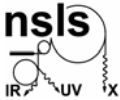


| | |
|--|---|
|  NATIONAL SYNCHROTRON LIGHT SOURCE BROOKHAVEN NATIONAL LABORATORY | Report No. 000641 |
| | Original Date: 06/02/2008 Revised 08/11/09 |
| | Prepared By: Andrew Ackerman |
| GENERAL REVIEW FORM | |
| TYPE OF REVIEW: | <input checked="" type="checkbox"/> Facility Safety |
| TITLE: | Revised Cryogen PPE Requirements (Update to NSLS report #000575) |
| PURPOSE: | Analyze NSLS PPE requirements for Work with Cryogens |
| REVIEWERS | Andrew Ackerman; Keith Klaus |
| DISTRIBUTION: | The "Reviewers" listed above and: Lori Stiegler |

This document presents a risk analysis and personal protective equipment requirements for use of cryogens at the NSLS. The text that follows has been reviewed by engineers and scientists who work at the NSLS and within BNL small sciences facilities who have experience working with cryogens or have cryogen safety oversight responsibility at BNSLS.

General Hazard Analysis; Cryogens

There are two significant hazards associated with cryogen use; the extreme cold that can cause tissue damage and oxygen deficiency that can result from liquid conversion to vapor in small volume areas or areas with limited ventilation. This document addresses only the risks associated with the extreme temperature hazard.

Exposure control for extreme temperature is directed towards avoidance of personnel contact with cryogen liquids, the vapor immediately adjacent to those liquids, and to equipment surfaces cooled to cryogen temperatures. Risk of injury is greatest from cryogen splashes to the eyes and other mucous membranes, immersion of any part of the body into the liquid, or spills that result in a volume of liquid trapped to the body as can occur with open cuffs or pockets. The risk of cryogen contact with exposed skin varies with the conditions of exposure such as time, volume, and contact pressure.

Common Cryogen Use

Liquid Nitrogen (LN2) is the most used cryogen. LN2 transport dewars (100-180 liters) are filled from the larger, exterior LN2 storage tanks or vendor trucks and then brought to the work areas for:

- Closed line transfer to dewars, cryostats, detectors, and magnets. These transfers typically involve volumes < 50 liters.
- Open line transfer to small dewars and various equipment. These transfers typically involve volumes < 5 liters.

Open, hand carried dewars (~ 5 liters) are also filled from the large, exterior storage tank at the NSLS and brought to the beam lines to fill smaller (~1 liter) dewars that hold samples or to fill 'dry transport' dewars (~5 liters).

LN2 is used to cool experiment samples and electronics by transfer from smaller insulated dewars (5 liters or less). LN2 'boil off' is used to direct a cold stream to samples and for vacuum system venting.

LHe is always used in closed systems. Transport dewars (~150 liters) are purchased and brought to the beam lines and laboratories to cool electronics and experiment sample cryostats.

Cryogen Characteristics and Handling

As noted above, the cryogen liquids in common use at BNL are LN2 and LHe. LHe is always transferred in closed systems, as the liquid is so volatile that it just flashes off if exposed to air at room temperature. LN2, however, can be transferred in closed systems or poured between open containers.

A useful comparison can be made between pouring small volumes (~500 ml) of LN2 and pouring small volumes of boiling water. Both present risk of contact with extreme temperatures that can be managed with care and attention to detail. The following table presents some basic physical characteristics of LN2, LHe, and water.

| Material | Boiling Point (°C) | Heat of vaporization (kJ/mol) |
|----------|--------------------|-------------------------------|
| LN2 | -195.79 | 5.57 |
| LHe | -268.15 | 0.0829 |
| Water | 100 | 40.68 |

From this table, it is obvious that the temperature of each of these liquids is extreme from typical ambient conditions, but also note that the energy required to bring each liquid to its vapor state is very different. It takes far more energy to boil water than to boil LN2 and far more energy to boil LN2 than to boil LHe. These are important differences when considering handling requirements as this characteristic has much influence over the hazard presented by each.

Almost any volume splash of boiling water to the skin will result in some injury as that liquid carries much energy; this is not true for LN2 or LHe. Milliliter volume spills of LN2 under ambient pressure, to exposed skin, present negligible risk of tissue damage as the available energy at the skin surface readily boils the LN2 on contact. LN2 essentially, “bounces” off the skin; a phenomenon referenced as the, “Leidenfrost Effect” which explains the behavior of liquids in near contact with a mass at much higher temperature.

This energy capacity difference also makes LN2 much harder to pour than boiling water. The rapid boiling of LN2 results in more splashing when pouring to a room temperature surface than does boiling water. Initial dispensing of LN2 to a room temperature receptacle must be done slowly to allow for sufficient cooling to minimize splashing.

Application of a graded approach to PPE requirements

Eye protection is always required when working with any volume of liquid cryogen. Safety glasses with side shields can be adequate, but for applications that can result in violent splashing as when transferring under pressure, chemical splash goggles are required as they provide added protection by better enclosing a larger volume around the eyes.

Avoidance of skin contact is always important. The amount of protection needed is determined by the likelihood of prolonged contact and the cold surface area size. In general:

- Gloves are needed for manipulation of fittings, valves, and tools at cryogen temperature as those actions involve purposeful extended contact.
- Work around transfer lines and insulated dewars presents little risk of injury and requires no special clothing beyond that required for non-office area entry. Accidental, momentary contact to these surfaces, as might occur when personnel brush up against a small cold surface, presents little risk of prolonged skin contact.
- Larger surface areas at cryogen temperature present risk of skin tearing from even momentary accidental contact. Long sleeves and gloves are needed for protection for work in areas with cold surface areas larger than the fittings and transport lines in common use.

- Long pants or long skirts (covering the ankles) are already required for entry to non-office areas¹. They can help divert a spill away from shoe openings and so must extend over the shoes when working with cryogenes.

General PPE Requirements (applicable to ALL cryogen use)

- **Eye protection is required for ALL cryogen use.** ANSI Z87.1 compliant, vented splash goggles are required when no face shield is used. ANSI Z87.1 compliant safety glasses with side shields are acceptable when used with a face shield.
- Long pants or long skirts (covering the ankles) and closed shoes are required. Clothing fabric must be tightly woven to avoid rapid wicking of liquid splashes or spills. No loose pockets or cuffs.

Cryogen Task Specific PPE Requirements

LN2: Pouring small (5 liters or less) volumes between open containers

Hazard Analysis

- Milliliter splashes to exposed skin present no significant risk.
- Any splash to the eyes or other mucus membranes is a concern.
- Any immersion of any body part to the liquid is a concern.
- Any circumstance that will trap a volume of liquid in contact or close proximity to the skin is a concern. This includes liquid poured to a pocket, a cuff, between clothing and the skin, or wicked into clothing fabric.
- LN2 will splash violently when poured to a room temperature surface.
- Cold surfaces are not a concern when pouring between these small dewars as only vacuum insulated receptacles are allowed.
- These transfers occur at ambient pressure. The ‘worst case’ accident involves dropping the dewar or rapidly spilling the full dewar contents. This event presents risk of mechanical injury from the falling dewar. The cryogen spill will rapidly boil off and dissipate.

Required Precautions

- Only receptacles rated to handle LN2 may be used.
- Initial pouring must be slow to allow temperature equilibration to minimize splashing.
- Pouring position must be ergonomic. Tight, cramped positions must be avoided. No liquid may be poured overhead. Pouring at waist height is best.

¹ “Non-Office Areas” are areas where work involves use of tools, material handling, chemical handling and storage, and cryogen handling and storage.

PPE requirements

- **Hand protection;** Insulated cryo-gloves or heavy duty leather gloves that extend beyond the wrist. Gloves must be loose fitting to allow rapid removal should a liquid splash enter the glove.
- **Eye protection;** ANSI Z87.1 compliant, vented splash goggles.
- **Arm Protection;** Long sleeve shirt or laboratory coat (fabric must be tightly woven to avoid rapid wicking of liquid splashes).

LN2: Pouring > 5 liter volumes between open containers

Hazard Analysis

- Hazards are the same as those for pouring small LN2 volumes except splashes and spills can be more severe.

Required Precautions

- Required precautions are the same as those for pouring small LN2 volumes. More care is needed to assure proper ergonomic positioning as the containers could be more awkward and heavy.

PPE requirements

- **Hand protection;** Insulated cryo-gloves or heavy duty leather gloves that extend beyond the wrist. Gloves must be loose fitting to allow rapid removal should a liquid splash enter the glove.
- **Eye protection;** Face shield worn over ANSI Z87.1 compliant safety glasses with side shields. Alternatively a face shield may be worn over ANSI Z87.1 compliant, vented splash goggles.
- **Arm Protection;** Long sleeve shirt or laboratory coat (fabric must be tightly woven to avoid rapid wicking of liquid splashes).

LN2: Dispensing from a pressurized line to an open dewar.

LN2 & LHe: Closed line transfer

Hazard Analysis

- Hazards include those discussed above for pouring between open containers. Additional concerns follow:
 - o Transfer lines are pressurized (<30 psi).

- Misdirection of the stream can result in liquid impact to skin under pressure. *[Open dewar fill only]*
 - Splashing potential is increased over open container pouring. *[Open dewar fill only]*
 - Fittings and equipment can be exercised without first relieving pressure.
 - Fittings and equipment can fail or be incorrectly chosen for a given application (not rated for the system operating or maximum pressures)
 - Transfer lines can be cold; fittings can reach cryogen temperature.
 - Valves and fittings are purposefully manipulated so hands must be protected. Accidental contact with other skin surfaces presents little risk.
 - Misaligned or loose fittings can leak which can result in an uncontrolled, pressurized stream of liquid or vapor.
 - Line transfer can be loud.
- The 'worst case' accident here involves the kind of mistakes that can be made with any pressurized system where there is a sudden release of energy resulting from component failure or human error. Release of cold gasses under these failure circumstances presents additional risk of tissue damage.

Required Precautions

- The same precautions listed above for pouring between open containers apply to dispensing from a line to an open container. Additional precautions follow:
 - Transfer lines get cold. Care is needed to avoid skin contact with lines, fittings, and the line outlet.
 - The line outlet must be fitted with a fritted fixture for diffuse liquid transfer to minimize splashing. *[Open dewar fill only]*
 - Care is required when connecting threaded fitting to assure no cross threading and application of adequate torque.
 - Pressure must be relieved to ambient before manipulating fittings.

PPE requirements

- **Hand protection;** Insulated cryo-gloves or heavy duty leather gloves that extend beyond the wrist. Gloves must be loose fitting to allow rapid removal should a liquid splash enter the glove.
- **Arm Protection;** Long sleeve shirt or laboratory coat (fabric must be tightly woven to avoid rapid wicking of liquid splashes).
- **Eye protection;** Face shield worn over ANSI Z87.1 compliant safety glasses with side shields. Alternatively a face shield may be worn over ANSI Z87.1 compliant, vented splash goggles.
- **Hearing protection;** Ear protection requirements are determined by the fill circumstances. Some applications can result in noise levels that exceed BNL allowable limits.

LN2: Work with experiment samples immersed in LN2 in small (~1 liter) dewars.

This task involves working with small (~2 cm diameter; ~4 cm long) cylindrical sample holders in close proximity to LN2 and with tools (tongs or forceps) in contact with LN2. Fine manipulations with sensitive dexterity are required.

Hazard Analysis

- Splashes can result when moving holders in and out of the dewar, particularly when inserting a room temperature holder.
- Working in close proximity to the liquid can result in accidental immersion of the fingers.
- Spill potential negligible
- Tools can reach LN2 temperature.

Required Precautions

- Whenever practical, tools must be used to manipulate samples.
- Extreme attention to detail must be exercised during hand manipulation near liquid.

PPE Requirements

- **Hand protection;** Cotton or nylon gloves covered with disposable Purple Nitrile® or some similar glove arrangement that provides basic protection yet still allows adequate dexterity.
- **Eye protection;** ANSI Z87.1 compliant, vented splash goggles.

LN2 Cold Stream Operation

Set up and filling of the large (~180 liter) LN2 dewar from the NSLS LN2 storage tank is the same as working with closed line LN2 transfers. Operation of the cold stream presents negligible risk and requires no precautions or PPE

Dry Ice Handling

Hazard Analysis

- Dry ice is cold enough to present risk of tissue damage with prolonged skin contact. Water on the skin can freeze on contact and cause the skin to stick to the ice.
- As dry ice is solid, there is no splash risk.

No special precautions are required

Required PPE

- **Hand protection;** Insulated cryo-gloves or heavy duty leather gloves.

Reference

Safe Handling of Cryogenic Liquids, 4th Edition; Compressed Gas Association, Inc.

| Operation | Significant Hazard | REQUIREMENTS | | | | | | Remarks |
|---|--|--|----------------|---|---------------|---------------------------|-------------------------------|---|
| | | Face Shield combined with either Safety Glasses (w/side shields) or Safety Goggles | Safety Goggles | Gloves (Cryo or Heavy Leather) | Closed Shoes* | Long pants or long skirt* | Long Sleeve Shirt or Lab Coat | |
| Pouring small (5 liters or less) volumes of LN2 between open containers | Eye injury from splashing | | X | X | X | X | X | Never pour from above chest level (see note 1) |
| Dispensing LN2 from a pressurized line to an open dewar. Closed line LN2 or LHe transfer Pouring large (>5l) volumes of LN2 between open containers | Frostbite & burns from cold surface contact; Eye and skin injury from splashing; Sudden, unexpected release of pressurized cold gas. | X | | X | X | X | X | |
| Work with experiment samples immersed in LN2 in small (~1 liter) dewars. | Frostbite & burns from cold surface contact | | X | Use insulated non-absorbent gloves with dexterity | X | X | | Tongs should be used where possible to manipulate specimens |

* General Non-Office Area Requirement

Note 1: Some physical configurations make it extremely difficult to comply with this requirement. If it appears that pouring must be performed with the dewar at a position that is above chest height, then prior approval of the Department ESH Committee must be obtained. Engineered solutions and/or additional PPE will be required as determined by the committee.

Regulatory Requirements

Outline

OSHA

OSHA provides no standard specific to cryogen use. The OSHA standards for, “Personal Protective Equipment; General Requirements (29 CFR 1910.132)” and for, “Compressed Gasses; General requirements (29 CFR 1910.101)” apply.

29 CFR 1910.132(d) outlines requirements for, “hazard assessment and equipment selection.” This rule is intended to allow employers discretion in their choice of PPE requirements and requires that a written hazard assessment be developed to determine the PPE needed to afford adequate protection based on the materials used and the tasks to be completed.

29 CFR 1910.101(b) references the Compressed Gas Association Pamphlet P-1-1965, “Safe Handling of Compressed Gasses”

Compressed Gas Association (CGA)

CGA is an industry group that provides guidance to users of compressed gas. They publish guidance pamphlets and three of the their pamphlets are pertinent here; P-1-1965, “Safe Handling of Compressed Gasses”, P-1-2006, “Safe Handling of Compressed Gases in Containers”, and P-12-2005, “Safe Handling of Cryogenic Liquids”

P-1-1965 is included to the OSHA rules by reference and so the guidance contained in that document has the status of legal requirement. This pamphlet has contains no PPE requirements for cryogen use. Section 3.7.2 indicates that persons handling cryogens are advised to contact the supplier for handling information.

P-1-2006 is the latest version of the CGA P-1 pamphlet. The guidance in this newer version does not have the status of legal requirement. Section 6.7.1 indicates that persons working with cryogenic liquids should wear ‘suitable’ eye protection such as a face shield and safety glasses or safety goggles, hand protection such as loose fitting insulated gloves, long sleeve shirts, and cuffless trousers over high topped shoes.

P-12-2005 is specific to cryogenic liquids and is not a legal requirement document. Section 5.2.6 indicates the following:

- Safety glasses with side shields are required for transfer and ‘normal’ handling.
- A face shield or goggles are needed when transferring from open topped containers or open ended piping.
- Insulated gloves are needed when handling anything in contact with cryogenic liquids. Gauntlet style gloves are needed when there is risk of spills like might occur from a broken hose. Leather is recommended.
- Trousers should have no cuffs and be left outside of work shoes or boots.

10 CFR Part 851

There is no reference to the Compressed Gas Association in 10 CFR part 851. OSHA rules are incorporated into this standard and so are legal requirements for all DOE sites.

Analysis

The salient rule here is the OSHA PPE standard (29 CFR 1910.132). That standard was developed in recognition that PPE decisions can only be made well through task specific hazard assessment. The PPE standard contains detailed guidance on performance of that assessment. PPE decisions are to be made by qualified personnel with a technical basis and must be well documented.

The CGA pamphlets provide very limited guidance on PPE selection, contain no quantity thresholds, and are intended as guidance for industrial cryogen users. Verbatim compliance with these guidelines is not intended. Instead, they provide some guidance to users for help in developing requirements specific to their operations. The advice given to contact suppliers for help in determining handling requirements is sensible, but suppliers can not accept responsibility for and are likely not qualified for completing hazard assessments at BNL. That responsibility must reside with BNL.

| | |
|-------------------------------|-------|
| APPROVAL (if required) | |
| Andrew Ackerman | Date: |