CRYOGENICS:
SAFE WORK PRACTICES INFORMATION PAGE

(07/17/09)

BACKGROUND

Cryogenic materials are those substances that must be cooled to an extremely low temperature to change from a gas to a liquid. Examples of common cryogens include liquid nitrogen, helium, hydrogen, argon, oxygen and methane. Cryogenics are characterized by their extremely low temperature and by their extremely high expansion rate when their physical state changes from liquid to gas. Due to these characteristics, work involving cryogenics presents certain health and safety hazards. Those working with cryogenics need to be aware of such hazards and ensure that they take the necessary precautions.

PURPOSE

The purpose of this page is to provide principal investigators (PIs) and their staff with information regarding health hazards, safe work methods, and provision of suitable personal protective equipment for the development of research protocols that effectively reduce risk of occupational exposure to cryogenics.

OCCUPATIONAL EXPOSURE HAZARDS

Cryogenic fluids present certain health and safety hazards that must be addressed when working with or introducing a cryogenic system or project. Hazard factors associated with cryogenics include ultra cold temperatures, flammability, displacement of oxygen/asphyxiation, and high-pressure gas resulting in over-pressurization of containers. These hazards are addressed further below.

1. <u>Cryogenic burns and frostbite hazards:</u> Cryogenic fluids (liquid or cold gas) that are allowed to come in contact with human skin can cause severe damage to living tissue, including cold burns and frostbite. Damage can occur very quickly with only brief contact, longer than only a few seconds. Cryogenic fluids have very low boiling points. The gases released can produce frostbite and permanently damage delicate tissues, such as the eyes by only brief exposure. Direct contact with cryogens can result in immediate injury, where as being subjected to a very cold atmosphere for an extended period of time, such as a result of a spill, can also cause physical harm by inducing hypothermia. Safe work methods, including using appropriate personal protective equipment, must be followed to protect oneself from such health hazards. Please note work methods in the section to follow.

2. <u>Flammability:</u> Cryogens are associated with fire and explosion hazards, and care must be taken to avoid such hazards. Some cryogen gases are flammable, including hydrogen, methane, and acetylene, while oxygen can support and accelerate the combustion of flammables and other materials. Ignition sources must be prohibited in areas where combustible cryogens are stored or used. Ignition sources include obvious ones such as open flames and welding, but electrical

equipment must also be considered. Flammables must be kept and stored away from oxygen. One must also be aware that liquefied inert gases, including liquid nitrogen and helium, may condense oxygen from the atmosphere causing oxygen entrapment in unsuspected areas. In addition, extremely cold surfaces are also capable of condensing oxygen from the atmosphere.

3. High-pressure gas: Working with or storing cryogenic fluids presents hazards from high-pressure gas, since the liquefied gases are usually stored at or near their boiling points, and therefore there is always some gas present in the container. Due to the large expansion ratio from liquid to gas, a build up of high pressure can occur when the liquid evaporates. The evaporation rate will depend on the fluid, storage container design and environmental conditions, but the container capacity must include an allowance for the evaporation of the liquid into the gaseous state. To prevent hazards associated with high-pressure gas, it is important to ensure that pressure relief devices are used appropriately. These devices should be maintained and checked regularly for leaks or damage. Pressure relief devices must be sized for maximum possible back pressure.

4. Displacement of Oxygen/Asphyxiation: Due to the large expansion that takes place upon the evaporation of a cryogenic fluid, cryogens, other than oxygen, are capable of causing asphyxiation by displacing breathable air. Even prolonged breathing of pure oxygen can result in harmful physiological effects. To avoid such conditions, natural ventilation should be used and transporting or using cryogenic containers in enclosed spaces should be avoided.

SAFE WORK METHODS

The list of potential cryogenic-related health hazards identified above makes it imperative that PIs conduct thorough risk assessments and prepare protocols which include measures for minimizing staff exposure potential. Implementation of the safe work methods listed below should be used in an effort to eliminate or reduce exposure potential to cryogenics as much as feasible.

1. Administrative Controls

a. Management considerations for cryogenics and other potentially hazardous chemicals must be included in the laboratory Chemical Hygiene Plan.

b. Principal investigators will develop and implement standard operating procedures (SOPs) for work procedures involving cryogens. In addition, all personnel working with cryogenic fluids must be appropriately trained on safe work methods.

c. All tasks having potential for occupational cryogenic exposure will only be conducted by competent staff who have received appropriate training (OSHA: “Worker Right to Know”) regarding the specific cryogenic-related health and safety risks, SOPs, and procedures to be followed in event of an exposure incident.

d. Exposures involving cryogens should be reported to Employee Health as soon as possible.

2. <u>Personal Protective Equipment (PPE)</u>: Cryogenic exposure is often attributable to the wearing of inadequate PPE. Staff involved with any tasks where potential for cryogenic exposure exists must don the following PPE:

a. Eye protection must be used whenever handling or transferring cryogens: Full-face shield, in combination with splash goggles or safety glasses with side shields, should be used when transferring liquids to an open container.

b. Hands should be protected with appropriate gloves. Gloves should either be designed to prevent cryogens from flowing into the glove or be loose fitting so the glove can be easily be shaken off in accidental contact with cryogens. Cotton or nylon gloves covered with disposable Purple Nitrile® or vinyl gloves are recommended for work that requires delicate handling of cold items in close proximity to liquid nitrogen. Cotton gloves can 'wick' the cold liquid, so should not be used without the nitrile outer glove. Inner cotton /outer nitrile glove combination is not designed to allow immersion of hands or fingers into liquid nitrogen.

Note: When handling liquids in open containers, it is advisable to wear high-top shoes. Trousers (which should be cuff less, if possible) should be worn outside the shoes. Also, tongs must always be used to withdraw objects immersed in liquid.

c. Lab coats or disposable coveralls that provide complete coverage of skin not otherwise protected by PPE and/or attire should be worn. All parts of the body must be protected from uninsulated pipes or vessels containing cryogenic liquids; the extremely cold metal may stick fast to the skin and result in torn flesh when the skin is withdrawn. Short pants/dresses and open toe shoes or shoes made of porous material (suede) are not appropriate laboratory attire.

d. Watches, rings and jewelry should not be worn, as metals can become frozen to the skin (arm, wrist, finger).

e. Caution: Objects that are soft and pliable at room temperatures usually become very hard and brittle at the temperatures of these liquids and are very easily broken.

3. <u>Work Methods:</u> The PI must establish safe work methods into the Chemical Hygiene Plan for the specific work in the laboratory involving cryogens. The following work methods should be implemented when handling cryogens:

a. Do not directly touch or make contact with cryogenic liquids or uninsulated cryogenic equipment or pipes. Tongs can be used to withdraw objects immersed in a cryogenic liquid.

b. Do not overfill containers. In addition, when pouring or transferring cryogens, one must do so slowly to minimize boiling and splashing.

c. Avoid the path of boil-off gases.

d. Ensure that cryogenic fluids are stored in appropriately insulated containers which minimize the loss of product due to boil-off. (Dewar flasks are commonly used.)

e. Containers of cryogenic liquid must never be closed so that they cannot vent. Where a special vented stopper or venting tube is used, as on some small portable containers, the vent must be checked regularly to ensure it has not plugged with ice formed from water vapor condensed from the air.

(1) Ordinary glassware must not be used to store or transfer cryogenic liquids. All unprotected glass Dewar must be wrapped with a heavy adhesive tape to prevent fragmentation and to provide a better gripping surface. The materials used in cryogenic systems must have the appropriate physical properties to qualify them for use at these extremely low temperatures. Some acceptable materials are:

(a) Aluminum
(b) Series 300 Stainless steels (such as 304, 316)
(c) Copper
(d) Brass
(e) Fiberglass (i.e., G-10)

.

(2) Materials susceptible to hydrogen attack and hydrogen embrittlement must NOT be used in hydrogen service. Avoid the following materials:

(a) Titanium
(b) Maraging steels
(c) SA-517 (or similar heat-treated steels
(d) Series 400 Stainless steels
(e) MIL-S-16216 and
(f) Precipitation-hardened stainless steels.

f. All system vents must be directed away from personnel or designated work areas. Venting fluids (liquids or cold gases) should not impinge on any part of the body of either the worker or other personnel.

1. Pressure may build-up in liquid Nitrogen storage cylinders. Ensure all safety valves and vent valves are unobstructed and functioning properly. Check the safety vents on liquid nitrogen tanks at least twice a week.

g. Inspect and maintain cryogenic systems and equipment on a regular basis.

h. Ensure that appropriate personal protective equipment is worn when working with cryogens.

4. <u>Engineering Controls:</u>

a. Cryogenic fluids must be stored in appropriately insulated containers. In addition, adequate pressure-relief devices must be provided due to the potential for high-pressure gas build up as the liquid evaporates.

b. Ensure that an oxygen alarm is present in the work area when appropriate.

5. Spills:

a. If cryogenic material is spilled and involves any skin contact, immediate medical attention is required and those exposed should report to Employee Health as soon as possible. Any covering or clothing that may restrict circulation should be removed carefully, taking care not to remove skin. .

b. Spills involving a large amount of a cryogen (especially in a confined space) can lead to a dangerously oxygen deficient atmosphere. Personnel should be evacuated from the area and OEHS (emergency line: 828-9834) contacted for assistance.

c. Use appropriate PPE during spill clean-up and dispose of all waste generated through OEHS hazardous waste management program. For larger spills, contact the OEHS emergency line (828-9834) for assistance.

REFERENCES

Edeskuty, F.J., & Stewart, W.F. (1996). *Safety in the Handling of Cryogenic Fluids*. New York, NY: Plenum Press.

Cryogenic Safety Manual. Argonne National Laboratory, Physics Division. Available at: http://www.phy.anl.gov/div/esh/Cryogenic/Physics Division Cryogenic Safety Manual.pdf

Occupational Safety and Health Guideline for Nitrogen. U.S. Department of Labor OSHA. Available at: http://www.osha.gov/SLTC/healthguidelines/nitrogen/recognition.html

Safety Precautions for Cryogenic Liquids. UC Davis Health and Safety. Available at: http://ehs.ucdavis.edu/sftynet/sn-58.cfm

Cryogenics Safety Plan. Brookhaven National Laboratory. Available at: http://www.nsls.bnl.gov/newsroom/publications/manuals/prm/LS-ESH-PRM-5.1.0.html

Laboratory Chemical Safety Plan. University of Indiana. Available at: http://www.ehs.indiana.edu/LabSafety/lcsp.html

Safety First. E-compound. Available at: http://ecompound.com/Reaction%20reference/lab_safety_info.htm