ENVIRONMENT, SAFETY & HEALTH DIVISION

Chapter 36: Cryogenic and Oxygen Deficiency Hazard Safety

Cryogenic Requirements

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1 Purpose

The purpose of these requirements is to protect workers from hazards associated with working with cryogens. They cover the introduction and use of cryogens in work areas. They apply to workers, supervisors, and responsible persons.

The following hazards and controls are specific to cryogens. For hazards and controls related to oxygen deficiency hazards, including those caused by cryogens, see Cryogenic and Oxygen Deficiency Hazard Safety: ODH Requirements.

1.1 Hazards

Cryogens are extremely cold (roughly below 150 K) substances, typically stored in liquid form, used to cool other materials to extremely low temperatures. Cryogens used at SLAC include liquid nitrogen, liquid helium, liquid argon, and liquid hydrogen.

Cryogenic hazards fall into these general categories:

- Cold burns (frostbite)
- Pressure explosions
- Chemical explosions or exposures (when hydrogen is present)
- Oxygen deficiency, which can lead to asphyxiation

1.1.1 Cold Burns

The most likely cause of cold burns to the hands and body is contact with metal surfaces at extremely cold temperatures. Cold burns can occur within a few seconds, especially when the skin is moist.

The damage from cold burns occurs as the affected tissue thaws. Water expands as it freezes, and this expansion breaks cell membranes and allows body fluids to accumulate in intercellular spaces. Intense hyperemia (abnormal accumulation of blood) usually takes place in the affected areas. Additionally, a blood clot may form along with an accumulation of body fluids, which decreases the local circulation of blood. If the consequent deficiency of blood supply to the affected cells is extreme, tissue decay may result.

Although not a burn per se, cooling of the internal organs of the body can disturb normal functioning, producing a dangerous condition known as hypothermia.

1.1.2 Pressure Explosions

A pressure explosion can be caused by cryogenic temperatures either through material degradation or inadequate pressure relief.

Because material cracks can more easily develop at cryogenic temperatures, any volume cooled externally by a cryogen or any vacuum space in contact with a cryogen must have the ability to relieve pressure. The cryogen or air may leak into a sealed space through such cracks. Some atmospheric gases will condense under such conditions and exist as a cryogen in the sealed space. Upon warming, these cracks may be too small to vent the gas, and the contained, expanding fluid can shatter the vessel.

Cryogenic liquids allowed to heat above their boiling points undergo a phase change which drives large volume and/or pressure increases. When liquid cryogens warm to room temperature there is a volumetric change on the order of 700 to 900 times. Therefore, systems must be designed to contain the increased pressure in a closed system or relieve it through proper pressure relieving devices.

Certain cryogens, such as helium and hydrogen, are cold enough to solidify atmospheric air. Entry of air into cryostats containing these cryogens can be prevented by pressurizing the system. If openings to the atmosphere exist in an unpressurized system, they are likely to become plugged by solidified moisture from the air, leading to overpressure and vessel failure. Such conditions will also result in hazardous contamination of the fluid.

1.1.3 Chemical Explosions

The chemical properties and reaction rates of substances are influenced by cryogenic conditions. Condensing a cryogen from a pure gas at room temperature will concentrate the material typically 700 to 900 times its room temperature density. Oxygen-enriched air produced by either liquid helium or nitrogen has many of the same properties as liquid oxygen, which can react explosively with materials usually considered to be noncombustible. (Atmospheric oxygen concentrations above 23.5 percent pose a significant hazard.)

Cryogenic fluids with a boiling point below that of liquid oxygen have the ability to condense oxygen out of the air if exposed to the atmosphere. This is particularly troublesome if a stable system is replenished repeatedly to make up for evaporation losses as oxygen may accumulate as an unwanted contaminant. Violent reactions (for example, rapid combustion or explosion) may occur if the material is not compatible with liquid oxygen. An example of this could include a cryogenic fluid spill onto asphalt during a transfer between a tanker and a storage vessel.

Oxygen enrichment will also occur if liquefied air is permitted to evaporate (oxygen evaporates less rapidly than nitrogen). Oxygen concentrations of 50 percent may be reached near evaporating liquid air. Condensed air dripping from the exterior of cryogenic piping will be rich in oxygen.

1.1.4 Oxygen Deficiency or Asphyxiation Hazard

At temperatures above their boiling points, some cryogens can expand in volume 700 to 900 times. The resulting large volume of gas can displace part or all of the air in an unventilated enclosure, creating a potential for asphyxiation. This asphyxiation hazard, also known as an *oxygen deficiency hazard (ODH)*, is particularly serious in enclosed volumes that have no vents or ventilation systems.

2 Requirements

2.1 Environmental and Engineering Controls

2.1.1 Insulation

Surfaces at cryogenic temperatures must be protected to prevent contact with skin. This may be accomplished by means of vacuum jacketing, insulation, or location. Insulation systems must be specially engineered to prevent air penetration, or the insulation must have sufficiently low strength that it will yield at low gas pressure.

2.1.2 Pressure Relief

Adequate pressure relief devices must be provided to vent all gas that could be produced during a theoretical maximum heat flux into the system. The system configuration must ensure that any air that enters the cryostat and freezes cannot prevent proper functioning of pressure relief devices.

Heat flux into the cryogen is unavoidable regardless of the quality of the insulation installed. Pressure relief must be provided to permit routine release of gas vapors generated by this heat input. Typically such relief is best provided by rated spring-loaded relief devices or an open passage to the atmosphere with a check valve.

Additional relief devices should be provided as backup to the operational relief when the capacity of the operational relief device is not adequate to take care of unusual or accidental conditions. This may be the case if the insulation is dependent on the maintenance of a vacuum in any part of the system (this includes permanently sealed dewars), if the system may be subject to an external fire, or if rapid exothermic (heat releasing) reactions are possible in the cryogen or a container cooled by the cryogen. In each case, relief devices capable of handling the maximum volume of gas that could be produced under the most adverse conditions must be provided.

Each and every portion of the cryogenic system must have uninterruptible pressure relief. Any part of the system that can be valved-off from the remainder must have separate and adequate provisions for pressure relief.

Examples of parts that usually require separate relief systems:

- Pressurized supply dewars
- Piping (except ambient) and manifolds
- Tubing and hoses used to transfer a cryogen, unless an air gap is provided
- Bath space surrounding experimental volume
- Any volume cooled externally by a cryogen
- Vacuum spaces in contact with cryogen

See Chapter 14, “Pressure Systems”, for detailed requirements for design, installation, maintenance, and inspection of pressure relief devices.

2.2 Personnel Controls

2.2.1 Personal Protective Equipment

Eye, hand, and body protection must be provided to prevent potential cold burns when handling cryogens.

Eye protection is required at all times when handling cryogenic fluids. When pouring a cryogen or when working with a wide-mouth dewar (that is, open flow delivery), goggles or a full-face shield over safety glasses must be used. A face shield by itself does not provide adequate splash protection; safety glasses or goggles must be worn underneath as well. The only exceptions are for transporting cryogens in closed dewars or portable tanks and disposing of very small quantities (less than 0.5 liter) by evaporation.

For hand protection, it is best to wear loose, insulating gloves, which can be tossed off readily if they become soaked with cryogens. For tasks requiring a high degree of dexterity that are difficult or impossible to perform while wearing insulating gloves, such as manipulating samples in small cryovials, a better solution is the use of insulated hand tools.

Never use clean room gloves, which are absorbent (cotton) or porous (nylon), for hand protection.

Required body protection when working with large (multi-liter) quantities of cryogenic fluids includes

- Cuff-less trousers extended over work boots
- Leather or cryogenic material apron

2.2.2 Training

Personnel who

- Work directly with cryogenic liquids or use systems/equipment that involve cryogenic liquid or
- Have managerial control over areas and personnel who use these materials

are required to complete the following:

- ESH Course 175, Cryogenic Liquids and Oxygen Deficiency Safety Training (ESH Course 175)

2.3 Emergency Controls

2.3.1 Response to Uncontrolled Cryogen Release

In the case of an uncontrolled cryogen release:

- Leave the area immediately.
- Never exit the area through a vapor cloud. If you find yourself in a vapor cloud, hold your breath until you are out of the cloud.

Do not attempt to rescue an injured or unconscious person. Only those who are trained and qualified are authorized to perform rescue operations.

The following may be signs of an uncontrolled release of a cryogen:

- A sudden drop in temperature
- A visible water-vapor plume until the gas warms
- A hissing or whooshing sound associated with rushing gas

3 Forms

The following forms and systems are required by these requirements:

- None

4 Recordkeeping

The following recordkeeping requirements apply for these requirements:

- None

5 References

SLAC Environment, Safety, and Health Manual (SLAC-I-720-0A29Z-001)

- Chapter 36, "Cryogenic and Oxygen Deficiency Hazard Safety"
  - Cryogenic and Oxygen Deficiency Hazard Safety: ODH Requirements (SLAC-I-730-0A06S-002)
  - Cryogenic and Oxygen Deficiency Hazard Safety Program Site (SharePoint)
- Chapter 14, "Pressure Systems"

Other SLAC Documents

- ESH Course 175, Cryogenic Liquids and Oxygen Deficiency Safety Training (ESH Course 175)