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CHAPTER 6.4 WORKING SAFELY WITH CRYOGENIC FLUIDS

6.4.1. Applicability of this chapter

6.4.1.1 You are required to follow this chapter if you (at JSC or field sites):

- a. Use, handle, store, or transfer cryogenic fluids as a part of your job.
- b. Supervise anyone who does the above tasks.

6.4.2. What this chapter covers

This chapter covers the minimum requirements to handle and use common cryogenic fluids safely.

6.4.3. Definition of a cryogenic fluid

6.4.3.1 A cryogenic fluid is a liquid with a normal boiling point below -238°F (221°R , -150°C , 123 K). Commonly used cryogenic fluids include the following:

- a. Liquid helium (LHe): normal boiling point -452°F
- b. Liquid hydrogen (LH₂): normal boiling point -423°F
- c. Liquid nitrogen (LN₂): normal boiling point -320°F
- d. Liquid oxygen (LO₂): normal boiling point -297°F
- e. Liquid air (Lair): normal boiling point -318°F
- f. Liquid argon (LAr): normal boiling point -303°F

NOTE: Fluorine, neon, carbon monoxide, methane, nitric oxide, and krypton can be liquefied and are cryogenic fluids, but are rarely used at JSC in the liquid state.

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6.4.4. Hazards of cryogenic fluids

6.4.4.1 Cryogenic fluids could cause any of the following safety problems:

- a. Cryogenic burns to skin and eyes from the extreme cold. The difference in temperature between liquid nitrogen and your hand is about the same as the difference between a 400°F oven and your hand.
- b. Skin stuck to cold surfaces.
- c. Over-pressurization and rupture of a pressure system or vessel—when cryogenic fluids try to vaporize due to heating from the surroundings, they can increase the pressure 700 to 1,000 times.
- d. Asphyxiation, primarily through the displacement of oxygen from the atmosphere.
- e. Upper respiratory irritation from breathing cold vapors.
- f. Fire and explosion.
- g. Leaks, sprays, or spills contacting nearby equipment and causing structural failures due to excessive thermal stresses within the materials.

6.4.5. Precautions to observe when working with any cryogenic fluids

6.4.5.1 Employees who handle cryogenic fluids shall observe these precautions:

- a. Use the buddy system for tasks involving cryogenic fluids (two or more people), except for laboratory use from a small container.
- b. Deactivate systems using proper energy controls found in Chapter 8.2, “Lockout/tagout Practices,” before starting any maintenance or repair work.
- c. Vent cryogenic systems through appropriate valves. Release gases so that the wind or room ventilation will direct them away from people.
- d. Put warm objects in cryogenic fluids slowly and use tongs to insert or remove the objects.
- e. Put a cryogenic fluid into a warm container slowly to minimize boiling, splashing, and thermal stresses.
- f. Keep unprotected body parts away from the cold surfaces of pipes or vessels that contain cryogenic fluids.
- g. Leave frost that forms on un-insulated surfaces undisturbed to help prevent L_{air} (LN₂ plus LO₂) from accumulating.
- h. Do a written hazard analysis for any area where cryogenic fluids are used or stored.
- i. Have a procedure as described in Chapter 5.8, “Hazardous Operations: Safe Practices and Certification.”
- j. Ensure all personnel involved are trained in the safe handling of cryogenic fluids, to include selection and use of personal protective equipment (see 6.5.16).

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6.4.6. Locations for working with cryogenic fluids

6.4.6.1 Any work done with cryogenic fluids shall be:

- a. Near properly maintained safety and firefighting equipment.
- b. Away from combustibles.
- c. Away from unprotected or unauthorized personnel.
- d. Used in well-ventilated areas. Use oxygen analyzers and alarms to monitor for low oxygen concentrations, as required by the hazard analysis, if you are working with LHe, LH₂, LN₂, or LAr. Use oxygen analyzers and alarms to monitor for high oxygen concentrations if you are working with LO₂.

6.4.7. Storing cryogenic fluids

6.4.7.1 Locations where cryogenic fluids are stored shall:

- a. Be stored outside or in large, open, and well-ventilated rooms that are vented to the outside. Use oxygen analyzers and alarms as described in subparagraph 6.4.6.1.d.
- b. Be continuously ventilated, even at night and on weekends, unless they are removed from the area. Leave air handlers or exhaust ventilation on at all times.
- c. Be labeled at the entrance to any area with cryogenic fluids to alert personnel asphyxiation is possible due to oxygen-displacing cryogenics.
- d. For storing LH₂ inside, vent any gas that escapes either to the outside or to a safe location. If vented through ductwork, make sure the ductwork is independent of other systems and contain no ignition sources.
- e. Include hydrogen detectors (either permanently installed or portable) wherever hydrogen is used.
- f. Use Class I, Division 1, Group B electrical equipment as described in National Fire Protection Association Standard 70, "National Electric Code." within 3 feet of hydrogen sources (such as where connections are regularly made and disconnected),
- g. Use Class I, Division 2, Group B electrical equipment when hydrogen sources are more than 3 and less than 25 feet away.

6.4.8. Action to take in case of a skin burn from a cryogenic fluid

If someone spills cryogenic fluid on themselves, seek immediate medical attention at the JSC Clinic or call x33333 or (281) 483-3333.

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6.4.9. Precautions for storing, using, or transferring cryogenic fluids

6.4.9.1 Employees who transfer, use, or store any cryogenic fluids shall observe these precautions:

- a. Transfer liquid slowly to reduce thermal shock to containers.
- b. Never breathe cryogenic vapors.
- c. Never allow ice to accumulate on a neck of or near the vent of a cryogenic vessel. Ice could plug the vent and cause the vessel to rupture.
- d. Empty and purge any cryogenic vessel with ice accumulating on the outer surface and either dispose of it or take it out of service for repair. The ice indicates a poor vacuum in the annular space, resulting in poor insulation.
- e. Tape or cage exposed portions of glass containers to minimize flying glass if the glass breaks.
- f. Follow these requirements to prevent sparks or arcs:
 - (1) Ground all stationary hydrogen and oxygen equipment.
 - (2) Bond mobile and stationary equipment used to transfer and receive L_{air}, LO₂, and LH₂ and make sure that all equipment involved in the transfer shares a common ground.
 - (3) Purge all condensable gases from LH₂ transfer hoses in service with helium gas. Transfer LH₂ only with specially designed equipment.

6.4.10. Precautions for handling LN₂

6.4.10.1 As a gas, nitrogen is colorless, odorless, tasteless, nontoxic, and almost totally inert, as described in Attachment 6.4D, Appendix F. The main health hazard of nitrogen is asphyxiation. Nitrogen can displace oxygen in the air in enclosed or semi-enclosed areas. Employees who use or handle LN₂ shall observe these precautions:

- a. Never enter a tank, sump, or closed space that has contained LN₂ until you have purged the space and stabilized the oxygen concentration at normal levels. Air testing is required to document that oxygen concentration is at a safe level. To enter an oxygen-deficient space:
 - (1) Wear an air-supplying breathing apparatus.
 - (2) Approval is required from the Safety and Test Operations Division and Occupational Health for the entry. An approved confined space entry procedure and permit may also be required (see Chapter 6.9).
 - (3) Have specially trained rescue personnel on stand by to immediately rescue entry personnel during an emergency.
- b. Isolate the LN₂ source using a minimum of two positive blocks, such as valves, between the source and the system or equipment. Approval is required from the Safety and Test Operations Division for any other arrangement.
- c. If using valves to block a system, chain or lock them to prevent accidental opening and tag them with DO NOT OPERATE tags. See Chapter 8.2 for detailed requirements on lockout/tagout.

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- d. If using an open bleed valve to prevent nitrogen pressurization, chain or lock it open to prevent pressure buildup between blocks or flanges and vent it to outside the work area.
- e. Use blank or blind flanges as necessary. If the system contains no bleed valves, install a bleed valve on each flange.

6.4.11. Precautions for handling LO₂

6.4.11.1 Oxygen is nonflammable but vigorously supports and accelerates combustion as described in Attachment 6.4B, Appendix F. Many substances will burn or explode more easily in an oxygen-enriched atmosphere. Employees who handle LO₂ shall follow these precautions to avoid fires or explosions:

- a. Wear clothing specified in the Safety Data Sheet. Oxygen can saturate clothing, rendering it extremely flammable. Clothing described as flame resistant or flame retardant in air may be flammable in an oxygen-enriched atmosphere. Clothing with good insulating properties is effective in protecting the wearer from burns due to cryogenic splashes or spills, but even these components can absorb oxygen.
- b. Never allow any organic materials or flammable substances to come in contact with LO₂ or oxygen-enriched atmospheres. Some of the organic materials that can react violently with oxygen are oil, grease, asphalt, kerosene, cloth, tar, and dirt containing oil or grease.
- c. Open and close valves in LO₂ systems slowly.
- d. If clothing is soaked or splashed with LO₂ or oxygen vapors, and there are no further injuries, move to a safety shower and rinse with tepid (60° - 100°F) water. Remove clothing that is not adhered to the skin and place it in a well-ventilated area away from flammable and combustible materials for at least 30 minutes.
- e. Avoid or leave any area with an oxygen-enriched atmosphere. Avoid all ignition sources.
- f. Never do welding, cutting, or spark-producing operations within 100 feet of LO₂ storage units or pipes without monitoring the oxygen levels with an oxygen analyzer. Never do these operations if the work area atmosphere is oxygen-enriched. Monitor oxygen levels intermittently or continuously at the discretion of the Safety and Test Operations Division or the supervisor.
- g. Never smoke around oxygen systems. Post NO SMOKING signs around oxygen systems. Wait at least 30 minutes after exposure to LO₂ before smoking. Oxygen tends to cling to your clothing.
- h. Keep a fire extinguisher available wherever an exposure to LO₂ can occur.
 - (1) If most of the material that could be exposed to the LO₂ is paper or wood (Class A fuel), keep at least a 2½-gallon water-filled fire extinguisher within 75 feet. Dry chemical extinguishers are ineffective against this type of fire.
 - (2) If most of the material that could be exposed to the LO₂ is oil or grease (Class B fuel), keep at least 10-pound dry chemical (60-B:C) or multipurpose (4-A:60-B:C) extinguisher within 50 feet.

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- i. Never enter a tank, sump, or closed space that has contained LO₂ until you have purged the space and stabilized the oxygen concentration levels. Air testing is required to confirm the atmosphere is neither oxygen deficient nor oxygen enriched. Approval from the Safety and Test Operations Division is required to enter any space with an oxygen-enriched atmosphere. An approved confined space entry procedure and permit may be required.
- j. Isolate LO₂ source by using a minimum of two positive blocks, such as valves, between the source and the system or equipment. Approval is required from the Safety and Test Operations Division and Occupational Health for any other arrangement.
- k. If using valves to block a system, chain or lock them to prevent accidental opening, and tag them with DO NOT OPERATE tags. See Chapter 8.2 for detailed requirements on lockout/tagout.
- l. If using an open bleed valve to prevent oxygen pressurization, chain or lock it open to prevent pressure buildup between blocks or flanges and vent it to outside the work area.
- m. Use blank or blind flanges as necessary. If the system contains no bleed valves, install a bleed valve on each flange.

6.4.12. Precautions for handling LH₂

6.4.12.1 LH₂ vaporizes rapidly, is very flammable when mixed with air or oxygen, and burns with an invisible flame as described in Attachment 6.4C, Appendix F. Gaseous hydrogen can be “self-igniting” when released under high pressure. At ordinary temperatures, hydrogen is very light. However, LH₂ vapors are slightly heavier than 70°F air and can spread along the ground for considerable distances. Employees who handle LH₂ shall observe these precautions to avoid a fire or explosion:

- a. Keep combustible materials away from hydrogen.
- b. Never do welding, cutting, or spark-producing operations within 100 feet of hydrogen storage units, flare stacks, vent lines, or pipes. Use a hydrogen detector to make sure there is no hydrogen in the area.
- c. Never do any welding, cutting, or spark-producing operations on components of a LH₂ system until you drain them and purge them with an inert gas.
- d. Never enter a tank, sump, or closed space that has contained LH₂ until you have purged the space and stabilized the oxygen concentration at normal levels. Air testing is required to determine that the oxygen atmosphere is within safe levels. Approval is required from the Safety and Test Operations Division and Occupational Health for any entry into a space with a flammable or oxygen-deficient atmosphere. See paragraph 6.4.10.1.a. for restrictions on entry into a contaminated space. An approved confined space entry procedure and permit may be required (see Chapter 6.9).
- e. Isolate LH₂ source by using a minimum of two positive blocks, such as valves, between the source and the system or equipment. Make sure the line section between the valves has a safety relief device or bleed valve. Approval is required from the Safety and Test Operations Division for any other arrangement.

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- f. If using valves to block a system, chain or lock them to prevent accidental opening and tag them with DO NOT OPERATE tags. See Chapter 8.2 for detailed requirements on lockout/tagout.
- g. If using an open bleed valve to prevent hydrogen pressurization, chain or lock it open to prevent pressure buildup between blocks or flanges and vent it to outside the work area.
- h. Use blank or blind flanges as necessary. If the system contains no bleed valves, install a bleed valve on each flange.
- i. Keep a 10-pound multipurpose (4-A:60-B:C) or a 10-pound CO₂ (10-B:C) fire extinguisher within 50 feet of potential hydrogen sources.

6.4.13. Actions to take for an LO₂ spill or fire

- a. Keep all ignition sources, equipment, and people away from LO₂ spills for at least 30 minutes after all frost or fog has disappeared. The spill area surfaces, especially asphalt, could ignite from friction or shock.
- b. Attempt to extinguish an LO₂ fire with hand fire extinguishers immediately because many materials burn rapidly in LO₂. Then quickly evacuate the area in an orderly manner.

6.4.14. Actions to take for an LH₂ spill or fire

- a. Shut off the hydrogen flow as soon as possible, and especially before attempting to extinguish a hydrogen fire.
- b. Remember hydrogen burns with an invisible flame.
- c. If no hydrogen flame detector is available, use a long piece of wood or other combustible material to probe for flames before approaching the area of the spill.
- d. Spray water on the spill to prevent a fire.
- e. Spray large quantities of water on adjacent equipment to cool the equipment.
- f. Attempt to extinguish only small fires.

6.4.15. Special precautions for handling other cryogenic fluids

For cryogenic fluids not mentioned above, contact the Safety and Test Operations Division for additional safety requirements. Other cryogenic fluids may include LAr or LHe.

6.4.16. Protective clothing and equipment to use when handling cryogenic fluids

6.4.16.1 Employees working with cryogenic fluids shall wear the protective equipment that is appropriate for the hazards of the task. The following list includes common protective equipment for working with cryogenic fluids:

- a. Eye protection.
- b. Face shields.
- c. Insulated gloves with gauntlets—the gloves should be loose fitting.

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d. Cuff-less trousers outside of boots or work shoes; never wear tennis shoes or open-toed shoes.

e. Coveralls or smocks, with long sleeves, approved for use with the cryogen.

NOTE: See Chapter 5.6, "Personal Protective Equipment," for more requirements on protective equipment.

6.4.17. Training to work with cryogenic fluids

6.4.17.1 Employees shall be certified to handle cryogenic fluids as described in Chapter 5.8. Training shall cover the following subjects for each cryogenic fluid in the work area:

- a. Nature and properties of the cryogenic fluid in both liquid and gaseous states.
- b. Correct PPE to use in specific environments and where you can find it.
- c. Approved materials that are compatible with the cryogenic fluid.
- d. Proper use, to include donning and doffing, and care of protective clothing and equipment.
- e. First-aid procedures.
- f. Emergency procedures for handling situations such as leaks, spills, and fires.
- g. Good housekeeping practices.

6.4.18. Design requirements for cryogenic areas and systems

6.4.18.1 In addition to the standards listed in paragraph 6.4.19, systems handling cryogenic fluids shall meet these requirements:

- a. Insulate cryogenic vessels and lines and provide drip pans under exposed pipes.
- b. Insulate cryogenic containers.
- c. Provide frangible (burst) discs or other pressure-relief devices between the inner vessels and outer tank shell so pressure rupture cannot occur.
- d. Provide frangible (burst) discs or other pressure-relief devices between sections of a system that may trap cryogenic fluid, such as between two valves.
- e. Provide enough continuous ventilation and hazardous gas monitors where accidental releases or spills could occur, as indicated by the hazard analysis.

6.4.19. Other requirements to follow while handling cryogenic fluids

In addition to the requirements in this chapter, you shall follow these standards as they apply to the work you do. Chapter numbers are for chapters in this JPR.

<i>For . . .</i>	<i>Follow this standard . . .</i>
Working with cryogenic fluids	29 CFR 1910.103 and 29 CFR 1910.104
Certifying employees to work with cryogenic liquids	Chapter 5.8

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Designing cryogenic systems	<ul style="list-style-type: none"> JPR 1710.13, "Design, Inspection, and Certification of Pressure Vessels and Pressurized Systems," (current version) NFPA 55, "Compressed Gases and Cryogenic Fluids Code", 59A, "Liquefied Natural Gas," and others, as applicable
Finding more data on cryogenic fluids	Attachments 6.4A – 6.4D, Appendix F
Finding requirements for electrical equipment in areas with hydrogen	NFPA 70