Dryden Flight Research Center
Edwards, California 93523

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Dryden Centerwide Procedure

Code S

Cryogen Safety

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This Document Contains Hazardous Operations Procedures.

Electronically approved by
Assistant Director for Management Systems

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1.0 PURPOSE OF DOCUMENT

This document describes procedures and guidelines, delegates authority, assigns responsibility and provides documentation required for the safe use of cryogens at Dryden Flight Research Center.

2.0 PROCEDURE SCOPE & APPLICABILITY

Scope: This procedure applies to the use, handling, storage, and transfer of cryogenic liquids. It includes cryogenic hazards, appropriate safety procedures, training requirements, and references.

Additional procedures for specific tasks utilizing cryogens may be found in documents such as Technical Orders, OSHA Standards, equipment manufacturer's instructions, laboratory safety procedures, etc.

Applicability: This procedure applies to all persons at Dryden Flight Research Center who work with or handle cryogens.

3.0 PROCEDURE OBJECTIVES, TARGETS, METRICS, & TREND ANALYSIS

Objective: Identify, eliminate, or control potential hazards associated with cryogenic liquids.
Target: Zero cryogen mishaps.
Metric: Number of cryogen mishaps.

Trend analysis: Metrics will be analyzed to determine whether procedural objectives have been met.

4.0 WAIVER AUTHORITY

Requests for waivers and variances to DFRC specific safety documents will be made to the Chief, Safety, Health, and Environmental Office (Code SH). Requests for waivers and variances to NASA safety instructions will be made to NASA HQ in accordance with instructions provided by NPR 8715.3, NASA General Safety Program Requirements, Para. 1.13, Safety Variance Process, and Para. 1.6, Risk Assessment and Risk Acceptance.

5.0 RESPONSIBILITIES

5.1 Directorates and Single Letter Offices

Directorates and single letter offices will approve projects, ensure resources are available, and necessary training is provided to safely conduct cryogenic activity within their area of responsibility.

5.2 Program or Project Managers

Program or project managers will ensure that the design and construction of cryogenic systems and/or storage facilities meet the requirements of NASA STD 8719.17, NASA Requirements for Ground-Based Pressure Vessels and Pressurized Systems (PV/S).

5.3 Safety, Health, & Environmental Office

This office has safety oversight for cryogenic fluid operations at DFRC. Industrial Hygienists within the Safety, Health, and Environmental Office are tasked with:

A. Reviewing hazard assessments provided by program or project managers prior to start-up of new cryogenic operations.

B. Providing measurements to determine oxygen levels and other gases in a breathing atmosphere on an as needed basis.

C. Providing technical information regarding cryogenic liquids.

D. Including organizational cryogen procedures and equipment in scheduled and non-scheduled inspections.

5.4 Supervisors

A. Ensure that each worker who uses, handles, stores, or transfers cryogenic liquids is trained and follow appropriate safety procedures.

B. Enforce the wearing of appropriate personal protective equipment (PPE).

C. Ensure that appropriate warning signs are posted.

D. Notify the Safety, Health, and Environmental Office of any incidents or near misses resulting from cryogenic fluid operation.

E. Ensure that adequate ventilation is provided any time a cryogen is used, handled, stored, or transferred.

5.5 Employees

Employees who use, handle, store, or transfer cryogenic liquids are responsible for:

A. Following the procedures of this document and other documents that provide guidance for specific tasks involving cryogenic liquid.

B. Cooperating with supervisors and safety personnel to prevent cryogenic liquid accidents or incidents.

C. Notifying supervisor of known or suspected cryogenic hazards.

6.0 CRYOGEN HAZARDS

Cryogens present several inherent dangers. Persons working with a cryogen must be familiar with the properties and observe the safe handling practices required of the particular cryogen.

6.1 General

When a cryogen comes into contact with materials warmer than the cryogen's critical temperature, the cryogen boils and off-gases. When boiling occurs or a warm object is inserted into the cryogen, the cryogen may splatter and splash out of the container causing a hazard. Also, the properties of some materials change drastically when super-cooled:

A. Ductile materials become brittle and may break or shatter violently.

B. Material shrinkage may exceed anticipated values.

C. Undetectable leaks may develop even when contents are under pressure.

6.2 Cold Contact Injuries

A. Skin – Burns to the skin can result from contact with a cryogenic liquid, vapor, low temperature gas, or uninsulated piping and equipment containing a cryogen. Skin and tissue may freeze to super-cooled piping or equipment causing the tissue to tear if an attempt is made to withdraw it from the freeze point.

B. Eyes – An eye injury is a particular concern since eye injury can occur with less exposure to a cryogenic liquid or gas than it takes to cause cold contact burns to the skin.

6.3 Physiological Hazards

A. Asphyxiation occurs when oxygen is replaced by another gas or gases. Cryogen expansion ratio is very high and, therefore, may replace oxygen quickly when off-gassing. Should a person breathe 100 percent of a gas such as nitrogen or carbon dioxide, unconsciousness will occur almost instantly. If the person is not quickly removed from the environment and provided a breathing medium containing adequate oxygen, they will die.

B. Hypoxia (below normal oxygen) is a condition that mainly affects the brain when breathing oxygen is less than required. Common symptoms of hypoxia include confusion and decreased reasoning ability, increased breathing rate, loss of muscular coordination, and decreased visual acuity. Hypoxia is insidious it can sneak up on a person if he/she is not aware of their symptoms. As breathing oxygen decreases, symptoms become more pronounced with progression into unconsciousness. If a person is not removed from an environment where there is little or no oxygen, brain damage or death will occur.

C. Breathing super-cooled air or gas produced by cryogenic liquids can seriously and permanently damage lung tissue.

D. Most cryogenic liquids do not produce toxic gases; however, some may cause nausea or dizziness if breathed in high concentrations.

6.4 Overpressure and Expansion of Cryogenic Liquids

A. Overpressure – Liquid cryogens warmed above their critical temperature generate high pressures. The pressure required to maintain liquid nitrogen at room temperature, for example, is 43,000 psi. These pressures may cause containers to rupture or explode violently causing a serious safety hazard due to flying fragments, radical changes in temperatures, explosion, and fire.

   Because of these potential high pressures, each and every portion of a cryogenic system at DFRC must have uninterrupted pressure relief. Any part of the system that can be shut-off from the reservoir must have separate and adequate provisions for pressure relief. These include:

   1) Pressurized supply dewars
   2) Tubing and hoses used to transfer, unless an air gap is provided
   3) Bath space surrounding experimental volume
   4) Experimental volume, even if cryogen is in contact only with the exterior
   5) Vacuum space in contact with cryogen

Note: Some cryogens, such as helium, hydrogen, and neon have much lower critical temperatures than air (nitrogen and oxygen). If air is not excluded from systems containing these cryogens it can solidify and cause relief valves to become plugged, which may lead to a violent system failure. Also, cryogenic oxygen does not evaporate as rapidly as cryogenic nitrogen, and may accumulate resulting in a potential violent reaction with incompatible materials in the system.

B. Expansion – Cryogenic liquids have large liquid-to-gas expansion ratios, generally greater than 700 to 1. Therefore, a small spill produces a large volume of gas that can displace air in a poorly ventilated space.

Depending on the gas, certain physiological hazards such as hypoxia or asphyxiation may occur. Physical hazards may result from the rapid expansion of a cryogen: an explosion due to the expansion of a flammable gas such as hydrogen or a fire or explosion from expansion of an oxidizer, such as oxygen.

Should a cryogenic liquid container form frost on the outside, it should be taken out of service. Frost on the outside of the container indicates the vacuum within the container may have been lost. If a cryogen leak between the vacuum container and the outside casing occurs, the rapid expansion of the liquid between the two could cause a violent explosion of the container.

C. Fire and Explosion Hazards – There are two cryogenic liquid gases that pose particular hazards. These gases not only can cause physiological injuries, but also potential fire and explosion hazards. These gases are oxygen and hydrogen.

1) Oxygen – Oxygen supports combustion. The atmosphere contains approximately 21 percent oxygen. Any increase above this level increases the probability of fire and/or explosion. High concentrations of oxygen can cause material that normally would not burn to burn readily. Oxygen also causes an explosive hazard when mixed with certain material, some as common as dusts. When a high concentration of oxygen (above 21 percent by volume) is used, safety precautions will be taken to control the hazards it presents.

2) Hydrogen – Hydrogen gas is a potential fire and explosive hazard. The rapid expansion of cryogenic hydrogen into hydrogen gas can quickly create an explosive situation.

7.0 PROTECTION FROM CRYOGEN FLUID HAZARDS

7.1 Protection from Cold Contact Injuries

Cold contact burns may be prevented by:

A. Wearing or using proper PPE such as
   1) Face shields that protect the face and eyes.
   2) Loose fitting insulated or leather gloves that may be thrown off easily.
   3) Coveralls or apron to protect from splatters and spills.
   4) High top shoes or boots with cuffless trousers worn outside the footwear.

B. Remaining clear of cryogens that are boiling, splashing, or off-gassing.

C. Never allowing an unprotected part of the body to contact uninsulated equipment that contains a cryogenic liquid.

D. Using tongs to place or remove items from cryogenic liquids and performing these operations slowly to minimize boiling and splashing.

E. Keeping a source of water available to wash cryogenic liquids off the skin before they have time to cause burns.

7.2 Treatment of Cold Contact Injuries

A. Remove or isolate the victim from the cause of the exposure.

B. Call 911 and request medical assistance.

C. Calm the victim and avoid aggravating the injury. Examples: If a hand or hands show cold contact injuries, tell the victim not to use them. If the feet have cold contact injuries, the victim should not walk.

7.3 Protection from Physiological Hazards

Most physiological hazards resulting from the use and handling of cryogens is the replacement of breathing oxygen when the cryogen is allowed to give off gas rapidly, such as would occur with rapid exposure to ambient temperature due to a spill or release. There are two basic means for correcting this condition.

A. Ventilation – Adequate ventilation must be provided where cryogens are used. Systems will be designed to discharge pressure relief and purge lines to areas that do not endanger personnel. Supervisors will ensure that adequate ventilation is provided anytime a cryogen is used, handled, stored, or transferred. For questions regarding

ventilation requirements, contact an Industrial Hygienist in the Safety, Health, and Environmental Office.

B. Respiratory Protection – Training and fitting for air-supplied respirators and self-contained breathing apparatus (SCBA) equipment is available at the Safety, Health, and Environmental Office. See current DFRC procedure for respiratory safety for respirator equipment and training requirements.

7.4 Oxygen and Hydrogen Hazard Protection

A. Oxygen – Safety controls include venting oxygen from the work area and ensuring adequate ventilation to prevent oxygen build-up. In some cases, oxygen analyzers with alarms to alert for high oxygen content may be required. Precautions for handling liquid oxygen are:

1) Keep liquid or high concentrations of gaseous oxygen away from contact with materials containing carbon compounds such as oil, grease, asphalt, kerosene, or any material such as cloth or wood that has a carbon compound in it because oxygen can react violently with these compounds.

2) Quickly remove clothing that has been splashed with liquid oxygen or exposed to high concentrations of gaseous oxygen. Place clothing in a safe well ventilated location for at least 30 minutes.

3) Do not have open flames such as welding operations within 100 feet of liquid oxygen storage units or pipes without first monitoring for oxygen level. Contact the Safety, Health, and Environmental Office for monitoring procedures and equipment.

4) Post *No Smoking* and warning signs around oxygen systems. Remain clear of open flames for 30 minutes after exposure to oxygen because it tends to cling to clothing

5) Keep an appropriate class fire extinguisher available. .

6) Do not enter an area where a high concentration of oxygen is known or suspected until the area is monitored and purged. A Safety Office Industrial Hygienist must approve entry into a space that has a known or potential hazardous atmosphere and for all designated confined spaces. (See DCP-S-067.)

7) Oxygen sources will be isolated by at least two positive blocks, such as valves, between the source and the equipment. A relief device must be located between the valves. If a valve is used to block a system, the valve must be locked to prevent accidental opening and there must be a DO NOT OPERATE tag in place.

For additional requirements and information see NFPA 53, Recommended Practice on Materials, Equipment, and Systems used

in Oxygen-Enriched Atmospheres, available for review at the Safety, Health, and Environmental Office.

B. Hydrogen – Hydrogen is highly explosive; therefore, flames will not be permitted in areas where cryogenic hydrogen is used, stored, handled, or transferred, and approved electrical systems may also be required.

Precautions that must be observed when handling liquid hydrogen:

1) Keep combustible materials away from hydrogen.
2) Do not have open flames, such as welding operations, within 100 feet of liquid hydrogen storage units or pipes without first contacting the Safety Office for monitoring procedures and equipment.
3) Do not enter a poorly ventilated or confined space that has the potential of containing hydrogen until the space has been monitored and purged if necessary. A Safety Office Industrial Hygienist must approve entry into a space that has a known or potential hazardous atmosphere and for all designated confined spaces.
4) Hydrogen sources will be isolated by at least two positive blocks, such as valves, between the source and the equipment. A relief device must be located between the valves. If a valve is used to block a system, the valve must be locked to prevent accidental opening and there must be a DO NOT OPERATE tag in place.
5) If liquid hydrogen is stored inside, it must be vented to the outside. If the vent is through ductwork, the ductwork must be free of ignition sources.
6) For class and division requirements of electrical equipment near hydrogen usage, see NFPA 70, National Electrical Code (NEC).
7) Ground all stationary hydrogen equipment. Bond mobile and stationary equipment used to transfer and receive hydrogen and ensure each piece of equipment has a common ground.
8) Purge liquid hydrogen transfer hoses with helium gas, and ensure liquid hydrogen is transferred in approved equipment.

For additional requirements and information see NFPA (Fire) 55, Compressed Gases and Cryogenic Fluids Code available for review at the Safety, Health, and Environmental Office.

8.0 HANDLING REQUIREMENTS FOR CRYOGENIC FLUIDS

8.1 Precautions

When handling, transferring, or storing cryogenic fluids, the following rules are mandatory:

A. Tasks involving a cryogen require two persons unless in a laboratory where small amounts of cryogen are used in a closed container.

B. Follow DCP-S-062, Lockout / Tagout program, to ensure cryogenic liquid systems are properly deactivated prior to any maintenance or modification.

C. Vent cryogens through proper valves and monitor for possible freeze-ups. Vent into the atmosphere away from people. Never vent a cryogen into a building or where it could enter a building ventilation system.

D. When putting a warm object into a cryogen, do it slowly to prevent splashing from boiling. Use tongs to insert and remove objects.

E. Transfer cryogenic fluids slowly from one container to another to minimize thermal shock and splashing from boiling.

F. Leave frost on uninsulated surfaces undisturbed. This will reduce the additional build-up of nitrogen and oxygen.

G. Always do a hazard analysis before starting a project that uses cryogenic liquids.

H. Keep appropriate safety and firefighting equipment available.

I. Keep cryogens that have the potential to cause fire or explosion away from open flames and combustibles.

J. Keep unprotected and unauthorized persons away from cryogens.

K. Ensure that an eyewash and shower are close to the point of cryogen operations.

L. Use cryogen liquids in well-ventilated areas. Continually ventilate areas where inert cryogens are used. Use oxygen analyzers with alarms to determine oxygen concentrations when working with cryogenic liquids except in laboratory settings where small amounts in closed containers are used.

M. Ensure appropriate signs are posted to alert personnel to cryogen hazards, such as the possibility of asphyxiation in cryogenic storage areas.

N. Store cryogenic fluids outside or in large well-ventilated rooms that have vents to the outside.

O. Do not enter an area that contains or has the potential of containing a concentration of toxic, inert, or explosive gas. Entry will be done only after the area is monitored, purged, or an air-supplying breathing apparatus is used. A Safety Office Industrial Hygienist must approve entering confined spaces where concentrations of gases may be present.

P. For procedures for handling potential fire and explosive gases see Section 7.4A, Oxygen, and Section 7.4B, Hydrogen.

Table 1
PROPERTIES OF COMMON CRYOGENIC LIQUIDS

	Argon	Helium	Hydrogen	Methane	Nitrogen	Oxygen
Cold Contact Burns	Yes	Yes	Yes	Yes	Yes	Yes
Possible Respiratory Damage	Yes	Yes	Yes	Yes	Yes	Yes
Frostbite Due to Vapor Contact	Yes	Yes	Yes	Yes	Yes	Yes
Confined Space Purging Required	Yes	Yes	Yes	Yes	Yes	Yes
Toxicity	Nil	Nil	Nil	Nil	Nil	Nil
Explosive With Combustibles	No	No	Yes	No	No	Yes
Cause Rupture if Trapped	Yes	Yes	Yes	Yes	Yes	Yes
Combustible	No	No	Yes	Yes	No	No
Promotes Ignition	No	No	Yes	Yes	No	Yes
Will Condense Air	No	Yes	Yes	No	Yes	No
Flammable Limits in Oxygen by %	N/A	N/A	4 to 94	5 to 61	N/A	N/A
Flammable Limits in Air by %	N/A	N/A	4 to 75	5 to 15	N/A	N/A
Spontaneous Ignition Temperature in Air	N/A	N/A	1076 F	1000 F	N/A	N/A

Other cryogens include ethane, ethylene, krypton, neon, and xenon. These cryogens are rarely used; however, if a project requires the need for any of these cryogens, contact an Industrial Hygienist in the Safety, Health, and Environmental Office (Code SH).

9.0 TRAINING & CERTIFICATION

Occupational Safety and Health Administration (OSHA) requires that persons working with or near hazardous chemicals be provided information about the hazards of the chemicals and be trained on how to safely work with such chemicals. See DCP-S-102, Environmental Management System Chemical Management.

9.1 Required Training

Personnel working with or near cryogens will receive hazard communication training required by 29 CFR 1910.1200(h). Personnel will receive effective information and training on hazardous chemicals in their work area at the time of their initial assignment and whenever a new physical or health hazard the employees have not been previously trained about is introduced into their work area. Information and training may be designed to cover categories of hazards or specific chemicals. Chemical-specific information must always be available through labels and material safety data sheets.

9.2 Refresher Training

Hazard communication refresher training is not defined in OSHA standards; however, supervisors are responsible for evaluating procedures, chemicals, and equipment in their area of responsibility, and provide training to their employees when procedures, chemicals, or equipment change.

10.0 MANAGEMENT RECORDS & RECORDS RETENTION

After completion of a project, the disposition of records generated will be made using NPD 1441.1, Records Retention Schedules, and DFRC records management procedures.

Training records will be retained by the training organization or in a central location where they are available to the trainee and authorized persons. Training records will be destroyed when no longer needed or after 3 years, whichever is sooner, in accordance with NPD 1441.1, NASA Records Retention Schedules, and DFRC records management procedures. Destruction of any records, regardless of format, without an approved schedule is a violation of Federal law.

11.0 RELEVANT DOCUMENTS

11.1 Authority Documents

29 CFR 1910.103 (c)	Liquefied Hydrogen Systems
29 CFR 1910.104	Oxygen
29 CFR 1910.1200	Hazard Communication
NPR 8715.3	NASA General Safety Program Requirements

11.2 Reference Documents

NASA STD 8719.17	NASA Requirements for Ground-Based Pressure Vessels and Pressurized Systems (PV/S)
29 CFR 1910	Subpart I, Personal Protective Equipment (PPE)
ASME Boiler and Pressure Vessel Code, Section VIII	Pressure Vessels
DCP-S-062	Lockout / Tagout Program
DCP-S-065	Pressure Vessels and Pressurized Systems Safety
DCP-S-067	Confined Space
DCP-S-102	Environmental Management System Chemical Management
NFPA (Fire) 55	Compressed Gases and Cryogenic Fluids Code, 2010 Edition
NFPA 53	Recommended Practice on Materials, Equipment, and Systems used in Oxygen-Enriched Atmospheres
DFRC DCP	Respiratory Safety

12.0 ACRONYMS & DEFINITIONS

12.1 Acronyms

ASME	American Society of Mechanical Engineers
CFR	Code of Federal Regulations
CGA	Compressed Gas Association
NEC	National Electric Code
NFPA	National Fire Protection Association

OSHA	Occupational Safety and Health Administration
PPE	Personal Protective Equipment

12.2 Definitions

Absolute Pressure	Pressure based on a zero reference point. Using this basis 1 ATM = 14.7 psi at sea level.
Cryogenic Liquid	A liquid having a boiling point lower than -150° F or -101° C at 1 ATM.
Dewar	a container with an evacuated space between two walls that are highly reflective, capable of maintaining its contents at a near-constant temperature over relatively long periods of time
Hypoxia	A deficiency in the amount of oxygen delivered to the body tissues
Liquefied Gas	A gas held as a liquid and a gas under pressure.
Oxidizing Gas	A gas that supports and accelerates combustion of other materials. Example: oxygen.
Pyrophoric Gas	A gas that will spontaneously ignite in air at or below 130° F or 54.4° C.
Scf	One cubic foot of gas at 70° F or 21° C and 1 ATM.

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