Compressed Gas Safety

Thousands of products are available which contain gases and mixtures of gases stored under pressure in cylinders.

There are three major groups of compressed gases stored in cylinders: liquefied, non-liquefied and dissolved gases. In each case, the pressure of the gas in the cylinder is commonly given in units of kilopascals (kPa) or pounds per square inch gauge (psig).

Gauge pressure = Total gas pressure inside cylinder - atmospheric pressure

Atmospheric pressure is normally about 101.4 kPa (14.7 psi). Note that compressed gas cylinder with a pressure gauge reading of 0 kPa or 0 psig is not really empty. It still contains gas at atmospheric pressure.

Liquefied Gases

Liquefied gases are gases which can become liquids at normal temperatures when they are inside cylinders under pressure. They exist inside the cylinder in a liquid-vapour balance or equilibrium. Initially the cylinder is almost full of liquid, and gas fills the space above the liquid. As gas is removed from the cylinder, enough liquid evaporates to replace it, keeping the pressure in the cylinder constant. Anhydrous ammonia, chlorine, propane, nitrous oxide and carbon dioxide are examples of liquefied gases.

Non-Liquefied Gases

Non-liquefied gases are also known as compressed, pressurized or permanent gases. These gases do not become liquid when they are compressed at normal temperatures, even at very high pressures. Common examples of these are oxygen, nitrogen, helium and argon.

Dissolved Gases

Acetylene is the only common dissolved gas. Acetylene is chemically very unstable. Even at atmospheric pressure, acetylene gas can explode. Nevertheless, acetylene is routinely stored and used safely in cylinders at high pressures (up to 250 psig at 21?C).

This is possible because acetylene cylinders are fully packed with an inert, porous filler. The filler is saturated with acetone or other suitable solvent. When acetylene gas is added to the cylinder, the gas dissolves in the acetone. Acetylene in solution is stable.

Pressure hazards associated with compressed gas cylinders

All compressed gases are hazardous because of the high pressures inside the cylinders. Gas can be released deliberately by opening the cylinder valve, or accidentally from a broken or leaking valve or from a safety device. Even at a relatively low pressure, gas can flow rapidly from an open or leaking cylinder.

There have been many cases in which damaged cylinders have become uncontrolled rockets or pinwheels and have caused severe injury and damage. This danger has happened when unsecured, uncapped cylinders were knocked over causing the cylinder valve to break and high pressure gas to escape rapidly. Most cylinder valves are designed to break at a point with an opening of about 0.75 cm (0.3 inches). This design limits the rate of gas release and reduces cylinder velocity. This limit may prevent larger, heavier cylinders from "rocketing" although smaller or lighter cylinders might take off.

Poorly controlled release of compressed gas in chemical reaction systems can cause vessels to burst, create leaks in equipment or hoses, or produce runaway reactions.

Fire and explosion hazards associated with compressed gases

Flammable Gases

Flammable gases, such as acetylene, butane, ethylene, hydrogen, methylamine and vinyl chloride, can burn or explode under certain conditions:

Gas Concentration within the Flammable Range: The concentration of the gas in air (or in contact with an oxidizing gas) must be between its lower flammable limit (LFL) and upper flammable limit (UFL) [sometimes called the lower and upper explosive limits (LEL and UEL)]. For example, the LFL of hydrogen gas in air is 4 percent and its UFL is 75 percent (at atmospheric pressure and temperature). This means that hydrogen can be ignited when its concentration in the air is between 4 and 75 percent. A concentration of hydrogen below 4 percent is too "lean" to burn. Hydrogen gas levels above 75 percent are too "rich" to burn.

The flammable range of a gas includes all of its concentrations in air between the LFL and UFL. The flammable range of any gas is widened in the presence of oxidizing gases such as oxygen or chlorine and by higher temperatures or pressures. For example, the flammable range of hydrogen in oxygen gas is 4 to 85 percent and the flammable range of hydrogen in chlorine gas is 4.1 to 89 percent.

Ignition Source: For a flammable gas within its flammable limits in air (or oxidizing gas) to ignite, an ignition source must be present. There are many possible ignition sources in most workplaces including open flames, sparks and hot surfaces.

The auto-ignition (or ignition) temperature of a gas is the minimum temperature at which the gas self-ignites without any obvious ignition sources. Some gases have very low auto-ignition temperatures. For example, phosphine's auto-ignition temperature of 100?C (212?F) is low enough that it could be ignited by a steam pipe or a lit light bulb. Some compressed gases, such as silane and diborane, are pyrophoric - they can ignite spontaneously in air.

Flash-back can occur with flammable gases. Many flammable compressed gases are heavier than air. If a cylinder leaks in a poorly ventilated area, these gases can settle and collect in sewers, pits, trenches, basements or other low areas. The gas trail can spread far from the cylinder. If the gas trail contacts an ignition source, the fire produced can flash back to the cylinder.

Oxidizing Gases

Oxidizing gases include any gases containing oxygen at higher than atmospheric concentrations (above 23-25 percent), nitrogen oxides, and halogen gases such as chlorine and fluorine. These gases can react rapidly and violently with combustible materials such as the following:

- organic (carbon-containing) substances such as most flammable gases, flammable and combustible liquids, oils, greases, many plastics and fabrics
- finely-divided metals
- other oxidizable substances such as hydrazine, hydrogen, hydrides, sulphur or sulphur compounds, silicon and ammonia or ammonia compounds.

Fires or explosions can result.

The normal oxygen content in air is 21 percent. At slightly higher oxygen concentrations, for example 25 percent, combustible materials, including clothing fabrics, ignite more easily and burn much faster. Fires in atmospheres enriched with oxidizing gases are very hard to extinguish and can spread rapidly.

Dangerously Reactive Gases

Some pure compressed gases are chemically unstable. If exposed to slight temperature or pressure increases, or mechanical shock, they can readily undergo certain types of chemical reactions such as polymerization or decomposition. These reactions may become violent, resulting in fire or explosion. Some dangerously reactive gases have other chemicals, called inhibitors, added to prevent these hazardous reactions.

Common dangerously reactive gases are acetylene, 1,3-butadiene, methyl acetylene, vinyl chloride, tetrafluoroethylene and vinyl fluoride.

Health hazards associated with compressed gases

Many compressed gases are toxic or very toxic. They could cause various health problems depending on the specific gas, its concentration, the length of exposure and the route of exposure (inhalation, eye or skin contact). Contact between the skin or eye and liquefied gases in liquid form can freeze the tissue and result in a burn-like injury.

Danger of an inert gas

Inert gases, such as argon, helium, neon and nitrogen, are not toxic and do not burn or explode. Yet they can cause injury or death if they are present in sufficiently high concentrations. They can displace enough air to reduce oxygen levels. If oxygen levels are low enough, people entering the area can lose consciousness or die from asphyxiation. Low oxygen levels can particularly be a problem in poorly ventilated, confined spaces.

Corrosive hazards of compressed gases

Some compressed gases are corrosive. They can burn and destroy body tissues on contact. Corrosive gases can also attack and corrode metals. Common corrosive gases include ammonia, hydrogen chloride, chlorine and methylamine.