Cryogenic Safety

A general guide for the safe handling of cryogenic fluids as well as general approaches to safety training.

Safety in handling cryogenic liquids and gases requires a thorough knowledge of the properties associated with each cryogen, an assessment of where and how the cryogen will be used, personal protective equipment appropriate to the cryogen, and a plan for dealing with any contingency. Table 1 shows the properties of cryogenic fluids.

There are three principal risks associated with handling any cryogen:

- Burns from freezing
- Asphyxiation
- Explosion

Burns

Brief contact (one to two seconds) with splashed cryogens on exposed skin may be harmless due to the vapor barrier that forms between the cold liquid and the warm skin. Even a small splash to the eye, however, can cause damage immediately. Longer exposure to skin will produce tissue damage similar to that caused by exposure to an open flame. Direct contact with an object at cryogenic temperatures will result in an immediate "burn".

Personal Protective Equipment (PPE)

A face shield with safety goggles is the ideal protection for the eyes and face. Insulated waterproof gloves specifically designed for handling cryogens should be worn together with insulated waterproof aprons. Gloves specifically designed for handling cryogens are available in wrist to shoulder length. Long sleeved shirts and pants without cuffs, worn outside boots or shoes, are advised. Never wear jewelry while handling cryogens.

How to Treat a Burn

The affected area of skin will appear white or bluish. Bathe the area with warm water. Do not use hot water. Do not flush with a heavy stream of water as further damage may occur. Do not rub or massage the affected area. When removing clothing from the affected area make sure the clothing is not frozen to the skin, otherwise you may remove skin with the clothing. Bandage the affected areas with dry, sterile dressings. Be sure to seek immediate medical attention.

Asphyxiation

Cryogens expand at an average ratio of nearly 1:1000 when heated from boiling point to ambient temperatures. (See Table 1, column 4: "Volume Expansion to Gas"). One liter of liquid nitrogen will displace nearly 700 liters of air. Spilling a forty-gallon Dewar would displace all the oxygen from a 15x20x9 foot room. Reducing the oxygen content of a room below the minimum required 19.5% produces the effects shown in Table 2.

PPE and Safe Practices

Gas monitoring equipment should be present in any lab or enclosed area where cryogenic liquids are stored or used. Self-contained breathing apparatus should be worn in any questionable atmosphere and in any confined space where a spill has occurred. If a spill does occur, the area should be evacuated until a gas analysis can determine the level of risk.

As shown in Table 1, column 7, labeled "Odor", most cryogens are odorless. Even outdoor oxygen-deficient areas can form in gullies or depressions where cold nitrogen gas will not mix with warmer air above unless moved by wind. Walking through such an oxygen-deficient area, one can loose consciousness without experiencing any signs of lightheadedness or other physiological warnings such as gasping, or struggling for breath. No attempt should be made to rescue a fellow worker who has lost consciousness in an enclosed space without first checking the oxygen content of the enclosed space.

Gas	Bioling Point Centigrade	Boiling Point Kelvin	Volume Expansion to Gas	Flammable	Toxic	Odor
Helium-3	=269.9	3.2	757 to 1	No	No (a)	No
Helium-4	-268.9	4.2	757 to 1	No	No (a)	No
Hydrogen	-252.7	20.4	851 to 1	Yes	No (a)	No
Deuterium	-249	23.6	851 to 1	Yes	Radioactive	No
Tritium	-248	25.1	851 to 1	Yes	Radioactive	No
Neon	-245.9	27.2	1438 to 1	No	No (a)	No
Nitrogen	-195.8	77.3	696 to 1	No	No (a)	No
Carbon monoxide	-192	81.1	696 to 1	Yes	Yes	No
Fluorine	-187	86	888 to 1	No	Yes	Sharp
Argon	-185.7	87.4	847 to 1	No	No (a)	No
Oxygen	-183	90.1	860 to 1	No	No (a)	No
Methane	-161.4	111.7	578 to 1	Yes	No (a)	No
Krypton	-151.8	121.3	700 to 1	No	No (a)	No
Tetrafluoromethane	-128	145	700 to 1	No	Yes	No
Ozone	-111.9	161.3	700 to 1	Yes	Yes	Yes
Xenon	-109.1	164	573 to 1	No	No (a)	No
Ethylene	-103.8	169.3	573 to 1	Yes	No (a)	Sweet
Boron trifluoride	-100.3	172.7	573 to 1	No	Yes	Pungent
Nitrous oxide	-89.5	183.6	666 to 1	No	No (a)	Sweet
Ethane	-88.3	184.8	666 to 1	Yes	No (a)	No
Hydrogen chloride	-85	188	666 to 1	No	Yes	Pungent
Aetylene	-84	189.1	666 to 1	Yes	Yes	Garlic
Fluoroform	-84	189.1	666 to 1	No	No (a)	No
1,1-Difluorethylene	-83	190	666 to 1	Yes	No (a)	Ether
Clorotrifluoromethane	-81.4	191.6	666 to 1	No	Yes	Mild
Carbon dioxide	-78.5	194.6	553 to 1	No	Yes (a)	Pungent

Table 1. Properties of cryogenic fluids [1]. NOTE: (a) indicates nontoxic, but can act as an asphyxiant by displacing air needed to support life. As with most chemicals, even harmless materials can be toxic or poisonous if taken in sufficient quantities under the right circumstances.

Explosion

Some cryogens are flammable (see Table 1). The risk of explosion however, is most often due to pressure building up in sealed containers. As cryogenic fluids warm, gases evaporate and pressure in the vessel builds. There have been instances reported of people stopping relief valves to reduce the white noise they produce. Such an incident could not occur if access to the area had been restricted to trained personnel.

Never replace a valve on a cryogenic container. If a hose doesn't fit, contact the company that supplied the vessel or the gas company that delivered the cryogen. If a hose doesn't fit don't use the tank.

Handling Cryogens: Avoid At-Risk Behaviors

For all three potential hazards mentioned above the only way to reduce or eliminate accidents is by identifying and eliminating "At Risk Behaviors". Task-specific training, proper maintenance of equipment, and the use of personal protective equipment are all essential to the elimination of at-risk behaviors and consequently, accidents.

Universal Rules of Thumb

1. Always handle cryogenic liquids carefully to avoid skin burns. Exposure that may be too brief to affect

% Oxygen at 1 atm total pressure	At Rest Symptoms
15-19	Decreased ability to perform tasks: may induce early symptoms in persons with heart, lung, or circulatory problems
12-15	Respiration deeper, pulse faster, poor coordination
10-12	Giddiness, poor judgment, lips slightly blue
8-10	Nausea, vomiting, unconsciousness, ashen face, fainting, mental failure
6-8	Death in 8 minutes, after 6-minutes 50% die and 50% recover with treatment in 4-5 minutes
4	Coma in 40 second, convulsions, respiration ceases, death

Table 2. Symptoms as a result of oxygen deprivation (Compressed Gas Association Bulletin CGA-SB-2.)

the skin of the face or hands may damage delicate tissues, such as the eyes.

2. Boiling and splashing always occur when charging or filling a warm container with cryogenic liquid or when inserting objects into these liquids. Perform these tasks slowly to minimize boiling and splashing. Use tongs to withdraw objects immersed in a cryogenic liquid.
3. Never touch uninsulated pipes or vessels containing cryogenic liquids. Flesh will stick to extremely cold materials. Even nonmetallic materials are dangerous to touch at low temperatures.
4. Cylinders and Dewars should not be filled to more than 80% of capacity, since expansion of gases during warming may cause excessive pressure buildup.
5. Check cold baths frequently to ensure they are not plugged with frozen material. Clear all objects from the path if you are carrying a cryogen in a small Dewar. Never work alone with a cryogen.
6. "If at all possible, the situation of trying to react to an emergency with on-the- spot decisions are to be avoided." [3]
7. "Personnel access should be restricted to those actually needed to perform the operations." Ibid.,p.3

At-Risk Behaviors Checklist

Users of cryogenic gases should review their internal procedures when considering safety in working with cryogenics. The following list was compiled by Praxair, which has safety personnel available for consultation in handling cryogenic fluids and gases. The list covers many areas, but is by no means exhaustive.

- The use of personal protective equipment (PPE)
- Proper design of cryogenic equipment such as valves, regulators, piping and storage tanks
- Safety monitoring of atmospheres, whether flammable or oxygen deficient
- Understanding the physical properties of any cryogenic liquefied gas (refer to your MSDS (material safety data sheets)
- Training in the safe handling of gases for all relevant employees; transportation safety training for drivers
- Proper identification and labeling of gas packages
- Placarding and Transportation and Hazardous Manifest recording
- Proper cylinder handling equipment, i.e. cylinder trucks and lift gates
- Emergency response team LEAP (Local Emergency Assistance Program)

Conclusion

Safety training is effective when risks are clearly understood along with the at-risk behaviors directly associated with them. People often don't realize that cryogens are extremely cold and that they can explode or cause asphyxiation. It is the responsibility of management to identify the risks inherent in any particular application of a cryogen, to anticipate at risk behaviors and to eliminate them wherever possible. Call experts, consult OEM suppliers and learn what you need to know to avoid accidents related to cryogens. They behave very predictably according to well-understood laws of physics. With proper risk assessment and training, accidents can be completely eliminated.

This article is intended as a general guide to safety and handling of cryogens. For a thorough discussion of the subject please refer to Safety and Handling of Cryogenic Fluids by Frederick Edescuty and the safety chapter in Cryogenic Engineering by Thomas Flynn. For specific safety instructions regarding cryogenic equipment always consult the manufacturer. G&I

References

1. See Eric Spencer, Ohio State EHS Handbook at www.chemistry.ohio-state.edu/ehs/handbook/gases/cryosafe.htm
2. F.J. Edescuty, W.F. Stuart. Safety in the Handling of Cryogenic Fluids, The International Cryogenic Monograph Series, ISBN 0-306-45161-1
3. T.M. Flynn. Cryogenic Engineering, Chapter 11, Safety With Cryogenic Systems, Marcel Dekker, NY, ISBN 0-203-02699-3

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