SUBJECT AREA CONTENT

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Management System: Worker Safety and Health

Subject Area: Cryogenics Safety

VIEW/PRINT ALL (No Exhibits and Forms)

Effective Date: **Aug 30, 2016** (Rev 4.0) Periodic Review Due: **Apr 14, 2020**	Subject Matter Expert: Michael Gaffney	Management System Executive: Ed Nowak	Management System Steward: Gail Mattson

Introduction

This subject area provides the requirements for the use and storage of cryogenic fluids in a safe manner and in compliance with 10 CFR 851 pressure safety requirements and Compressed Gas Association (CGA) recommendations.

Cryogens, cryogenic fluids, and their associated systems are a significant hazard because of their intense cold and substantial gas production when warmed. The extreme cold (temperatures at or less than 170° Kelvin) can cause tissue damage to personnel and bring about changes in the properties of metals and other materials. Asphyxiation and overpressure hazards may be created by the production of large quantities of gas. These potential problems require that careful attention be given to the storage, transfer, and use of cryogens to ensure the safety of personnel working.

Responsibilities

The Department Chair/Division Manager or designee is responsible for ensuring that cryogenic systems and the use of cryogens comply with the requirements in this subject area.

The Laboratory Environmental, Safety & Health Committee (LESHC) Pressure and Cryogenic Safety Subcommittee acts as the Authority Having Jurisdiction (AHJ) for pressure safety issues for the Laboratory and provides equivalent protection rulings ensuring a level of safety greater than or equal to the level of protection afforded by the national consensus standards; when national consensus standards, as referenced below, are not applicable.

This subject area describes the procedures for

- Establishing the safety requirements for using cryogens, cryogenic fluids, and their associated systems;
- Reviewing cryogenic safety matters associated with cryogenic uses at the Laboratory;
- Using liquid oxygen and flammable cryogens.

Contents

Definitions

Exhibits

None

Forms

None

Training Requirements and Reporting Obligations

This subject area contains training requirements (see the BNL Training and Qualifications website):

- Cryogen Safety (HP-OSH-025).

This subject area does not contain reporting obligations.

External/Internal Requirements

Requirement Number	Requirement Title
10 CFR 851	Worker Safety and Health Program
29 CFR 1910	Labor/Occupational Safety and Health Standards
49 CFR 173	Transportation/Shippers - General Requirements for Shipments and Packagings
ANSI/ASME B 31 Series	American National Standards Institute (ANSI)/American Society of Mechanical Engineers (ASME)/Piping Code
ASME Boiler and Pressure Vessel Safety Code	American Society of Mechanical Engineers (ASME)/Boiler and Pressure Vessel Safety Code
BSA Contract No. DE-SC0012704 - Clause C.4	Statement Of Work
BSA Contract No. DE-SC0012704 - Clause H.27 (ACT)	Non-Federal Agreements for Commercializing Technology (Pilot) (ACT)
BSA Contract No. DE-SC0012704 - Clause I.131 (DEAR 970.5223-1)	INTEGRATION OF ENVIRONMENT, SAFETY, AND HEALTH INTO WORK PLANNING AND EXECUTION (DEC 2000)
DOE-STD-1066-99	Fire Protection Design Criteria

NFPA 497	Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas
NFPA 55	Standard for the Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders, and Tanks
O 151.1C	Comprehensive Emergency Management System

References

BNL Training and Qualifications website

Compressed Gas Association Pamphlet, G-4.1 Cleaning Equipment for Oxygen Service

Compressed Gas Association Pamphlet, P1 Safe Handling of Compressed Gases in Containers

Compressed Gas Association Pamphlet, P12 Safe Handling of Cryogenic Liquids

Compressed Gas Cylinders and Related Systems Subject Area

Emergency Preparedness Subject Area

Engineering Design Subject Area

Environmental Safety and Health (ESH) Guide: Crogenic Safety website

Environmental Safety and Health (ESH) Guide: Pressure and Vacuum System Safety website

Facility Hazard Analysis Subject Area

Facility Use Agreements Subject Area

Fire Safety Subject Area

Movement by Vehicle of Hazardous and Radiological Materials On-site Subject Area

National Fire Protection Association Standard No. 50B, Liquefied Hydrogen Systems at Consumer Sites

National Fire Protection Association Standard No. 55, Storage, Use & Handling Compressed & Liquefied Gases in Portable Containers

OH&S Guide 5.1.0, Nonflammable Cryogenic Liquids

Oxygen Deficiency Hazards (ODH), System Classification and Controls Subject Area

Pressure Safety Subject Area

Readiness Evaluations Subject Area

Static Magnetic Fields Subject Area

Work Planning and Control for Experiments and Operations Subject Area

Standards of Performance

All staff and guests shall comply with applicable Laboratory policies, standards,and procedures, unless a formal variance is obtained.

Managers shall analyze work for hazards, authorize work to proceed, and ensure that work is performed within established controls.

All staff and users shall identify, evaluate, and control hazards in order to ensure that work is conducted safely and in a manner that protects the environment and the public.

All staff and users shall ensure that they are trained and qualified to carry out their assigned responsibilities, and shall inform their supervisor if they are assigned to perform work for which they are not properly trained or qualified.

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Questions/Comments Disclaimer

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PROCEDURE: PLANNING TO USE CRYOGENS/CRYOGENIC SYSTEMS

Management System: Worker Safety and Health		
Subject Area: Cryogenics Safety		
1. Planning to Use Cryogens/Cryogenic Systems		
Effective Date: **Apr 14, 2015**	Subject Matter Expert: Michael Gaffney	Management System Executive: Ed Nowak

Applicability

This information applies to BNL staff and non-BNL staff planning to use cryogens and/or cryogenic systems.

Required Procedure

Users must assess operational and safety needs, identify risks and methods to manage or mitigate the hazards by ensuring the following:

Step 1	The Department Chair/Division Manager or designee performs a Hazard Evaluation/Job Risk Assessment. See the Facility Hazard Analysis or Work Planning and Control for Experiments and Operations Subject Areas. Identify all applicable work, risks, hazards, and related control measures for desired use of cryogens, including pressure safety, oxygen deficiency and oxygen enrichment hazards. Ensure all components are rated for the temperatures and pressures used and the materials are compatible with cryogens. Refer to the Environmental Safety and Health (ESH) Guide: Crogenic Safety website for information on cryogenic properties and system design and safety issues. Users must be familiar with the hazardous properties of the cryogen and must understand how to safely store and use cryogens and cryogenic systems, refer to the section on Storage and Use of Cryogens/Cryogenic Systems. **Note:** If part of an experiment, users include this as part of their Experimental Safety Review (ESR) process. Depending on organization structure, approval to proceed with this activity will be given by the ESH Coordinator, organizational Safety Committee, or other qualified safety professional.
Step 2	The Department Chair/Division Manager or designee determines if a Laboratory Environment, Safety, and Health Committee (LESHC) Safety Review is required/desired. A LESHC Safety review is required for the following:

	• If any amount of liquid oxygen (LOX) will be used, refer to the section on Using Liquid Oxygen. • If any amount of flammable cryogens, such as liquid hydrogen (LH2) will be used, refer to the section on Using Flammable Cryogens. • If a new storage and/or process piping system will be used and must conform to the requirements of the Pressure Safety Subject Area. **Note:** LESHC review is not required if the only device is a standard-catalog cryogenic commercial vessel, built to industry standards (DOT, TC, or CE stamped) and used exclusively for storage. New devices should be verified by Safety Engineering to ensure their use meets manufacturer's specification. The replacement of a previously approved/used device with one that has the same form, fit, and function does not require additional review (for unstamped devices, the SME will document approved devices via the label provided on the Pressure System Labeling page, ESH Guide: Pressure and Vacuum System Safety website).
Step 3	The Department Chair/Division Manager or designee ensures that personnel with the potential for exposure to cryogens and/or ODH have completed training. See the BNL Training and Qualifications website.
Step 4	The Department Chair/Division Manager or designee ensures equipment is maintained for safe use and that up-to-date schematics and operating instructions of cryogenic systems are posted as required.
Step 5	The Department Chair/Division Manager or designee ensures the Facility Use Agreements, Emergency Pre-plan response cards, and Emergency Hazard Placard are updated as necessary. See the Facility Use Agreements and the Emergency Preparedness Subject Areas for more information. When there is potential for contact with cryogens or uninsulated cryogenic piping and components, controls such as postings, barriers, and/or guards must be used as defined by the work planning/experimental review process. Examples of Caution Postings are provided on the Cryogenics Safety Postings page, ESH Guide: Cryogenic Safety website).

Guidelines

Valuable information on the hazards and properties of cryogenic fluids can be found on the Material Safety Data Sheets (MSDS). MSDS data sheets can be found on the BNL Material Safety Data Sheets (MSDS)*, Safety and Health Services Web site. Contact the CMS Team for help in locating a MSDS in the database or from the gas manufacturer.

Users should consult with the Cryogenic Safety SME, Pressure Safety SME, or the Laboratory Environmental, Safety & Health Committee (LESHC) Pressure and Cryogenic Safety Subcommittee, for assistance on changes in existing systems or installation of new systems.

References

BNL Training and Qualifications website

Emergency Preparedness Subject Area

Environmental Safety and Health (ESH) Guide: Crogenic Safety website

Environmental Safety and Health (ESH) Guide: Pressure and Vacuum System Safety website

Facility Hazard Analysis Subject Area

Facility Use Agreements Subject Area

Firehouse Response Card System*

Material Safety Data Sheets (MSDS)*, Safety & Health Services website

Pressure Safety Subject Area

Work Planning and Control for Experiments and Operations Subject Area

*Access Limited to BNL Staff and Authorized Non-BNL Staff

The only official copy of this file is the one on-line in SBMS.

Before using a printed copy, verify that it is the most current version by checking the *effective date*.

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https://sbms.bnl.gov/sbmsearch/subjarea/164/164_pro6.cfm

PROCEDURE: STORAGE AND USE OF CRYOGENS/CRYOGENIC SYSTEMS

Management System: Worker Safety and Health		
Subject Area: Cryogenics Safety		
2. Storage and Use of Cryogens/Cryogenic Systems		
Effective Date: **Aug 30, 2016**	Subject Matter Expert: Michael Gaffney	Management System Executive: Ed Nowak

Applicability

This information applies to BNL staff and non-BNL staff doing work for BNL that will use cryogenic fluids and/or systems at BNL.

Required Procedure

Cryogens, cryogenic fluids, and their associated systems are a significant hazard because of their intense cold and substantial gas production when warmed. Cryogens have very low-temperature boiling points and large gas expansion characteristics. For additional information on expansion rates and properties of cryogens, refer to the Characteristics of Cryogens page, Environmental Safety and Health (ESH) Guide: Crogenic Safety website.

The extreme cold can cause serious tissue damage to staff, and can adversely change the properties of metals and other materials. Asphyxiation and overpressure hazards may be created by the production of large quantities of gas generated. These potential problems require that careful engineering attention be given to the storage, transfer, and use of cryogens.

Storing and Using Cryogenics Systems contains two subsections:

2.1 Storage
2.2 Use (Transferring and Handling)

2.1 Storage

Step 1	Store cryogens in containers that have been designated by the manufacturer for holding cryogenic fluids. Such containers are made from materials that can withstand the rapid changes and extreme differences in temperature encountered in working with these liquids. **Ordinary glassware must not be used** to store or transfer cryogenic liquids. All unprotected glass dewars must be wrapped with a heavy adhesive tape to prevent fragmentation and to provide a better gripping surface.

Step 2	Containers designed for cryogenic liquids are built to withstand normal operating pressures. However, all containers must be open or protected by a vent or other safety device that permits the escape of gas that has formed. **CAUTION** **EXPLOSION** Contaminates (such as water) entering the cryogenic container can interfere with normal venting of boiling gases, causing the build up of excessive pressure 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. For assistance/procedures in removing the plug, contact any of the following: • Department's/Division's staff who are authorized to remove dewar plugs; • Collider-Accelerator Department Cryogenic Group; • Cryogenic Safety SME; • LESHC Pressure and Cryogenic Safety Subcommittee member. Ensure all unnecessary personnel leave the area. Notify emergency services (dial x2222 or 911) if pressure cannot be safely reduced. Additional information on plugged dewars can be found on the Plugged Dewars page, ESH Guide: Cryogenic Safety website.
Step 3	When large volumes of liquid nitrogen are required, liquid nitrogen (LN2) buggies are available (1200 liters capacity) to store and transport liquid nitrogen. Use the operating instruction posted on the buggy. A copy of the operation instruction is provided in the Operating Instructions for Liquid Nitrogen Buggies, ESH Guide: Cryogenic Safety website. **Note:** The Procurement & Property Management Division is responsible for a program for preserving the safety of these vehicles through maintenance and repair; and the safety verification of incoming vendor-owned cryogenic storage units.
Step 4	Store cryogenic liquid dewars in well-ventilated areas and evaluate the area for Oxygen Deficiency Hazards. See the Oxygen Deficiency Hazards (ODH), System Classification and Controls Subject Area for information. **Note:** Use the ODH tool found on the Hazard Evaluation Tools page on the Safety Engineering Group homepage to submit the ODH analysis to the ODH SME for concurrence and documentation. **CAUTION** **FIRE RISK FROM OXYGEN ENRICHED ATMOSPHERE**

When working with cryogens at temperatures less than 90°K, it is possible to develop a localized oxygen-enriched atmosphere from air condensation. Enhanced combustion is possible and appropriate controls are required (i.e., no smoking or hot work in area). Combustible materials that can absorb or collect liquefied oxygen (i.e., foam insulation) must be removed from the area.

Step 5

To ensure compliance with NFPA 55 (Compressed Gases and Cryogenic Fluids Code), the following separation distances for portable dewars containing cryogenic liquids are provided in the table below:

Building Exits*	10 feet
Air Intakes	10 feet
Easily Ignitable**	15 feet
Room or area exit*	3 feet
Wall openings	1 foot

Note: Since cryogenic liquids are gases at room temperatures, incompatible hazard materials (i.e., flammables, oxidizers, toxics) are required to be stored using the same separation distances listed in the Compressed Gas Cylinders and Related Systems Subject Area.

*Contact Fire Protection Engineering to determine if the building/room exit is classified as a required egress exit and if this requirement applies.
**Easily Ignitable Materials include paper/cardboard, leaves/weeds/dry grass, wood debris. Contact Fire Protection Engineering or Cryogenic Safety SME for additional guidance.

2.2 Use (Transferring and Handling)

Step 1

Use approved procedures for transferring and handling cryogenic fluids that address how hazards such as exposure to low temperature fluids, overpressurization, spills, over-filling of containers, and oxygen deficient atmosphere are controlled. Procedures can be in the form of work planning, Department/Division standard operating procedures/training, or part of the Experimental Safety Review.

When filling pressurized dewars, the system will exceed 40.6 psia and the dewars are regulated as compressed gas cylinders. Filling of these dewars requires a written procedure as specified in the section Transfilling Compressed Gas Cylinders of the Compressed Gas Cylinders and Related Systems Subject Area.

	CAUTION **PERSONAL INJURY** Seek immediate medical attention if cryogens come in direct contact with eyes, skin, or mucus membranes
	CAUTION **EXPLOSION** Contaminates (such as water) entering the cryogenic container can interfere with normal venting of boiling gases, causing the build up of excessive pressure
	Boiling and splashing of cryogenic liquids, including solid carbon dioxide or Dry Ice, occurs when charging a warm container or when inserting warm objects into the liquid. Perform these operations slowly to minimize boiling and splashing. Do not pour cryogens above shoulder height. **Note:** 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.
Step 2	During transfer and handling of cryogenic liquids within enclosed piping system or containers, wear safety glasses with side shields. **Note:** Safety (chemical/splash) goggles can be used instead of safety glasses with side shields. During pressurized transfer of cryogenic liquids into open containers, wear a full-face shield (providing protection for the nose and mouth) and safety glasses (with side shields). When transferring small amounts of cryogenic liquids (5 liters or less) between open containers, safety goggles are required. (If transferring amounts of cryogenic liquids greater than 5 liters, full-face shield and safety glasses are required.) **Note:** The extremely low temperatures of cryogenic liquids can quickly produce frostbite. The gases released are also extremely cold and can produce frostbite and permanently damage delicate tissues, such as the eyes, nose and mouth by only brief exposure.
Step 3	Wear gloves designed for protection at cryogenic temperatures when handling objects that are in contact with solid carbon dioxide or Dry Ice, cryogenic liquid and vapors, or when performing open (non-pressurized) transfers of cryogens. If a spill potential exists, use gloves designed to prevent cryogens from flowing into the glove, or be loose fitting so the glove can be easily removed. Use gauntlet-style gloves that provide lower arm protection if a hose or line breakage can cause an excessive cryogenic spray risk (i.e., high volume pressurized transfer). Examples

	of personal protective equipment are provided on the Cryogenic Personal Protective Equipment page, ESH Guide: Cryogenic Safety website. When manual dexterity is required when working with experiment samples that are immersed in liquid nitrogen in small dewars (1 liter or less), insulated, non-absorbent gloves (i.e., nitrile gloves over cotton gloves) are allowed for use. Tongs must be used to withdraw objects immersed in liquid.
Step 4	All parts of the body must be covered to provide protection 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. If a cryogenic spill potential exists, wear nonporous closed-toe footwear, trousers and a long-sleeved shirt/lab coat. Use measures to prevent spills from being allowed to contact the feet or to be trapped in footwear, such as ensuring trousers cover the outside of the shoes. Use measures to prevent cuffs and open pockets from collecting spilled cryogens.
Step 5	**CAUTION** **TIPPED DEWARS - PERSONAL INJURY** Pressurized dewars (> 50 liters) exceed safe lifting limits and can expose staff to cryogenic burns and/or asphyxiation. **Do Not attempt to right the dewar.** Contact Fire Rescue (2222) or 911 (BNL internal phone) immediately. Move dewars filled with cryogenic liquids cautiously. Many dewars are unstable due to their high center of gravity and movement over doorways and other floor obstructions, such as grates or gaps, can be hazardous. Use only approved carts and dollies to move dewars. For a detailed discussion of the safe handling and moving of dewars, refer to the ESH Guide: Cryogenic Safety website. • One person clears the elevator of personnel and rides it to the appropriate floor. • Once the elevator is clear and a qualified person is waiting to receive the cylinder, secure the cylinder in the elevator. Place a posting in the elevator to caution personnel that they may not use it while transporting the cylinder (see the ESH Coordinator for postings or the ESH Guide: Cryogenic Safety website). Return the elevator to unrestricted service once the cylinder is safely removed. If a dewar must be rigged, contact the Rigging Supervisor at ext. 8233. Only devices designed to lift the dewar must be used. Controls must be in place to protect staff in the area in case of a failure.
Step 6	All on-site transfers of cryogenic liquids must comply with the Movement by Vehicle of Hazardous and Radiological Materials On-site Subject Area. Flammable cryogenic liquid hydrogen must not be transferred on-site without the prior review of the Laboratory Environment, Safety and Health Committee (LESHC) Pressure & Cryogenic Safety Subcommittee (PCSS) and the BNL Transportation Safety Officer.

	Non-flammable cryogenic liquids (e.g., argon, helium, and nitrogen) contained in transportation Dewars or cylinders have been evaluated with an on-site transportation safety assessment methodology. The approved packaging and transport controls approved for the safe transfer of non-flammable cryogenic liquid containers--one for those that do not exceed 25.3 psig and one for those at 25.3 psia and greater--are provided on the Cryogenic Liquid Safety Assessment Methodology (SAM) page, ESH Guide: Cryogenic Safety website (applicable for staff who are not part of the Procurement & Property Management Division). **Note:** It is recommended to use government vehicles when transferring cryogens on BNL roadways if possible. When transferring cryogens (other than LN2 buggies), place cryogen container (Dewar, flask, cylinder) in the non-occupied cargo compartment. Secure (e.g., block, brace, tie-down) container to vehicle to prevent shifting and spillage during transport. Ensure precautions are in place to prevent out-gassing from affecting passengers. Bulk liquid nitrogen (LN2) is typically transferred on-site using LN2 buggies capable of being pulled by a motor vehicle. The user of the buggy is responsible for ensuring it is in good working order by inspecting (for example) the following: integrity and function of valves and process piping, physical condition of the tank, and tire wear and proper inflation. (**Note:** Tire failure is common if the tires are not moved occasionally due to routine freezing.) Do not use if integrity issues are suspected. Ensure the operating instruction for the LN2 buggy is posted on the buggy. A copy of the operation instruction is provided in the Operating Instructions for Liquid Nitrogen Buggies, ESH Guide: Cryogenic Safety website. All shipments of cryogenic liquids off-site must comply with the Movement by Vehicle of Hazardous and Radiological Materials On-site Subject Area and the U.S. Department of Transportation (DOT) regulations for the transport of hazardous materials.

References

Compressed Gas Cylinders and Related Systems Subject Area

Environmental Safety and Health (ESH) Guide: Crogenic Safety website

Movement by Vehicle of Hazardous and Radiological Materials On-site Subject Area

Oxygen Deficiency Hazards (ODH), System Classification and Controls Subject Area

https://sbms.bnl.gov/sbmsearch/subjarea/164/164_pro1.cfm

PROCEDURE: USING FLAMMABLE CRYOGENS

Management System: Worker Safety and Health
Subject Area: Cryogenics Safety
3. Using Flammable Cryogens

Effective Date: **Apr 14, 2015**	Subject Matter Expert: Michael Gaffney	Management System Executive: Ed Nowak

Applicability

This information applies to BNL staff and non-BNL staff doing work for BNL that will use or transport flammable cryogenic fluids, which includes liquid hydrogen (LH2) and liquid deuterium. **Warning:** Flammable Cryogenic Systems have not been used at BNL for several years, therefore changes in technology (e.g., the use of hydrogen refrigerators instead of storage dewars) and changes in relevant standards (i.e., National Fire Protection Association Standard No. 55) might require a re-evaluation of past acceptable practice and this section of this subject area before the approval of any new design of flammable cryogenic systems.

Required Procedure

In addition to the hazards associated with cryogens, these fluids in their gaseous state exhibit extremely high-fire and explosion hazards. Gaseous hydrogen can form an explosive mixture over a range of 4% to 75% concentration in air.

The procedures below are used to minimize the possibility of fire or explosion resulting from the use of flammable cryogens. Also, review the Liquid Oxygen and Flammable Cryogenics Safety page, Environmental Safety and Health (ESH) Guide: Crogenic Safety website.

Step 1	The Principal Investigator/Cognizant Engineer • Informs the Laboratory Environmental, Safety and Health Committee (LESHC) Chair that the proposed design involves the use or storage of flammable cryogenic fluids and needs to be reviewed; • Requests an LESHC meeting (see the Pressure Safety Subject Area). **Note:** The LESHC must review all newly proposed flammable cryogenic fluids system designs for both the equipment design and the integration within a building or laboratory. When equipment previously reviewed is put back in service in the original or slightly modified condition, the review may be limited to an LESHC subcommittee. • Informs the Emergency Services Division of the proposed design for equipment and storage systems for flammable cryogenic fluids. The Emergency Services Division evaluates the facility for Fire/Life Safety issues and recommends mitigation and engineered safety systems.

Step 2	The LESHC submits recommendations, including the Emergency Services Division's evaluation, to the Associate Laboratory Director (ALD), Environment, Safety, Health and Quality (ESH&Q) for approval. After the ALD for ESH&Q approves the design and use, construction and installation are permitted.
Step 3	The F&O Facility Project Manager reviews and changes the facility's safety documentation (Safety Assessment Document/safety operating envelope/Facility Use Agreement).
Step 4	The Project Leader or Principal Investigator determines if an Operational Readiness Evaluation (ORE) is required. See the Readiness Evaluations Subject Area for information.
Step 5	The Responsible Person in the Department/Division requests a review (including walk-through) by the appropriate safety committees before the admission of flammable cryogens. These committees may include the • Accelerator Safety Committee; • Experimental Safety Committee; • Laboratory Environmental, Safety and Health Committee.
Step 6	The Department/Division ensures adequate provisions are established for delivery of flammable cryogenic fluids. These include • Deliveries only to areas designated by the LESHC; • The appropriate supervisor designates qualified staff to receive, store, and dispense flammable cryogenic fluids; • Liquid H2 must be transported only in containers designed for the purpose. These containers must be clearly marked "Hydrogen Flammable;" • All liquid H2 trailers must be provided with "Hydrogen Flammable" marking, reflectors, and safety tow chains, and be properly secured; • Equipment used for storage and delivery of liquid H2 must be maintained by persons authorized by the Organization's Management. **Note:** To ensure the liquid hydrogen delivered to BNL is sufficiently pure to be used safely, the vendor certifies the contents of all shipments to meet the specification of MIL-P-27201 (Propellant, Hydrogen), DOD-1971 (Liquid Propellant Fuels and Oxidizers, Chemical Base).
Step 7	When transferring flammable cryogens over Laboratory roads, the Department/Division ensures that all on-site transfers of cryogenic liquids comply with the Movement by Vehicle of Hazardous and Radiological Materials On-site Subject Area. Flammable cryogenic liquid hydrogen must not be transferred on-site without the prior review of the Laboratory Environmental, Safety & Health Committee (LESHC) Pressure and Cryogenic Safety Subcommittee and the BNL Transportation Safety Officer. All shipments of cryogenic liquids off-site must comply with the Movement by Vehicle of Hazardous and Radiological Materials On-site Subject Area and the U.S. Department of Transportation (DOT) regulations for the transport of hazardous materials.

	Note: The specific requirements of the BNL On-site Transfer/Safety Assessment Form (TSAF) in the Movement by Vehicle of Hazardous and Radiological Materials On-site Subject Area must be followed. If container pressure cannot exceed 23.3 psig and the volume is 4 liter or less, then transportation can be considered as Material of Trade.
Step 8	The Department/Division ensures all storage tanks, portable dewars, equipment and systems used in handling liquid hydrogen meet the requirements of National Fire Protection Association Standard No. 50B, “Liquefied Hydrogen Systems at Consumer Sites.”
Step 9	Venting to atmosphere must be via piping to the outside, never within a building. • Maintain normal boil-off venting systems upstream of pressure relief devices at pressures slightly above atmospheric to minimize infiltration of air. Emergency venting systems need not meet this requirement but must be separate from the normal venting (boil-off) systems; • Do not use liquid hydrogen in unvented spaces. Maintain positive air flow to ensure adequate air-change minimizing stagnation or collection within the space.
Step 10	Use portable combustible gas detectors for checking points not readily accessible or not monitored by stationary sampling heads. When a temporary structure, such as a tent, is installed inside of a building to enclose flammable cryogenic equipment, that enclosure must be continuously monitored by a combustible gas detector system. If gas is detected (at 25% of Lower Exposure Level [LEL]), local audible alarms, remote watch station alarms, increased airflow ventilation, and the de-energizing of any ignition sources are initiated automatically. **Note:** The emergency systems must all be tested before start-up and must be in proper operating condition when LH2 is being used. The detecting system must be capable of being checked from outside the enclosure and holding a calibration of 25% of the LEL (LEL of hydrogen gas is 4%).
Step 11	Keep the area within a radius of 10 ft of flammable cryogenic equipment free of combustible materials. In particular, store solvents and other flammable fluids away from the equipment. • Exclude all unauthorized persons from the area. The area must have limited access. Prominently post signs indicating flammable cryogen is in use; • Clearly mark the safest route for moving dewars between the enclosure and a building exit. Keep it free of obstructions. Provide an additional route for personnel access and egress.
Step 12	All equipment designed for flammable cryogens (unless specifically designed to be pressurized) must have a normal boil-off vent and an emergency vent. • Maintain normal boil-off vents at slightly above atmospheric pressure to prevent back diffusion of air and plugs in the vent. The emergency vent must contain a positive pressure relief device to prevent rupture of the LH2 container; • Vacuum-insulated equipment and pumps must be provided with pressure reliefs that are vented to the outdoors.

Step 13	Ensure all controls are connected to an emergency power circuit.
Step 14	Ensure the equipment is electrically grounded. Any dewar or transfer device must then be electrically bonded to the equipment before transfer. Make sure first electrical contact with an H2 container is made away from any vent opening.
Step 15	Protect dewars from back diffusion and plugs by a check valve or other devices, which will ensure a slight positive pressure in the vent spaces. • Connect the dewars to a normal boil-off vent to the outdoors, when not connected to equipment; • Check them daily to ensure proper venting; • Do not use openmouthed and/or glass dewars.
Step 16	Unless specifically exempted by the LESHC, at least one qualified operator must monitor the equipment while it has any liquid or gas in it, and until it has been completely emptied and purged. The operator must be able to communicate with the shift supervisor or department representative having emergency responsibilities. **Note:** A person is designated a qualified cryogenic equipment operator by the person's supervisor upon completion of required training and after demonstrating the capability of safe system operation. Some of the areas of knowledge required before designation are • Properties and hazards of liquefied gases; • Equipment safety systems; • Building safety systems; • Appropriate SBMS Subject Areas (see the Compressed Gas Cylinders and Related Systems, Fire Safety, Oxygen Deficiency Hazards [ODH], System Classification and Controls, Pressure Safety, and Static Magnetic Fields Subject Areas); • Local departmental operating and safety procedures.
Step 17	Before introducing flammable cryogen into any system, either purge the system with inert gas or evacuate it to remove air. Repeat this to ensure that no explosive mixture remains. When it is necessary to open the system to atmosphere, first purge it to ensure that the resulting flammable cryogen-air concentration is less than 1%. Detailed procedures for purging will differ with different systems. Department/Divisions may develop their own written procedures for this operation.

References

Compressed Gas Cylinders and Related Systems Subject Area

Environmental Safety and Health (ESH) Guide: Crogenic Safety website

Fire Safety Subject Area

Movement by Vehicle of Hazardous and Radiological Materials On-site Subject Area

National Fire Protection Association Standard No. 55, Storage, Use & Handling Compressed & Liquefied Gases in Portable Containers

Oxygen Deficiency Hazards [ODH], System Classification and Controls Subject Area

Pressure Safety Subject Area

Readiness Evaluations Subject Area

Static Magnetic Fields Subject Area

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PROCEDURE: USING LIQUID OXYGEN

Management System: Worker Safety and Health
Subject Area: Cryogenics Safety
4. Using Liquid Oxygen

Effective Date: **Apr 14, 2015**	Subject Matter Expert: Michael Gaffney	Management System Executive: Ed Nowak

Applicability

This information applies to BNL staff and non-BNL staff doing work for BNL that will use liquid oxygen (LOX) at BNL. **Warning:** LOX has not been used at BNL for several years, therefore changes in technology and in relevant standards must be re-evaluated before any design review of LOX Systems.

Required Procedure

Liquid Oxygen (LOX) is inherently nonflammable, however, when combined with organic materials, energetic reactions can occur. Gaseous oxygen has a much greater capacity for supporting combustion than air. Therefore, in addition to the requirements of this section (see also the Liquid Oxygen and Flammable Cryogenics Safety page, Environmental Safety and Health (ESH) Guide: Crogenic Safety website), a review by the Laboratory Environment, Safety and Health Committee is required.

Step 1	The Principal Investigator/Cognizant Engineer informs the Laboratory Environmental, Safety and Health Committee (LESHC) Chairperson that the proposed design involves the use or storage of Liquid Oxygen (LOX) and needs to be reviewed. **Note:** The LESHC must review all newly proposed LOX system designs for both the equipment design and the integration within a building or laboratory. When previously reviewed equipment is put back in service in the original or slightly modified condition, the review may be limited to an LESHC subcommittee.
Step 2	The Principal Investigator/Cognizant Engineer contacts the Emergency Services Division for an evaluation of the facility for Fire/Life Safety issues.
Step 3	The LESHC submits recommendations to the Assistant Laboratory Director for Environment, Safety and Health (ES&H) for approval. After the Assistant Laboratory Director for ES&H approves the design/use, construction and installation are permitted.
Step 4	

	The F&O Facility Project Manager reviews and changes the facility's safety documentation (Safety Assessment Document [SAD]/safety operating envelope, FUA).
Step 5	The Principal Investigator/Cognizant Engineer determines if an Operational Readiness Evaluation (ORE) is required. See the Readiness Evaluations Subject Area for information.
Step 6	The Principal Investigator/Cognizant Engineer requests a review (including walk-through) by the appropriate safety committees of the completed installation before delivery of LOX.
Step 7	The Department/Division ensures adequate provisions are established for delivery of LOX. These include • Deliveries must only be made to those areas designated by the LESHC. • The appropriate supervisor must designate qualified staff to be available to receive, store, and dispense LOX.
Step 8	The Department/Division follows the Movement by Vehicle of Hazardous and Radiological Materials On-site Subject Area for transferring LOX over Laboratory roads. **Note:** The specific requirements of the BNL On-site Transfer/Safety Assessment Form (TSAF) must be followed. If container pressure cannot exceed 23.3 psig and the volume is 4 liter or less, then LOX transportation can be considered as Material of Trade.

References

Environmental Safety and Health (ESH) Guide: Crogenic Safety website

Movement by Vehicle of Hazardous and Radiological Materials On-site Subject Area

Readiness Evaluations Subject Area

https://sbms.bnl.gov/sbmsearch/subjarea/164/164_pro5.cfm

DEFINITIONS

Definition: Cryogenics Safety

Term	Definition
brittle fracture	The material phenomena that at low temperatures, the material catastrophically fails at stresses typically less than yield stresses. These materials usually have a Body Centered Cubic (BCC) lattice structure. Materials with Face Centered Cubic (FCC) lattice structures, typically show ductility at cryogenic temperatures.
cryogens	Fluids that exhibit extremely low (less than 170°K) boiling-point temperatures. These include liquefied atmospheric gases, such as nitrogen, helium, argon and neon, hydrogen, and oxygen.
cryostat	An engineered device designed to provide thermal insulation for a cryogenic system. Typically, a vacuum vessel surrounding the cryogenic (cold) mass such as a magnet or detector.
dewar	Container for storage or transport of cryogenic liquids. Typically it has a vacuum jacket for thermal insulation.
DOT	U.S. Department of Transportation.
engineered system	A cryogenic system for an experimental device containing a refrigeration source (closed cycle refrigerator or bulk storage) that has been designed with the appropriate safety features.
European Conformity (CE)	Products that meets the requirements of the relevant European Directives.
F&O Facility Project Manager	Manages and operates specific facility(s) within a designated complex area, related equipment and systems; ensuring resolution of problems, maintaining safe and reliable operations. Serves as the single point of contact for the execution of the obligations agreed to between the approving parties of the Facility Use Agreements (FUA). **Note:** This is not a one to one replacement of all the responsibilities of the former Building Manager, but contains many of the Building Managers' responsibilities as described in the Building Manager R2A2.
flammable cryogens	Liquefied hydrogen and oxygen. Liquid Oxygen is included due to its ability to effect combustion rates.
LH2	Liquid Hydrogen

LHe	Liquid Helium
LN2	Liquid Nitrogen
LN2 Buggy	Large volume (approximately 1200 liters) transportation and storage dewar for LN2.
LOX	Liquid Oxygen
oxygen deficiency hazard (ODH)	The condition where the body does not absorb sufficient oxygen from the atmosphere to support the biochemical activity of the brain and other vital organs.
plug	Contamination (usually in the form of ice) that can act as a pressure boundary in either a transfer line or dewar opening.
safety assessment methodology (SAM)	Performed by the Laboratory's Transportation Safety Officer that documents the following: safety hazards identification, operational limitations and controls required to move hazardous material between BNL facilities on-site.
Transport Canada (TC)	Canadian Government’s agency regulating transportation safety.