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Sponsor: Dori Ellis, 4000, Acting

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GN470100 – SAFE HANDLING OF CRYOGENIC FLUIDS

Subject Matter Expert: Roger Shrouf
GN470100, Issue B
Revision Date: October 31, 2006; Replaces Document Dated: April 13, 1999
Review Date: October 16, 2006

* Indicates a substantive change

Change History

APPLICABILITY AND OWNERSHIP

For purposes of this document, Members of the Workforce are:

- Sandia employees.
- Sandia contractors as specified in Section 1B, "What Is the Scope."

This document applies to all operations that use cryogenic fluids in either open or closed handling operations and supplements MN471000, *Pressure Safety Manual.*

Although this document addresses cryogenic safety issues in general, it primarily focuses on, and gives specific examples of, the inert cryogenic fluids of liquid nitrogen, liquid helium, or liquid argon. Liquid nitrogen is the most frequent cryogenic application at SNL.

A thorough evaluation of the safety of a cryogenic application may require a joint effort involving safety engineering, industrial hygiene, and facilities organization(s) for design and maintenance. Division ES&H Teams provide assistance in establishing the appropriate reviews.

The ES&H Teams and Safety Engineering Department (10322) is responsible for the development, approval, revision, and administration of this document. Forward suggestions for improvement to the manager of the ES&H Teams and Safety Engineering Department.

TRAINING

Requirements

Members of the Workforce whose activities involve cryogenics shall:

- Complete the appropriate training as required in CPR400.1.1.27/MN471000, Pressure Safety Manual, Chapter 2, "The Pressure Safety Program."
- Before beginning operations involving cryogenics, be trained on site-specific procedures for safe operations, including training on:
    - Applicable operating procedures.
    - Original equipment manufacturer's procedures.
    - Valve sequencing checklists.

Note: Members of the Workforce whose activities involve the use of cryogenic fluids may use SF 2001-PQF, Pressure System Operator Qualification Form (Word file/Acrobat file), to document their qualifications, such as training.

CRYOGEN HAZARD AWARENESS

Requirements

Members of the Workforce who handle cryogens or operating cryogenic fluid handling systems shall:

- Be aware of the hazards related to the equipment.
- Know the methods for controlling those hazards.
- Follow the proper operating procedures applicable to the equipment.

Cryogenic burns can be serious. Members of the Workforce shall select the appropriate level (s) of protection commensurate with their application. Considerations include:

- The eyes are especially sensitive and require protection from splashes or sprays of cryogenic fluids.
- Fingers (or hands) are also frequently involved in accidents.
- Large quantities or pressurized streams of cryogenic liquids present a higher level of

hazard.

The use of PPE is discussed in "Personal Protective Equipment (PPE)."

Guidance

The tables in Attachment A identify properties and the major hazards associated with the use of inert cryogenic liquids, focusing primarily on liquid nitrogen. The hazard list should **not** be considered all-inclusive.

DESIGN FOR SAFETY

Requirements

Cryogenic system owners shall be responsible for the design, operation, and maintenance of laboratory cryogenic systems and shall verify that:

- All apparatus for handling cryogenic liquids is constructed of compatible materials and designed according to the requirements of MN471000, Pressure Safety Manual, and other applicable industry standard requirements.
- Pressure relief is provided for all applicable spaces, such as where cryogenic liquids can be trapped.
- Relief valves vent to safe locations.

Guidance

Laboratory personnel **should not** authorize or perform maintenance or modification on facilities-owned system or to the facilities-owned portion of a system.

Specific operator aids, such as valve sequencing checklists, are encouraged. Technical work documents (TWDs) may be needed in cases where the level of hazard or operational complexity warrants; see MN471001, ES&H Manual, Chapter 21, "Technical Work Documents (TWDs)."

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*PERSONAL PROTECTIVE EQUIPMENT (PPE)

*Requirements

Engineered controls should be the primary means of worker protection. Where engineered controls may not be complete or feasible, workers shall wear the appropriate PPE to augment any engineered controls in place. Members of the Workforce shall wear:

- PPE where there is a reasonable potential for injury that could be prevented by the use of such protective equipment.
- The appropriate levels of protection commensurate with the level of hazard associated with a given activity.
- Safety glasses with side shields or indirect vented style goggles, as a minimum, for the open handling of cryogens.
- A face shield when the application involves more severe splashing or potential exposure to pressurized sprays of liquids or cold gases.

  Note: Consult with the appropriate Division ES&H Team to determine the need for utilizing a face shield.

- Insulating gloves to protect the hands when the potential exists for injury from exposure to cryogenic liquids, cold gases, or surfaces cooled to low temperatures (e. g., uninsulated transfer lines and tubing).

  Note: Gloves should be loose fitting and easy to remove in the event that liquid is spilled into the glove. Trapping a liquid cryogen in contact with the skin, such as within a glove, shoe, or boot, will result in cryogenic burns. Cryogenic aprons and sleeves are also available for additional protection.

- Safety shoes when there is a reasonable potential for foot injury from lifting or rolling heavy dewars or other equipment.
- Hearing protection during transfer operations generating high noise levels.

  Note: Consult the appropriate Industrial Hygiene team member to determine the need for hearing protection.

Members of the Workforce shall **not** wear:

- Open-toed shoes or sandals when handling cryogenic fluids.

  Note: Certain types of personal attire (e.g., shorts) also increase the risk of exposure to cryogenic liquid hazards and are not recommended.

Guidance

Members of the Workforce should be aware that certain types of operations may also increase the risk of exposure to cryogenics and the selection of appropriate PPE should carefully be considered for these operations, the specific system configuration, and the potential for exposure to the hazards. Examples of these operations are:

- Dewar filling operations where Members of the Workforce could be exposed to pressurized sprays or splashing.
- Making or breaking of connections where residual amounts of liquid or gas under pressure may be encountered.
- Inserting probes or other instrumentation into liquid baths producing rapid boiling of the cryogenic liquid.

Cryogenic system owners should be involved in the design of cryogenic fluid handling systems, such as fill stations, to verify that systems are designed to minimize exposure to the liquids, gases, and cold surfaces.

The handling of cryogens within closed systems with the controlled venting of liquids or boil-off gases may not require the use of PPE. Each system should be carefully evaluated for potential exposure to personnel. The system integrity and layout, as well as the frequency of making and breaking connections should be taken into consideration. Remember to vent system pressure before breaking connections. Consider using PPE (eye and hand protection) when breaking connections in order to prevent exposure to residual amounts of liquid or cold gases.

CRYOGENIC LIQUID HANDLING EQUIPMENT

Requirements

Managers shall be responsible for verifying that:

- Members of the Workforce use only equipment intended for cryogenic service during activities involving cryogens.
- Commercial equipment is **not** modified in a fashion that could defeat the designed safety features of the equipment or otherwise create an unforeseen hazard, such as inadequate venting of cryogen spaces.
- All spaces of a vessel or piping system containing cryogenic liquids shall have adequate pressure relief.

  Note: consumer products, such as Thermos® bottles, are not approved for cryogenic applications. Although the container itself may hold cryogenic liquid in an adequate manner, the lid, even when loosely applied, does not allow for proper venting of boil-off gases.
- Piping and connections for pressurized cryogenic liquid handling systems are constructed of safe materials and maintained in leak free, good condition, including dewars, flex lines, tubing, valves, fittings, brazed joints, transfer equipment, and pressure relief valves. Failures involving these components could result in exposure of personnel to pressurized sprays of the cryogenic liquid.
- Pressure relief is provided for any piping segment that has the potential to trap cryogenic fluids (i.e., cryogenic fluid trapped between closed valves).
- Pressure relief is provided for any sections of a dewar containing cryogenic fluid.
- Pressure relief is provided in vacuum insulation spaces to address potential leakage of cryogenic fluids into the vacuum space.

Guidance

Members of the Workforce may provide pressure relief by opening vent lines, pressure relief valves or burst disks, depending on the application. See Figure 1 for an illustration of pressure relief locations.

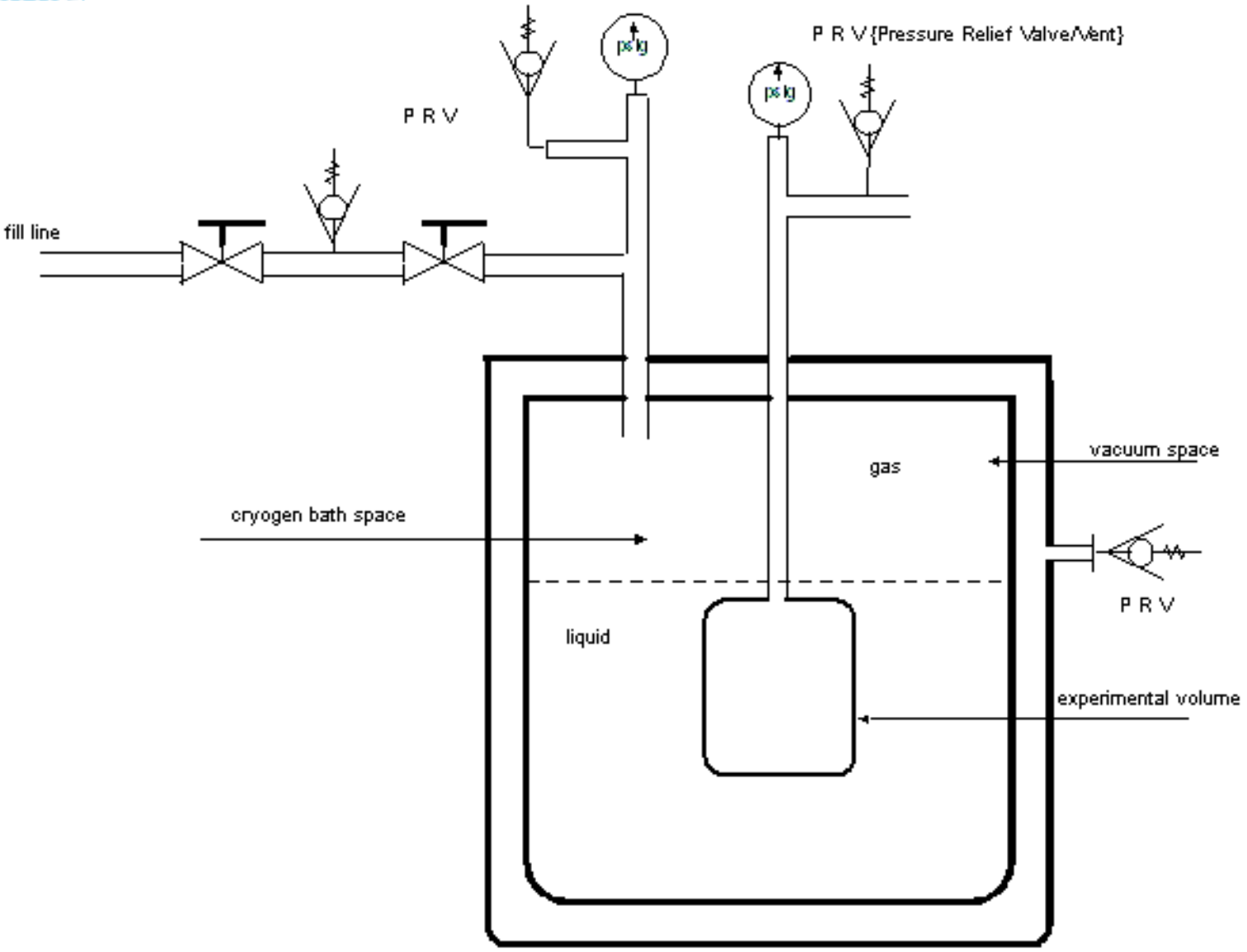

Figure 1. Pressure Relief Locations.

MATERIALS OF CONSTRUCTION

Guidance

Members of the Workforce should verify that material and equipment that are used in cryogenic applications are constructed only of materials that do not become brittle and hazardous at low temperatures. In general, carbon steels and iron become brittle and fracture easily at cryogenic temperatures and are not suitable for these applications. Common acceptable materials include the 300 series stainless steels, copper, and brass. If brittle materials are used, equipment owners should consider mitigating hazards by using shielding or remote testing.

OXYGEN MONITORS

Guidance

Members of the Workforce should consider using oxygen monitors in laboratories where the potential to create an oxygen-deficient atmosphere warrants them. Contact the appropriate Division ES&H Team for assistance in determining the need for oxygen monitors.

*OPERATIONAL CONCERNS

*Requirements

During operations involving cryogenics, Members of the Workforce shall:

- Only operate systems for which they are trained and authorized, e.g., laboratory personnel **shall not** operate or modify house systems.
- Validate that applicable valves are labeled in agreement with drawings or checklists and readily accessible to laboratory and emergency response personnel.
- Pay attention to unusual behavior of equipment that may signal a malfunction or a potential hazard. These include elevated pressure, the unexpected formation of frost on components, excessive or unusually frequent refill cycles, or the failure of a system to purge or vent per normal operations. See Figure 1 in Attachment A for discussion of LN_2 house systems.
- Transfer cryogenic liquids slowly and at low pressure to minimize the splashing and boil-off of liquid, insert transfer lines slowly to minimize boil-off of cryogen liquids and the resultant pressure increase, and check the pressure on storage dewars before starting transfer procedures.
- Pump or purge air out of transfer lines and experimental apparatus before transferring cryogenic liquids, especially LHe.

- Keep containers for cryogenic liquids clean and free of contamination from fuels, oils, and greases.

- Verify that open LN_2 dewars have insulating covers or loose fitting stoppers to reduce the condensation of air into the LN_2 while still allowing for venting of the LN_2 gas. See Attachment B for example valve sequencing instructions for an LN_2 fill station.

- Continuously attend manually operated valves during operation.

  Note: Hazardous quantities of cryogenic liquids can be released into lab spaces or into building exhaust systems when manual valves are left unattended. When pre-cooling house LN_2 piping lines, consider where the liquid and the resultant boil-off gas is going and at what point will it begin to collect as a liquid and present a hazard. The overflow of cryogenic liquids may present an immediate hazard to personnel and facilities.

- Use cryogenic liquids only in well-ventilated areas or with local exhaust ventilation.

  Note: Both system design and operational practices should be used to limit accidental releases of cryogenic liquids. Consider the use of small volume sources (as opposed to large volume house sources) of cryogenic liquids as a way to limit accidental releases.

- Wear the appropriate PPE for a given application as determined by the potential for exposure to the hazards. PPE s hall be consistently used during cryogenic liquid operations.

- Secure cryogenic dewars from physical damage. Consider, where applicable, the potential for seismic activity or strong winds pushing a dewar across the dock pad, or the potential for damage by vehicle traffic.

- For transport of cryogenic dewars in elevators, allow only individuals associated with the transport of the dewar into the elevator at the time of transport.

At the conclusion of operations, Members of the Workforce shall verify that appropriate valves are shut off.

In the event of an emergency, Members of the Workforce shall:

- Evacuate or **not** enter the area when oxygen monitors indicate a lack of oxygen.

- Notify personnel in surrounding areas who may be affected.
- Seek medical attention for any injuries or cryogenic burns.
- Report the event, as appropriate (see "ES&H Documentation and Reporting/ Notification").

WASTE DISPOSAL

Requirements

Members of the Workforce **shall not:**

- Dump liquid cryogens into any drain.
- Accumulate liquid cryogens in significant quantities in areas not appropriate for that purpose.

Note: Even relatively small quantities can damage equipment or facilities, such as crack floor tiles, damage water pipes, and damage electrical insulation on wiring. Also, consider the hazard presented by the boil-off gas when any significant quantities of a cryogenic liquid are released.

Guidance

Contact the appropriate Division ES&H Team for assistance in determining the best way to dispose of cryogenic liquids.

ES&H DOCUMENTATION AND REPORTING/ NOTIFICATION

Requirements

Members of the Workforce shall apply the requirements for pressure safety aspects of a

cryogenic fluid handling system as stated in MN471000, Pressure Safety Manual.

For SNL designed and assembled systems, the system owner shall compile a data package according to the requirements in MN471000, Pressure Safety Manual.

Guidance

Any significant accidental releases should be reported to the appropriate manager and center ES&H coordinator. Notification through an emergency or nonemergency hotline may be appropriate, depending on the severity of the release. Any personnel in the vicinity who could be exposed to the hazards of the release should also be notified. A predetermined point of contact, such as the person responsible for ordering the product, could also be useful because the schedule for re-ordering may be affected by large volume releases.

Note: Incidents that are reported to the nonemergency hotline are useful in tracking and analyzing accident and failure scenarios, determining trends, and changing engineering configuration or procedures.

Commercial (off-the-shelf) vessels may be used as is, but available owner or operator manuals should be retained for reference as part of the system data package.

POINTS OF CONTACT

Guidance

For assistance on cryogenic fluid applications, including safety engineering, industrial hygiene, and the facilities engineering and maintenance organization(s), Members of the Workforce should contact the appropriate Division ES&H Team. The organization's pressure advisor may also provide assistance.

Members of the Workforce should contact facilities organizations, such as the Mechanical and Civil Engineering Department, for assistance with the design, installation, maintenance, and modification of LN_2 house systems.

RELATED HAZARDS AND ACTIVITIES

Hazards and activities related to the use of cryogenic fluids include:

Hazard/Activity	Reference
Asphyxiation	Section 6R, "Indoor Air Quality"
Confined spaces	Section 6I, "Confined Space Entry" Section 6T, "Confined Space Entry at SNL/CA"
Pressure	MN471000, Pressure Safety Manual

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*REFERENCES

*Requirements Source Documents

29 CFR 1910.101, *Compressed Gases*

49 CFR 173.316, *Cryogenic Liquids in Cylinders*

ANSI/ASME B31.3, *Process Piping*

ASME Section VIII Division 1

CGA Publication P-12, *Safe Handling of Cryogenic Liquids*

*NFPA 55, *Standard for the Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders, and Tanks*

*Public Law 91-596

*International Fire Code (IFC)

Implementing Documents

SNL, MN471000, *Pressure Safety Manual*

Related Documents

British Cryogenics Council, Safety Panel, *Cryogenics Safety Manual*

Edeskuty, F. J., and W. F. Stewart, *Safety in the Handling of Cryogenic Fluids*

Timmerhaus, K. D., and T. M. Flynn, *Cryogenic Process Engineering*

Back to Supplements

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CHANGE HISTORY
GN470100, *Safe Handling of Cryogenic Fluids*

October 31, 2006

Note: (*) asterisk denotes substantive change.

This chapter was revised to:

- **Add:** The Review Date to the header to indicate that an ES&H Manual Self-Assessment (SA) was completed on this section.

- Under topic, “Applicability and Ownership”:

  - **Change:** The organization number for the Safety Engineering Department in the last paragraph **from** “7527” **to** “10322.”

- Under topic, “Personal Protective Equipment (PPE)”:

  - ***Change:** The second sentence in “Requirements” **from** “Where engineered controls may not be complete or feasible, workers should wear the appropriate PPE to augment any engineered controls in place” **to** “Where engineered controls may not be complete or feasible, workers shall wear the appropriate PPE to augment any engineered controls in place.”

  - **Delete:** The following note listed after the second bullet in “Requirements”:

    - **Note:** Certain types of personal attire (e.g., shorts, skirts, open-toe shoes, or sandals) increase the risk of exposure to cryogenic liquid hazards and the wearing of them should be considered when selecting PPE.

  - ***Change:** The third bullet listed under “Requirements” **from** “Safety glasses with side shields or goggles, as a minimum, for the open handling of cryogens” **to** “Safety glasses with side shields or indirect vented style goggles, as a minimum, for the open handling of cryogens.”

- ***Move:** The first four bullets **from** "Guidance" **to** "Requirements," and rephrase these new requirements (some with added notes) as follows: Members of the Workforce shall wear:
  - A face shield when the application involves more severe splashing or potential exposure to pressurized sprays of liquids or cold gases.
    - **Note:** Consult with the appropriate Division ES & H Team to determine the need for utilizing a face shield.
  - Insulating gloves to protect the hands when the potential exists for injury from exposure to cryogenic liquids, cold gases, or surfaces cooled to low temperatures (e.g., uninsulated transfer lines and tubing).
    - **Note:** Gloves should be loose fitting and easy to remove in the event that liquid is spilled into the glove. Trapping a liquid cryogen in contact with the skin, such as within a glove, shoe, or boot, will result in cryogenic burns. Cryogenic aprons and sleeves are also available for additional protection.
  - Safety shoes when there is a reasonable potential for foot injury from lifting or rolling heavy dewars or other equipment.
  - Hearing protection during transfer operations generating high noise levels.
    - **Note:** Consult the appropriate Industrial Hygiene team member to determine the need for hearing protection.
- ***Add:** The following requirement and associated note: "Members of the Workforce shall **not** wear:
  - Open-toed shoes or sandals when handling cryogenic fluids."
  - **Note:** Certain types of personal attire (e.g., shorts) also increase the risk of exposure to cryogenic liquid hazards and are not recommended.

- Under topic, "Operational Concerns":

- ***Add:** The following requirement after the eleventh bullet:
  - For transport of cryogenic dewars in elevators, allow only individuals associated with the transport of the dewar into the elevator at the time of transport.

- Under topic, “References”:
  - ***Replace:** Requirement Source Documents “NFPA 50” and “NFPA 50B” with “NFPA 55”. These requirements have been superseded by NFPA 55.
  - ***Change:** Requirement Source Document “Public Law 91-596, Section 5, Duties, November 5, 1990” **to** “Public Law 91-596.”
  - ***Replace:** The Requirement Source Document “Uniform Fire Code” and all associated subordinate Articles and Standard listed with “International Fire Code (IFC).”

Administrative Changes Only
June 29, 2005

This document was administratively revised to:

- **Change:** Executive Policy Sponsor from Les Shephard to Frank Figueroa

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Administrative Changes Only
May 30, 2003

This document was administratively revised to:

- **Change:**
  - Under the topic, "Training," the training table was replaced by a link that connects to the training requirements in MN471000, *Pressure Safety Manual*, Chapter 2, "The Pressure Safety Program," Table 2-1, "Training for Pressure System Personnel."

- Personnel who have completed PRS102 prior to December 2000, are strongly encouraged to take PRS150.

April 13, 1999

Created new supplement to:

- **Provide** specific information for personnel who use cryogenic fluids with or without associated pressure.
- **Add** definitions for the following terms:

- Ar
- bcc
- Closed handling of cryogens
- Closed cycle cryogenic system
- Cryogenic fluid
- Dewar
- fcc
- He
- House system
- H_2
- Inert
- LAr
- LH_2
- LHe
- LN_2
- N_2
- LOX
- O_2
- Open handling of cryogens

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GN470100 - Safe Handling of Cryogenic Fluids

ATTACHMENT A – HAZARDS ASSOCIATED WITH INERT CRYOGENIC LIQUIDS

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GN470100, Issue B
Revision Date: October 31, 2006; Replaces Document Dated: April 13, 1999
Review Date: October 16, 2006

The following tables identify properties and the major hazards associated with the use of inert cryogenic liquids, focusing primarily on liquid nitrogen. The hazard list should **not** be considered all-inclusive. Properties and hazards associated with cryogens include:

Cryogen	Temperature @ 1atm °F/(K)	Liquid/gas expansion	Pressure generated from trapped liquid – allowed to warm to room temperature
LOX	- 297 (90.2)	860 to 1	[Not Specified]
LAr	- 302 (87.3)	847 to 1	[Not Specified]
LN_2	- 320 (77.4)	696 to 1	43,000 psi
LH_2	- 423 (20.3)	851 to 1	25,000 psi
LHe	- 452 (4.2)	757 to 1	15,000 psi

Hazard	Description
Thermal (low temperature)	Contact with cryogenic liquid, its boil-off gases, or components cooled to these low temperatures can readily cause frostbite or cryogenic burns. In addition, the accidental release of these cryogens into the work area can damage equipment and property (e.g., frozen water pipes, damaged flooring, damaged electrical cables and their insulation).

Pressurization	Cryogenic fluids, confined and allowed to warm, can generate very high pressures. LN_2 confined and allowed to warm up to room temperature will generate a pressure of ≈ 43,000 psig. The pressure similarly generated by LHe is 18,000 psig. Other cryogens behave in similar fashion. Dry ice (CO_2) can generate hundreds of psig pressure if confined. See Attachment B for example valve sequencing instructions for an LN_2 fill station. This points out the potential for rupture of piping or vessels if appropriate venting and pressure relief is not provided. The function of vent lines can be defeated by the formation of ice (from condensed moisture) in the vent line. With LHe, air or other gases can be solidified to form this blockage. If a cryogenic fluid is subjected to a large amount of heat input, a flash vaporization can occur. This will result in a rapid pressure rise that can be described as a BLEVE (boiling liquid expanding vapor explosion).
Venting	Required vents and pressure relief devices should be vented to a safe location, considering the specific cryogen in question, the volume and flow rates of the potential releases, and the potential hazards presented by accumulation of the gases or liquids being vented.
Oxygen deficiency/asphyxiation	Cryogenic fluids have large liquid to gas expansion ratios, with LN_2 ≈ 680 to 1, (based on volume), LHe is ≈ 740 to 1, and LAr ≈ 820. With this in mind, it should be noted that any accidental release or overflow of these cryogenic liquids will quickly boil into the gas phase and may create an asphyxiation hazard by displacing the oxygen content of the surrounding area. In the case of LN_2, the N_2 gas generated from malfunctioning equipment or spills of LN_2 will be cold and denser than ambient air. Even well-ventilated lab spaces that have pits or other low-lying (or recessed) areas could have the oxygen displaced by this cold, dense N_2 gas. Argon or carbon dioxide will also present these heavier-than-air hazards. Large volume sources used in small laboratory spaces or in poorly ventilated areas increase the asphyxiation hazard. Oxygen monitors may be advisable in some applications.

Ice build-up	The temperatures associated with cryogenic liquids can easily condense moisture from the air and cause the formation of ice. This ice can cause a malfunction from the design intent of components or systems (e.g., plug vent lines and impede valve operation) or can damage piping systems. In the case of LHe, air itself can freeze solid and block vent lines. Building exhaust systems accidentally cooled to LN_2 temperatures can also be damaged by ice formation (or the weight of the accumulated ice and the weight of the LN_2 itself). The resultant run-off water when the ice melts can also present a hazard.
Materials concerns	The low temperature of cryogenic liquids will adversely affect the properties of some materials resulting in system or vessel failure. The selection of the materials of construction for vessels and piping systems for cryogen handling should consider the appropriate behavior of the material at the cryogenic temperatures. In general, carbon steels and other bcc-structured metals can become brittle and fracture easily at cryogenic temperatures. Commonly accepted materials of construction include fcc-structured metals such as the 300 series stainless steels, some of the aluminum alloys, and copper or brass. Plastics, such as Tygon® tubing, become brittle and can easily fail in cryogenic applications. Be sure to consult the appropriate references when selecting materials for cryogenic applications. Even when the appropriate materials are selected, thermal stresses that can lead to failure can be generated in some applications. Thermal gradients across a material or piping system or the rapid cool-down of a vessel can generate thermal stresses. The joining of materials with dissimilar coefficients of expansion can also generate thermal stresses.
Oxygen enrichment	LN_2 is cold enough to condense the surrounding air into a liquid form. The concentration of O_2 in this condensed air is enhanced. This condensed "liquid air" can be observed dripping from the outer surfaces of uninsulated/nonvacuum jacketed lines carrying LN_2. This "liquid air" will be composed of ≈ 50% O_2, and will amplify any combustion/flammable hazards in the surrounding areas. Open dewars of LN_2 can condense O_2 from the air into the LN_2 and cause an O_2 enrichment of the liquid, which can reach levels as high as 80% O_2. Air should be prevented from condensing into LN_2 by the use of loose-fitting stoppers or covers that still allow for the venting of

	LN_2 boil-off gas. Large quantities of LN_2 spilled onto oily surfaces (such as asphalt) could condense enough O_2 to present a combustion hazard. In some cases, such as a large-volume LN_2 spill onto asphalt, the surface can become saturated with condensed oxygen and can be shock sensitive (can detonate when shocked). LHe can also condense air into the liquid or even the solid phase with an enriched O_2 content.
Lifting, physical	Studies of accident statistics involving cryogenics will always include back strains or other lifting injuries associated with dewars. Although this hazard is not specifically cryogenic in nature, it is appropriate to note this as a hazard associated with cryogenic applications. Care should be taken in the lifting and movement of cryogenic dewars. The proper use of carts or hand trucks can help prevent these injuries. Alternately, the use of low-pressure liquid transfer equipment and procedures can replace lifting and pouring operations.
LN_2/ionizing radiation field	A unique hazard can result from the use of LN_2 in high ionizing radiation fields where the generation of ozone or nitrogen oxides may cause a potential explosion hazard when the LN_2 has condensed quantities of oxygen from the atmosphere. The applicable control measure is to minimize the accumulation of oxygen into the LN_2 and to keep containers free of hydrocarbon contamination.
Noise	Transfer or venting of cryogens can generate, in some cases, noise levels that could require hearing protection. Sound levels in excess of 150 dBA have been recorded during routine tank filling. A redesign of the equipment or procedure could also be addressed in these cases.
Other, specific	Other cryogenic fluids will present specific hazards in addition to the above concerns. Examples include: • LOX and the additional hazards of enhanced combustion, with materials compatibility and cleanliness (hydrocarbon contamination) as added concerns. • LH^2 and the additional hazards of flammability and materials embrittlement, with the added concerns of low ignition energy, proper bonding and grounding of equipment, and venting of boil-off gases. • Toxicity concerns of carbon monoxide (CO) and fluorine. This list is not to be considered as all-inclusive. Seek additional

	guidance from the appropriate Division ES&H Team for a thorough hazard analysis and safe operation of these systems.

SNL personnel should have an awareness of known, common accident scenarios for the SNL environment. The following table lists known, common accident scenarios involving LN_2 applications.

Injury/Event	
Accidental releases (or overflows)	Accidental releases (or overflows) of LN_2 can present hazards and cause property damage as noted in the hazards discussed above. This most often is a result of inadequate training on the specific hazards and procedures. These releases can come from automated level control systems, but more frequently are the result of manual operations left unattended. The level of concern over these releases increases with the volume of the cryogen source. House LN_2 systems represent very large quantities with the potential for release. Separate (stand-alone) supply dewars are inherently safer in this respect because they have smaller volumes. Releases into the building or lab space are the most hazardous, presenting the primary hazards of asphyxiation, personnel exposure, and property damage may result from significant releases of LN_2.
Releases into building exhaust systems	Releases into building exhaust systems also can present significant hazards. These releases typically occur when the operator opens a bypass valve in an attempt to pre-cool the piping to LN_2 temperatures and then mistakenly leaves the bypass valve open. See Figure 1 for a typical house LN_2 system configuration. These releases can adversely affect the normal operation of the building's exhaust system or can cause the exhaust system to fail and release significant quantities of LN_2 into the building's air space. Figure 1 shows one of the piping configurations installed in some SNL buildings. This configuration presents the potential for human error in that the bypass valve can be left open and the system emptied without the operator knowing it.

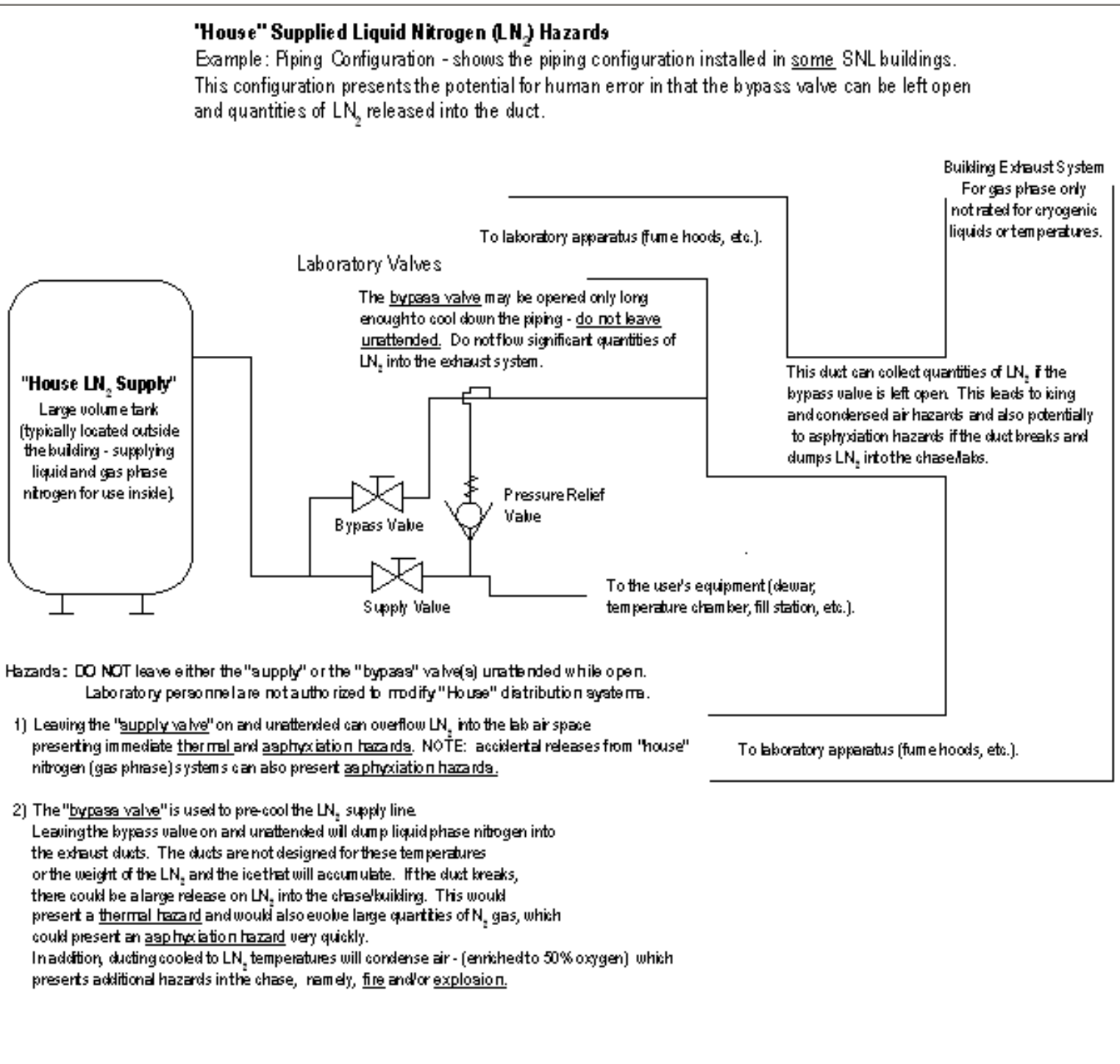

Figure 1

Pressure buildup (pressure relief valves [PRVs])	Pressure relief valves (PRVs) are required on cryogenic liquid piping systems to prevent excess pressure build-up when the liquid is trapped between closed valves. These PRVs should be vented to a safe location (not into the lab or the ceiling plenum) in order to prevent a hazardous accidental release upon actuation of the valve or on failure of the valve to re-seal. In addition, the PRV should be rated for that specific application. PRVs rated for LN_2 are not appropriate for liquid CO_2 applications.

Back injuries	Back injuries may result from lifting cryogenic liquid dewars.
Tipping of dewars	Storage dewars of LN_2 or LHe may be accidentally tipped over when crossing obstructions, such as door thresholds. Handle these dewars with the appropriate care and on the appropriate floor surfaces. Maintain the general condition (wheels, handles, etc.) of the dewars in proper functioning condition.
Accidents caused by equipment failure (equipment not designed for cryogenic service)	Cryogenic fluids should only be handled in apparatus specifically designed for that purpose. Accidents frequently occur where equipment not designed for cryogenic service is used, such as when a consumer-rated Thermos® bottle is used for LN_2 or dry ice. Over pressure and resultant rupture of the container is frequently the result. These types of accidents can also occur when cryogenic-rated equipment is inappropriately modified and the original safe venting design is compromised.

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GN470100 - Safe Handling of Cryogenic Fluids

ATTACHMENT B – EXAMPLE VALVE SEQUENCING INSTRUCTIONS FOR AN LN_2 FILL STATION

Subject Matter Expert: Roger Shrouf
GN470100, Issue B
Revision Date: October 31, 2006; Replaces Document Dated: April 13, 1999
Review Date: October 16, 2006

INTRODUCTION

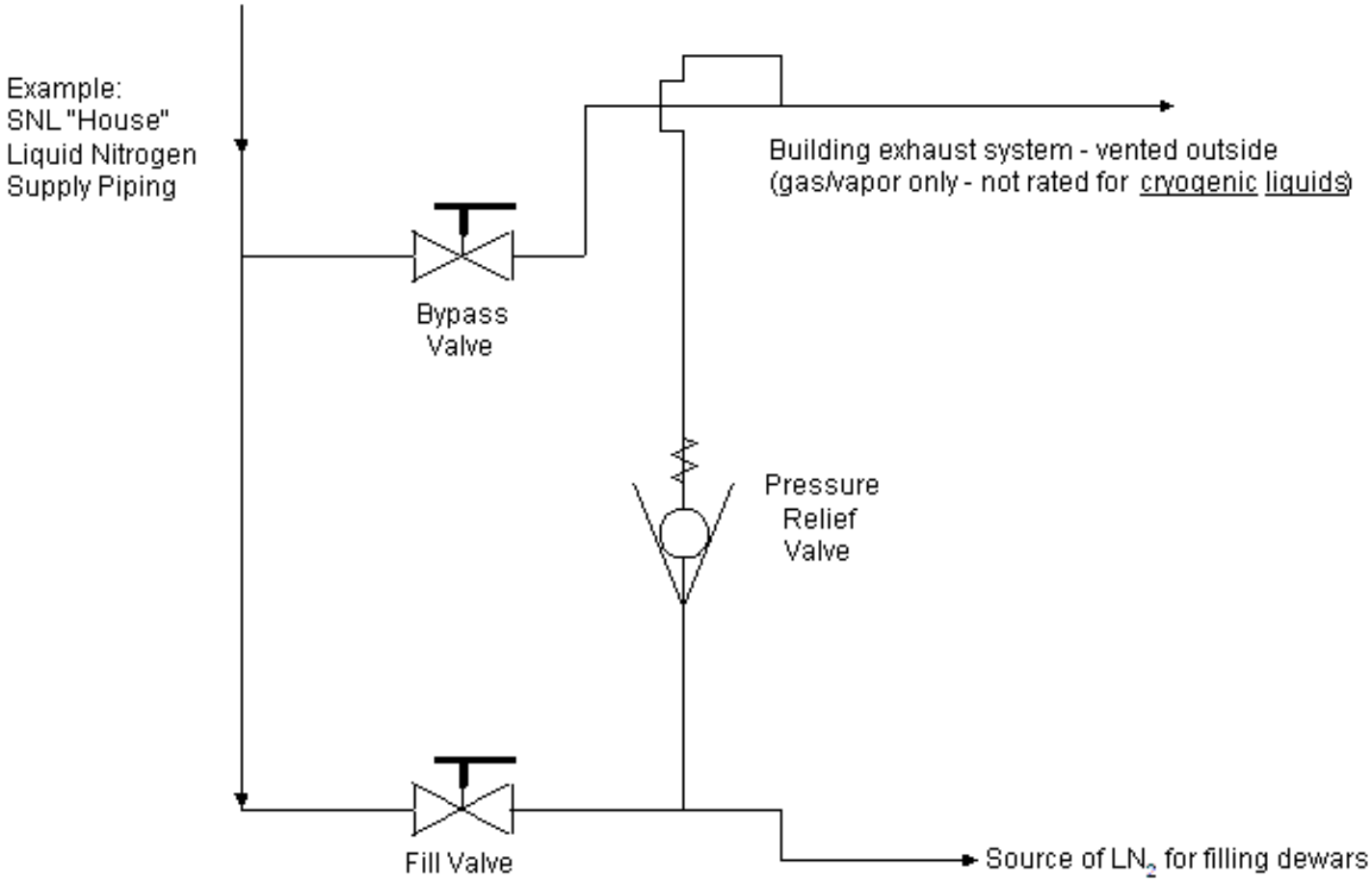
This attachment applies to house-supplied LN_2 fill stations located within laboratory spaces, and is intended for guidance only. Specific system procedures should always be reviewed by persons who are knowledgeable of the installation.

To make site-specific fill station instructions, enter:

- The appropriate points of contact for the fill station operation.
- Any applicable laboratory equipment.
- The building point of contact for bulk ordering of LN_2.
- The ES&H point of contact for notification for events, such as accidental releases.

Step	Action
PREPARATION FOR USE	
1	**Check** that the oxygen monitor (if applicable) is operational.
2	**Locate** flex lines and fill valve away from point of discharge.
3	**Make** any connections for fill or vent that are required.
4	**Position** the dewar for filling.

5	**Don** personnel protective equipment (PPE). Wearing safety glasses is required for the open handling of LN_2. Additional PPE, such as face shield and gloves, may also be required. Need is dependent on the specific system design and operation.
USE	
Caution: Safe use of this system requires 100%-manned operation. **Operators should not leave the area** with either valve in the open or partially open position.	
3	When necessary**, pre-cool** the LN_2 line by opening the bypass valve and allowing flow until the supply line is adequately pre-cooled. This may be evidenced by frost appearing on the valve or piping and components. **Do not** leave the area during line pre-cool. The line is pre-cooled in an effort to minimize the quantity of nitrogen gas that will be vented into the laboratory air space during the filling process.
4	**Close** the bypass valve at this time. The line should be adequately pre-cooled so that when the fill valve is opened, liquid phase nitrogen (or a minimum of gas phase) will flow.
5	**Slowly open** the fill valve. You should be able to hear the LN_2 flowing through the line and into the dewar. **Do not** leave the area during the dewar fill operation.
SHUTDOWN	
6	When the dewar is full, **close** the fill valve and ensure that both valves are in the fully closed position (90 degrees from the line orientation).
7	**Vent off** any residual pressure, **then disconnect** any connections made and **remove** the dewar from the fill station.



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