Cryogenic Safety – Quick Tips

What Does Cryogenic Mean?

The term “cryogenic” means producing or related to low temperatures. Cryogenic liquids are liquefied gases created by cooling a liquid to a low temperature under high pressure, which creates special health and safety hazards. These liquids have boiling points below –238° F (–150° C) and are gases at normal room temperatures and pressures. Different cryogens become liquids under different conditions of temperature and pressure, but all have two common properties: they are extremely cold and small amounts of the liquid can expand into very large volumes of gas. Dry ice is a super-cooled solid (carbon dioxide) that sublimes directly into gaseous carbon dioxide at –109.3° F. *Sublimation* is the transition of a substance directly from the solid to the gas state, without passing through the liquid state.

Dry ice, most cryogenic liquids and the gasses they produce can be placed into one of three groups:

- **Inert gases**– These gases do not react chemically to any great extent and do not burn or support combustion. Examples of this group are nitrogen, helium, neon, argon, dry ice (carbon dioxide) and krypton.
- **Flammable gases**– Some cryogenic liquids produce a gas that can burn in air. The most common examples are hydrogen, methane and liquefied petroleum gas (LPG).
- **Oxygen**– Many materials considered as non-combustible can burn in the presence of liquid oxygen. Organic materials can react explosively with liquid oxygen.

Cryogenics and dry ice have many uses and often play a role in industrial and medical applications. Other applications include fast freezing of some foods and the preservation of some biological materials. The freezing of portions of the body to destroy unwanted or malfunctioning tissue is known as cryosurgery.

Physical Effects of Cryogenic Liquids and Dry Ice

The extreme temperatures of cryogenic liquids and dry ice cause most solid matter to become more brittle. Materials such as carbon steel, plastics and rubber should not be used in direct contact with cryogenic liquids or dry ice because they can fracture or shatter extremely easily.

Flammable gases such as hydrogen, methane and LPG can burn or explode. Hydrogen is particularly hazardous.

Liquid hydrogen and liquid helium are both so cold that they can liquefy air on contact resulting in an oxygen-enriched atmosphere.

Materials that are usually considered non-combustible, such as aluminum, carbon steel, cast iron, stainless steel and zinc may burn in the presence of liquid oxygen.

Dry ice sublimes directly to a gas which can lead to dangerous pressures when stored in closed containers or areas.

Without adequate ventilation or pressure-relief devices on cryogenic containers, enormous pressure can build up. The pressure can cause a boiling liquid expanding vapor explosion (BLEVE).

Health Hazards of Cryogenic Liquids and Dry Ice

There are three groups of health hazards associated with cryogenic liquids and dry ice – extreme cold, asphyxiation and toxicity.

Extreme cold:

Contact with cryogenic liquids and their cold gases can produce effects on the skin similar to a thermal burn, as can contact with dry ice. Brief exposures that may not affect the hands can damage delicate tissues such as the eyes. Prolonged exposure of the skin or contact with cold surfaces can cause frostbite. Tissues that have been frozen will be painless while still frozen and might look waxy yellow. Thawed frostbitten skin will be very painful, red and swollen and can become infected.

Unprotected skin can stick to materials that are cooled by cryogenic liquids and dry ice, similar to the way some children stick their tongues to flagpoles in the winter. However, where cryogenic liquids and dry ice are involved, metallic materials are not the only ones that cause this risk. It is important to remember that even nonmetallic materials are extremely dangerous to touch. Removing skin from any material can cause a tearing of the flesh.

Asphyxiation:

Prolonged breathing of extremely cold air may damage the lungs. Also, when cryogenic liquids and dry ice form a gas, the gas is very cold and some are heavier than air. These cold, heavy gases do not disperse well, tend to accumulate near the floor and displace air. When there is not enough air, asphyxiation and death can occur. This is a serious hazard especially in enclosed or confined spaces.

Toxicity:

Both cryogenic liquids and dry ice can produce very large volumes of gas at room temperatures. For example, one liter of liquid nitrogen vaporizes into 695 liters of nitrogen gas when at room temperature.

Each cryogenic liquid or dry ice can cause specific health effects. Refer to the manufacturer’s Safety Data Sheet (SDS) for information about the toxic hazards of a specific cryogen.

First Aid

Contact with dry ice, cryogenic liquids and their gases, and any cooled surfaces should be avoided. If contact does occur, immediately flush the area with large quantities of warm water (104°F). Do not rub the affected area as rubbing can cause further damage. Obtain medical attention as quickly as possible.

If oxygen loss overcomes a person working with cryogenic liquids or dry ice, move the victim to a well-ventilated area. Apply CPR if the victim’s breathing has stopped.

Supply oxygen if the victim has difficulty breathing and summon emergency medical help.

Personal Protective Equipment for Cryogenic Liquids and Dry Ice Safety

Personal protective equipment (PPE) is critical to cryogenic liquid and dry ice safety. It is essential to choose the right PPE for each job. Consult each material's SDS for specific guidance. Generally, chemical-splash goggles and face shields should always be worn during the transfer and handling process of cryogenic liquids to guard against splashes and spills. Loose-fitting, insulated cryogenic gloves should also be worn. The gloves must be loose so they can be thrown off quickly if cryogenic liquid spills into them. To protect any exposed skin, long-sleeve shirts and trousers without cuffs are suggested. Additionally, when handling cryogenic liquids, pant legs should go over the tops of footwear so spills cannot get into boots or shoes and cause extreme tissue damage before the footwear can be removed. Cryogenic liquids flow very freely and can penetrate woven or other porous clothing. Wearing a cryogenic apron is suggested to help prevent this from occurring.

If working in an area where an oxygen-deficient atmosphere could be produced due to the off-gassing of cryogenic liquids or dry ice, an air-supplying respirator must be used, such as an airline respirator with an egress bottle or a self-contained breathing apparatus (SCBA).

Cryogenic Liquid and Dry Ice-Specific Equipment

Cryogenic liquids and dry ice are shipped and used in thermally insulated containers specifically designed to withstand rapid temperature changes and extreme differences in temperature and vent gases to prevent pressure build-ups within the container.

Dewar flasks are non-pressurized, vacuum-jacketed vessels, somewhat like a thermos bottle, designed for cryogenic liquids. They have a loose-fitting cap or plug that prevents air and moisture from entering yet allows excess pressure to vent. Some dewar flasks have an outer vessel of liquid nitrogen for insulation.

Liquid cylinders are pressurized containers designed for cryogenic liquids. This type of cylinder has valves for filling and dispensing the cryogenic liquid and a pressure-control valve with a bursting disk as backup protection.

Commonly Asked Questions

Q: Why can't I wear a cartridge-style air-purifying respirator to protect from liquid-nitrogen vapors?

A: Nitrogen itself is not a danger. In fact, normal air is 78 percent nitrogen. The danger is that liquid nitrogen vaporizes so quickly that it displaces oxygen. Oxygen comprises about 21 percent of normal air. When it falls below 18 percent, we do not have enough oxygen to function normally. Cartridge-style air-purifying respirators are only made to remove contaminants, so they are inappropriate for an environment that is oxygen deficient.

Q: What kinds of gloves are needed for working with cryogenics and dry ice?

A: Gloves should be insulated and made to withstand the low temperatures of cryogenic liquids and dry ice. They should also be loose fitting for cryogenic liquids, so they can be easily removed if a cryogenic liquid spill should go inside the glove.

Q: How cold is liquid nitrogen, and how cold is dry ice?

A: Nitrogen condenses to a liquid at –320°F. Dry ice starts subliming at –109.3°F.

Sources

Pamphlet P-12: Safe Handling of Cryogenic Liquids, Compressed Gas Association, March 2017

Cryogen Safety, National Institute of Standards and Technology (NIST)

NFPA 55: Compressed Gases and Cryogenic Fluids, National Fire Protection Association, 2020 Edition

Laboratory Safety Guideline: Dry Ice, Harvard Campus Services Environmental Health and Safety, November 2019