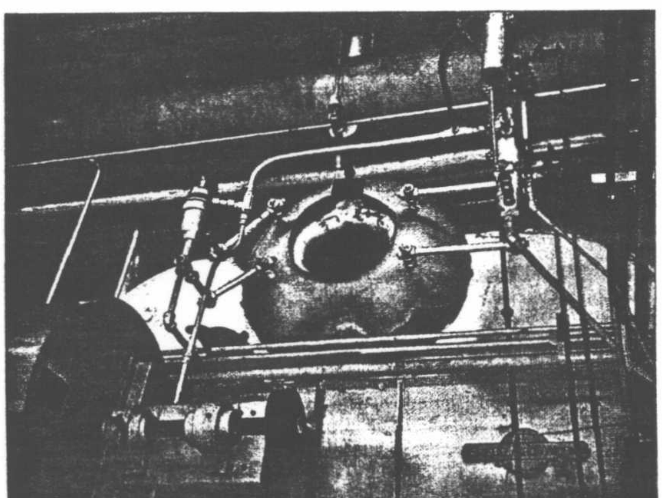
*Flammable / explosive atmospheres*—OSHA defines a flammable or explosive atmosphere as one that poses a



**Confined spaces in tanks may have bad atmospheres.**

hazard because flammable gases, vapors or dusts are present at a concentration greater than 10 percent of their lower flammable limit.[5] Flammable atmospheres are typically caused by enriched oxygen atmospheres, vaporization of flammable liquids, byproducts of some types of work, chemical reactions, concentrations of combustible dusts and *desorption* of chemicals from inner surfaces of the confined space.[9]

An atmosphere becomes flammable when oxygen and fuel are present in the right concentrations to make a flammable mixture and an ignition source is available. For combustion to occur, this flammable mixture must be present within well-defined concentration limits known as "flammable or explosive limits" (see Figure 1). The lowest concentration at which a sufficient air/fuel mixture can cause a fire or explosion is called the lower explosive limit (LEL) or the lower flammable limit (LFL). The highest concentration at which a sufficient air/fuel mixture can cause a fire or explosion is called the upper explosive limit (UEL) or the upper flammable limit (UFL). These limits are usually expressed in percent by volume.



**Elevated entry to furnace makes access and rescue challenging.**

In an oxygen-enriched atmosphere, flammability of the confined space's contents may be enhanced significantly, greatly increasing the danger of fire or explosion. It is therefore critical for rescuers to use intrinsically safe or "explosion proof" lighting and communications equipment.

Enriching an atmosphere by only a small amount of oxygen above 21 percent will cause an increase in the range of flammability, with both clothing and hair being capable of absorbing oxygen and burning violently. Enriched oxygen atmospheres, which expand the explosive range, may result from improper "blanking off" of oxygen lines, chemical reactions that liberate oxygen, or an inadvertent purging or ventilating of the space with oxygen in place of air.[9]

Flammable atmospheres can accumulate at different levels within a confined space. This is because all gases have a different weight or *vapor density* (VD) compared to air, which has a VD of 1. While some flammable gases are heavier than air (VD>1) and sink to the lower levels in the confined space, others are lighter than air (VD<1) and may be found at upper levels (see Figure 2). Thus, it is important to test all levels of an atmosphere within a confined space.

When testing a confined space, it is important to remember that many gas detectors can only record combustible gases at a level that is usually well above the concentration that may pose a health hazard. Therefore, even though the meter may indicate the gas as being less than 10 percent of the explosive level, a toxic atmosphere may still be present.

For example, carbon disulfide has an LEL of 1.3 percent, or 13,000 parts per million (PPM). Ten percent of the LEL for this gas equals 1,300 PPM. However, the limit set by OSHA for this substance is only 20 PPM. At 10 percent of the LEL, the atmosphere would exceed the OSHA level by 62 times. Thus, even though the atmosphere could be considered safe from an