BY ORDER OF THE
SECRETARY OF THE AIR FORCE

AIR FORCE OCCUPATIONAL SAFETY AND HEALTH STANDARD 91-67

1 OCTOBER 1997

Safety

LIQUID NITROGEN AND OXYGEN SAFETY

NOTICE: This publication is available digitally on the SAF/AAD WWW site at: http://afpubs.hq.af.mil. If you lack access, contact your Publishing Distribution Office (PDO).

OPR: HQ AFSC/SEGS
(SMSgt Pennie Hardesty)
Supersedes AFOSH Standard 127-67,
30 April 1987

Certified by: HQ AFSC/SEG
(Colonel Robert W. Scott)
Pages: 20
Distribution: F

The criteria in this standard are the Air Force's minimum safety, fire prevention, and occupational health requirements for Liquid Nitrogen (Air Force abbreviation-LIN-also known as LN_2) and Liquid Oxygen (LOX) operations. Major Commands (MAJCOM), direct reporting units (DRU), or field operating agencies (FOA) may supplement this standard when additional or more stringent safety, fire prevention, and health criteria are required. Refer to Air Force Instruction (AFI) 91-301, *Air Force Occupational and Environmental Safety, Fire Protection, and Health (AFOSH) Programs*, for instructions on processing supplements or variances. Report conflicts in guidance between this standard, federal standards, or other Air Force directives through MAJCOM, DRU, or FOA ground safety offices to Headquarters Air Force Safety Center, Ground Safety Division, Safety Engineering and Standards Branch (HQ AFSC/SEG), 9700 Avenue G, SE, Kirtland AFB NM 87117-5670.

This standard applies to LIN (LN_2) and LOX production, receipt, storage, issue, and servicing operations. It provides Air Force personnel with guidance on LIN (LN_2) and LOX hazards and their control. This information is intended to supplement the general and specific technical data for production, storage, and aerospace support equipment. Although unique operations such as missile launch and research operations are not specifically addressed in this standard, much of the information contained herein may be used. The standard applies to all US Air Force organizations, including US Air Force Reserve personnel and when National Guard personnel are on federal service.

There are no federal safety standards directly applicable to LIN (LN_2) and LOX production, receipt, issue, and servicing. However, there is some information on LOX storage in Occupational Safety and Health Administration (OSHA) Standard 29 CFR 1910.104, *Oxygen*. Department of Transportation (DOT) Standard 49 CFR, Parts 171-179, addresses the transportation of hazardous materials but does not specifically address LIN (LN2) or LOX. OSHA cross-references are included at the end of applicable paragraphs.

SUMMARY OF REVISIONS

Administrative changes have been made to update this standard to electronic format. Paragraphs have been renumbered and references updated. Adverse weather condition procedures have been updated

(paragraph 2.9.). A glossary of references, abbreviations, acronyms, and terms is provided at **Attachment 1**. ***NOTE:*** AFOSH 127-series standards are being converted to 91-series standards and the 161-series to 48-series standards. However, not all standards have been converted as of the effective date of this standard. To help you locate these documents, references to AFOSH standards are stated in the updated series and standard number, with the outgoing series and standard number stated as "formerly designated as" in the 'references' section of **Attachment 1.** A | indicates revisions from previous edition.

Chapter 1

HAZARDS AND HUMAN FACTORS

The hazards of LIN (LN_2) and LOX may be categorized as physical, physiological, and chemical. These categories are discussed below. In addition, sections discussing solvents and chemicals used for LIN (LN_2) and LOX production and storage, plus the hazards associated with spills, have been included.

1.1. Physical Hazards. These hazards are primarily associated with phase change and low temperature effects of cryogens. When either LIN (LN_2) or LOX undergoes a phase change from liquid to gas, a tremendous volume increase occurs. For example, when LIN (LN_2) is vaporized each cubic foot of liquid is converted to 695 cubic feet of nitrogen gas. For LOX, the expansion ratio is 860 to 1. This means that containment of cryogens offers the potential of tremendous pressure increase should liquid to gas conversion occur. A sealed container can essentially become a bomb. The expansion ratio of LIN (LN_2) can result in the displacement of oxygen in a confined space causing an asphyxiation hazard. This is discussed further in physiological hazards below. Similarly, the expansion ratio of LOX can result in an oxygen enrichment, producing fire and explosion hazards (paragraph 1.3.). The temperature of LIN (LN_2) and LOX alters important properties of materials such as strength, ductility, thermal expansion, thermal conductivity, and heat capacity. For example, mild carbon steels become unacceptably brittle and failure-prone when exposed to cryogens. However, properly treated metals such as austenitic steels, nickel, aluminum, copper, and a number of alloys are safely used for low temperature work. One other major effect is the tendency for LIN (LN_2) to liquefy air that contacts it. Therefore, an open container of LIN (LN_2) will slowly condense air causing a gradual LOX concentration buildup within the LIN (LN_2). The presence of LOX within LIN (LN_2) can result in unexpected chemical reactivity with other materials. The hazards of LOX reactivity are discussed under chemical hazards below.

1.2. Physiological Hazards . These include asphyxiation and cryogenic burns. Sufficient evaporation of LIN (LN_2) in a poorly ventilated or unventilated enclosure may cause a dangerous reduction of the oxygen content of the air and may produce asphyxiation and death. Because the brain requires the most oxygen, a reduction in available oxygen will first affect the mental processes. A slight impairment of the ability to concentrate and think coherently is the first symptom noticed, progressing toward a loss of consciousness. In atmospheres with very high concentrations of nitrogen, unconsciousness can occur in seconds. Recovery in fresh air is rapid and complete, provided the time of reduced oxygen consumption is not prolonged. In the latter case, death may result. The extremely cold temperature of LIN (LN_2) and LOX presents a dangerous hazard to personnel. It can freeze or seriously damage human tissue upon contact. The effect is similar to that caused by frostbite or thermal burn and is instantaneous. Uninsulated parts of equipment are cooled to extremely low temperatures by LIN (LN_2) and LOX and will freeze to the skin upon direct contact. Flesh can be badly burned and can be severely torn in the attempt to free it, but this must be done immediately since the results of prolonged skin contact are even worse.

1.3. LOX Chemical Hazards . These hazards result from the extreme chemical reactivity of LOX. Most experience and data relating to the combustion of materials are related to fire behavior in normal air, containing about 21 percent oxygen and 79 percent nitrogen. In the case of LOX, the inert nitrogen has been removed and the pure oxygen has been concentrated 860 times by liquefaction. This results in a liquid that contains about 4,100 times more oxygen than the same volume of air. Under these conditions combustible materials and organic compounds react at explosive rates and materials not normally thought of as combustible can burn or explode. Because of this, the control of combustible and potentially reactive materials in LOX work becomes as important as the control of ignition sources when flammable gases are handled. Because of the unpredictability of LOX reactions with various materials, unauthorized substitutions of various LOX-service parts, fittings, hoses, seals, lubricants, and so forth, can be (and has been) disastrous. Difficulties are more likely to arise out of hydrocarbon contamination than substitution of unsuitable materials. Numerous cases have been reported where hydrocarbon contamination has resulted in explosions or initiated fires. Oil, dirt, and other foreign debris are special concern during aircraft servicing. Serious aircraft fires have resulted from combustible foreign matter in aircraft LOX systems. If spilled onto asphalt, LOX will seep into cracks and form shock-sensitive compounds which can explode violently upon impact. It is vital to ensure that LOX is handled only in areas where it will not come in contact with hydrocarbon materials when leaked or spilled, and this includes all areas where LOX might flow after a spill. Finally, LOX spills result in localized atmospheric oxygen enrichment. This is very persistent and increases the fire danger in the area substantially.

1.4. Solvents and Chemicals Used for LIN (LN_2) and LOX Production and Storage Hazards. Some of these solvents and chemicals present hazards. Trichloroethylene, trichloroethane, trichlorotrifluoroethane, and methylene-chloride solvents are used to clean some plant and tank parts. Sodium hydroxide, ammonium hydroxide, ammonium chloride, and pyrogallic acid are LIN (LN_2) and LOX test chemicals. Chemical hazards include skin irritations, burns, and irritating or harmful vapors. Some solvents can be absorbed through the skin and may cause liver damage. Some chemicals are poisonous when taken internally.

1.5. Spill Hazards. A LIN (LN_2) and LOX spill presents several hazards including asphyxiation, fire, explosion, severe cryogenic burns, and equipment damage. A key consideration is the control of the emergency without adding to its severity. Whenever the cryogenic liquid is exposed to the atmosphere, it condenses moisture in the air and forms a fog which extends over the immediate area.

Chapter 2

GENERAL REQUIREMENTS

2.1. Characteristics and Production of LIN (LN_2) and LOX:

2.1.1. Liquid Nitrogen. LIN (LN2) is a colorless, odorless, nonflammable, nontoxic, and chemically inactive water-like fluid with a boiling point of -320 degrees Fahrenheit (F). LIN (LN_2), less dense than water, weighs approximately 6.7 pounds per gallon. The expansion ratio for LIN (LN_2) (from LIN (LN_2) to gaseous nitrogen) is 695 to 1 at normal temperature and pressure. The critical temperature of LIN (LN_2) is -233 degrees F at 493 pounds per square inch absolute (psia). At temperatures higher than this, LIN (LN_2) cannot be liquefied regardless of pressure (refer to table 2.1 for physical properties of LIN (LN_2) and LOX).

2.1.2. Liquid Oxygen (LOX). LOX is a pale blue, nontoxic, water-like fluid with a boiling point of -297 degrees F. It is heavier than water, weighing approximately 9.5 pounds per gallon. The expansion ratio for LOX is 860 to 1 at normal temperature and pressure. The critical temperature of oxygen is -181 degrees F at 737 psia. At temperatures higher than this, LOX cannot be liquefied regardless of pressure. Liquid oxygen is attracted to an electromagnet much like iron and will combine readily with other substances to actively support combustion.

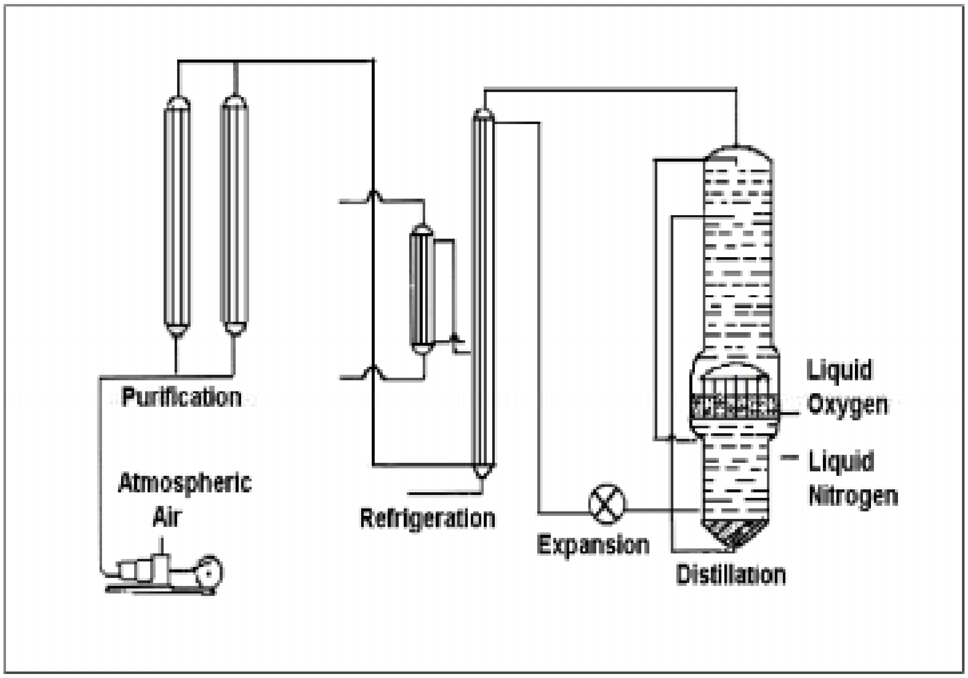
Table 2.1. Physical Properties of LIN (LN_2) and LOX.

Property	LIN(LN_2)	LOX
Boiling Point	-320 degrees F	-297 degrees F
Freezing Point	-346 degrees F	-361 degrees F
Density, Liquid	6.74 lb./gal at -320 degrees F	9.52 lb./gal at -297 degrees F
Liquid-to-gas Expansion Ratio (Gas Vol./Liq Vol.)	695	860
Critical Pressure	493 psia	737 psia
Critical Temperature	-233 degrees F	-181 degrees F

2.1.3. Storage Tanks (Cryotainers*).* LIN (LN_2) and LOX storage tanks are self-contained, skid-mounted units. They are constructed of an inner cylinder securely supported in an outer jacket. The support system is designed to reduce conductive heat transfer. The evacuated space between the inner and outer vessels contains highly efficient insulating material which reduces radiation and convection heat transfer. Pressure buildup in the inner tank necessary to transfer liquid from the tank is accomplished by vaporizing liquid in coils located beneath the tank. All operating controls are located in a cabinet at the front end of the tank. Storage tanks are manufactured in various sizes with capacities from 400 to 5,000 gallons. They shall be designed and constructed to meet the requirements of The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code. Suitable safety relief valves shall be installed so moisture cannot collect, freeze, and interfere with the proper operations of the device. Frangible disks shall also be included in the design (figure 2.1). (29 CFR 1910.104.)

2.1.4. Generating Plants**.** The production capacities of Air Force LIN (LN_2) and LOX plants are rated at one and one half to five tons. Production rates are given in tons of liquid oxygen produced per day (24 hours). The plants produce four products: liquid and gaseous nitrogen and liquid and gaseous oxygen. LIN (LN_2) and LOX is generated from atmospheric air through five basic steps: compression, purification, refrigeration, expansion, and distillation (figure 2.2).

Figure 2.1. Typical LIN (LN_2) and LOX Storage Tank.



2.1.4.1. Compression. Multi-stage air compressors filter and compress atmospheric air. Filters remove airborne solids (dust, etc.). The compressed air is cooled between and after each stage of compression. The high pressure air flows from the final compressor stage cooler slightly above ambient temperature.

2.1.4.2. Purification. The cooled, compressed air is dried and purified to remove moisture, hydrocarbons, and carbon dioxide. These contaminants are removed by passing the air through activated alumina, molecular sieve, and silica gel materials.

2.1.4.3. Refrigeration. The purified air is cooled by counterflow heat exchangers. Some plants use expansion engines for additional cooling. The heat exchangers use mechanical refrigeration and distillation column by-products (gaseous nitrogen) to cool the high-pressure air.

2.1.4.4. Expansion. The cold, high-pressure air, near its liquefaction temperature, is passed through an expansion valve. The expansion of the air causes a pressure and temperature drop, which liquefies the air.

2.1.4.5. Distillation. The liquid air flows through “high” and “low” pressure distillation columns. The high pressure column produces pure liquid nitrogen (99.5 percent) and a crude liquid oxygen and nitrogen mixture (35/65 percent). The low pressure column produces pure liquid oxygen (99.5 percent) and gaseous nitrogen (98 percent). The pure oxygen or nitrogen is drawn off as a liquid product or diverted to heat exchangers for conversion to gaseous products.

2.1.5. High Pressure**.** Pressures approaching 4,000 pounds per square inch (psi) may be found in production facilities. To prevent personnel injury and property damage due to whipping of failed lines, all high-pressure lines shall be secured with brackets, braces, or other suitable tie-down devices.

2.1.6. Contamination. Atmospheric contamination during production runs may result in impurities being introduced into the cryogens. To avoid this, the following operations are not permitted during production runs:

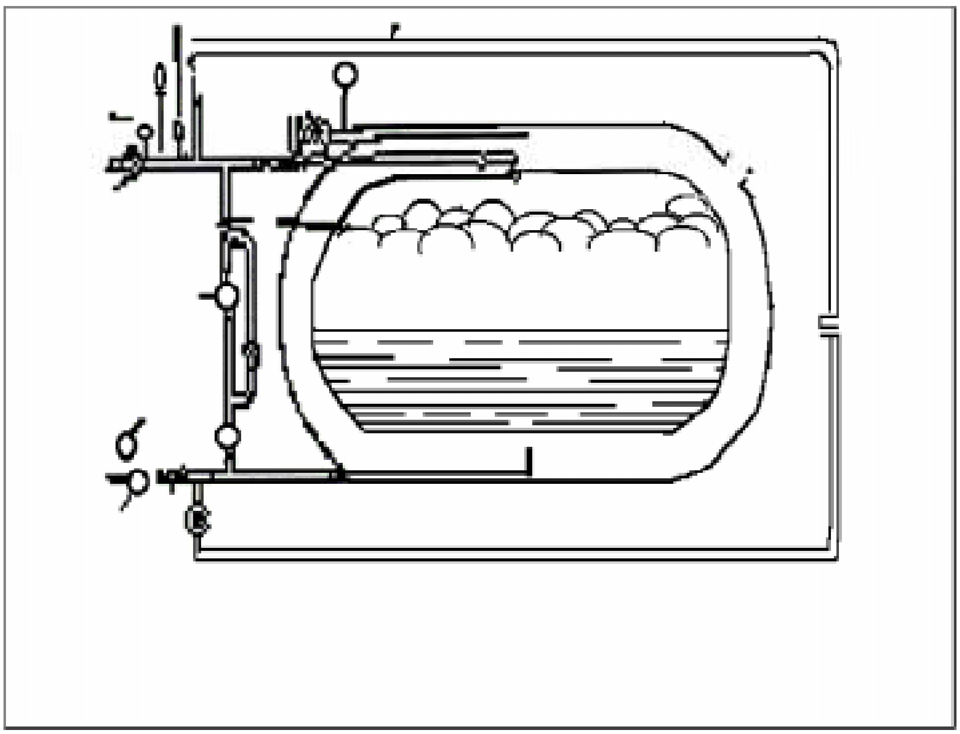
2.1.6.1. Painting.

2.1.6.2. Welding, cutting, and brazing.

2.1.6.3. Solvent use.

2.1.6.4. Any operation generating toxic and noxious gases or vapors.

Figure 2.2. Generating Plant Flow.



2.2. Cryogenic Facility Siting:

2.2.1. Because of the special hazards associated with LIN (LN_2) and LOX, care must be exercised in siting these facilities. Production or storage facilities having a capacity of 100 gallons or more will conform to these minimum separation distances. Further information will be found in Air Force guidance within the 32-series, *Civil Engineering* and Technical Order (TO) 00-25-172, *Ground Servicing of Aircraft and Static Grounding/Bonding*. The following are required:

2.2.1.1. Fifty feet from flammable liquid or gas storage.

2.2.1.2. Fifty feet from any type "C" combustible structure.

2.2.1.3. Twenty-five feet from any type "N" noncombustible structure.

2.2.1.4. Twenty-five feet from property lines.

2.2.1.5. Twenty-five feet from sidewalks, roadways, or vehicle parking areas.

2.2.1.6. Fifty feet from railroads.

2.2.1.7. Seventy-five feet from aircraft parking, fueling, or defueling areas.

2.2.1.8. Liquid oxygen carts for servicing aircraft will be parked according to TO 00-25-172. (OSHA 29 CFR 1910.104)

2.2.2. In addition to safe distance criteria, the following requirements shall be provided to ensure a safe, functional, and secure facility:

2.2.2.1. AFI 23-201, *Fuels Management*, will be consulted for information on security fencing and lighting.

2.2.2.2. LIN (LN_2) and LOX production facilities and storage locations shall be permanently placarded to indicate "OXYGEN-NO SMOKING-NO OPEN FLAMES" or an equivalent warning.

2.2.2.3. The installation civil engineer will be contacted regarding utility service (water, electricity, sewage, telephone).

2.2.2.4. Joint sealer shall be LOX-compatible (where spills are most likely to occur) in LOX handling and storage areas. This area will cover a 25-foot radius from the LOX cart fill point during servicing. The area around the LIN (LN_2) and LOX plant itself (where spills are most likely to occur) shall be concrete (refer to AFI 23-201 and AF 32-series).

2.2.2.5. A paved road shall be provided to and from the facility for delivery, maintenance, and emergency vehicles (refer to AFI 23-201).

2.2.2.6. Generator plants shall be permanently grounded. Storage and servicing tanks shall be provided adequate grounding points (refer to AFI 23-201).

2.2.2.7. Blowdown and condensate drains in the oil separator of the generating plant shall comply with local environmental pollution standards (consult the installation civil engineer and the bioenvironmental engineer).

2.2.2.8. Generating plants shall be sited to reduce airborne contamination to the maximum extent practical in consideration of local conditions.

2.3. Occupational Health:

2.3.1. Solvents and Chemicals. Refer to paragraph 1.3. for a discussion of the hazards of chemicals used in LIN (LN_2) and LOX production and storage. Proper ventilation and personal protective equipment (PPE) are required when handling these solvents and chemicals. The installation bioenvironmental engineer will provide guidance on the hazards and precautions required.

2.3.2. Noise. In generating plants noise levels can reach high levels, particularly during defrost, start-up, and shut-down operations. The installation bioenvironmental engineer shall determine which operations require hearing protection and provide information on suitable protection. Hearing protective equipment shall be readily available to all personnel when required.

2.3.3. Medical Treatment. Current first aid procedures for cryogenic burns involve removing the victim from exposure immediately. The victim will be transported to the emergency room of the hospital or clinic as soon as possible, identifying the exposure to LIN (LN_2) or LOX. The victim will be kept dry and warm by wrapping the exposed area in a cotton blanket. No attempt to rewarm frozen body parts shall be made until the victim is under proper medical care. Affected parts will not be rubbed because the tissues may be damaged. Clothing that may restrict circulation to the frozen area should be loosened or removed. The victim will not be allowed to drink alcoholic beverages. Also, the individual should be discouraged from smoking because both of these actions decrease blood flow to the frozen tissue. Control of shock and pain and rewarming of frozen parts shall be done only by base medical services.

2.4. Safety Precautions When Working With LIN (LN_2) and LOX:

2.4.1. Personal Protective Equipment (PPE). In a LIN (LN_2) or LOX generation plant, PPE is of two distinct types — cryogenic and chemical protection. Each type shall be used for its intended protection but in no case shall the PPE items be interchanged. Local procedures shall be developed to prevent hydrocarbon or chemical contaminated PPE from being used during cryogen transfers (refer to **Attachment 2** for a listing of PPE required for LIN (LN_2) or LOX operations. Also, refer to AFOSH Standard 91-31, *Personal Protective Equipment*, and TO 00-25-172 for more complete coverage of PPE.

2.4.1.1. Personnel who handle LIN (LN_2) or LOX will wear clean, protective gloves with gauntlet cuffs. Long sleeves shall extend to the gloves. Cuffless trousers shall be worn outside boots or over high-top shoes to shed spilled liquid. Shoes will be laced tightly to prevent spilled cryogen from seeping inside. Only tightly woven materials will be used for clothing worn during LIN (LN_2) or LOX operations. Also, face shields and an apron will be worn.

2.4.1.2. LIN (LN_2) and LOX both saturate clothing and will contact the skin via this route. Such contact may be more hazardous than that due to direct splashing. Clothing will be removed, hung up, and air dried for 1 hour if contaminated.

2.4.1.3. The PPE listed in **Attachment 2** and AFOSH Standard 91-31 will be used to provide protection from the chemicals used in LIN (LN_2) and LOX operations.

2.4.2. Low Temperature Precautions*:*

2.4.2.1. Avoid splashing on exposed skin. Cryogenics burn on contact.

2.4.2.2. Do not touch an uninsulated cryogenic surface unless wearing the proper PPE. Bare skin will freeze to any uninsulated cryogenic surface and portions of the skin will continue to adhere to the surface after removal of the affected part. Remove the affected part immediately, however, since leaving the skin in contact with the surface will freeze the underlying tissue and cause an even worse problem.

2.4.2.3. Assume all surfaces are cold until proven otherwise. External frost is not always present.

2.4.3. Equipment and Materials Precautions:

2.4.3.1. Most metal becomes very brittle at cryogenic temperatures and will shatter or crack under stress.

2.4.3.2. Valves may freeze if any moisture is present in the system. Droplets of moisture freeze into balls and pit valve seats causing them to leak.

2.4.3.3. Most glass and some plastics will shatter on contact with LIN (LN_2) or LOX due to thermal stress.

2.4.4. Asphyxiation Prevention:

2.4.4.1. Small amounts of liquid generate large amounts of gas. Avoid using cryogenics in small unventilated rooms.

2.4.4.2. LIN (LN_2), when vaporized, is heavier than air and sinks to the floor or lowest point, displacing oxygen. There may not be sufficient oxygen remaining to support life.

2.4.5. Fire Prevention**:**

2.4.5.1. Always avoid contact between LOX and petroleum-based products. Such a mixture is shock sensitive and will explode when struck. Note that most hair tonics are petroleum-based.

2.4.5.2. Ensure no oil or grease is present on clothing or equipment when working with or around LOX. In the case of clothing, remove and replace with clean ones. In the case of equipment, remove oil or grease with approved non-petroleum solvents.

2.4.5.3. Static electricity may ignite combustible materials in an oxygen-rich atmosphere. Wear only approved clothing and ensure workers ground themselves before they begin LOX operations.

2.4.5.4. Never use LOX for cooling.

2.4.5.5. Avoid open containers of LIN (LN_2). Although inert, LIN (LN_2) is colder than LOX. It liquefies oxygen from the surrounding air and the open container quickly becomes a LIN (LN_2) and LOX mixture. When the LIN (LN_2) is pale blue in color, there is LOX present in the mixture.

2.5. Fire Protection:

2.5.1. Consult base fire department personnel on fire protection for LIN (LN_2) and LOX facilities. Use care when selecting compatible fire fighting agents in production and storage areas. Nitrogen is a fire suppressant but oxygen supports combustion. In an oxygen supported fire, stop the oxygen flow if possible. Use large quantities of water, preferably in the form of a spray, to cool the burning material. If electrical equipment is involved in the fire, ensure the main electrical panel is locked in the off position before applying water. LOX is a vigorous oxidizing agent and supports combustion of many materials not flammable in air. A LOX fire cannot be effectively blanketed by such agents as carbon dioxide (CO), dry chemical, or foam. Unless the LOX flow can be stopped or the combustible materials isolated from the LOX, such fires are difficult if not impossible to extinguish.

2.5.2. Always maintain a clear and unobstructed access to and from LIN (LN_2) and LOX facilities for fire fighting equipment.

2.5.3. Do not permit LOX to come in contact with organic material or flammable substances of any kind. Some of the materials that can react violently with oxygen under certain conditions of pressure and temperature are oil, grease, asphalt, kerosene, cloth, paint, tar, and dirt which may contain oil or grease. If LOX is spilled on asphalt or other surfaces contaminated with combustibles (for example, oil-soaked concrete or gravel), do not walk on or roll equipment over the area of the spill. Keep sources of ignition away for at least 15 minutes after all frost has disappeared.

2.6. Electrical Safety. Depending upon size, LIN (LN_2) and LOX production plants and tank support equipment require electrical service up to 480 volt alternating current (AC). Use extreme care when working around any electrical connections, panels, motors, or other energized components. Moving fluids, drive belts, removal of clothing, and almost any friction can generate a static charge. Ground LIN (LN_2) and LOX plant components and storage tanks at all times.

2.7. Housekeeping:

2.7.1. As noted, LOX reacts violently when it comes into contact with many types of commonly used materials. Therefore, it is important the floors and drip pans in LOX plants and storage areas are kept in a spotless condition. Tanks shall be kept clean and free of all hydrocarbons.

2.7.2. Because dirty tools and equipment are sources of hydrocarbon contamination of oxygen components and systems, all tools and equipment will be kept meticulously clean and shall be stored properly.

2.8. Receipt, Storage, and Issue of LIN (LN2) or LOX *:*

2.8.1. Because of the catastrophic consequences of mixing LIN (LN_2) and LOX in storage tanks and carts, workers will exercise great care in verifying that the correct product is transferred to the correct storage tank or cart (refer to TOs 42B6-1-1, *Quality Control of Aviators Liquid Breathing Oxygen*, and 42B7-3-1-1, *Quality Control of Nitrogen*, for detailed procedures). Only fittings designed specifically for LOX or LIN (LN_2) equipment will be used; workers will never fabricate and use ones that are compatible for both LOX or LIN (LN_2) equipment.

2.8.2. At least two personnel, fully knowledgeable in Air Force safety criteria and operational procedures, shall be within normal voice or eye contact when generating or transferring cryogenic fluids. This also applies to maintenance actions on cryotainers or plants when cryogenic fluids are present in the system. Personnel requirements for aircraft servicing operations will be according to TO 00-25-172.

2.8.3. To minimize the extent of a spill or leak, all transfers shall be closely monitored. The use of drip pans is required. If the storage tank is located in a building, asphyxiation or oxygen enrichment hazards will exist in the event of a spill. Appropriate local emergency procedures shall be developed for this contingency.

2.9. Adverse Weather Conditions . The following procedures will be followed in the event of severe weather conditions, especially thunderstorms and lightning are within 5 miles of cryogen facilities or servicing operations.

2.9.1. The base weather station (BWS) is responsible for making the initial notification to predetermined support agencies of adverse weather conditions. Adverse weather conditions include: strong surface winds, heavy rain, freezing precipitation and thunderstorms (i.e., frequent dangerous lightning, and damaging winds, heavy rain and hail).

2.9.2. General lightning safety for all AF activities and operations:

2.9.2.1. Whenever lightning is detected or observed within the immediate vicinity of any activity or operation the following precautions should be taken:

- Do not go out of doors or remain out unless it is absolutely necessary. Seek shelter as follows:
- Dwellings or other buildings that are protected against lightning;
- Protected underground shelters;
- Large metal framed buildings;
- Enclosed aircraft, automobiles, buses, and other vehicles with metal tops and bodies;
- Streets that may be shielded by nearby buildings.

2.9.2.2. Certain locations are extremely hazardous during thunderstorms and should be avoided:

- Hilltops and ridges;
- Areas on top of buildings;
- Open fields, athletic fields, golf courses;
- Parking lots, tennis courts;
- Swimming pools, lakes, and seashores;
- Near wire fences, clotheslines, overhead wires, and railroad tracks;
- Under isolated trees;
- Near electrical appliances, telephones, plumbing fixtures, and metal or electrically conductive objects.

2.9.3. Each Air Force installation will develop a local procedure to ensure that key personnel and agencies involved in high weather risk activities and operations are notified according to the base weather support plan. Key personnel, in turn, will advise all on-duty supervisors to take proper precautions and timely actions.

2.9.3.1. Two-tiered Lightning notification procedure for high lightning risk activities and operations. Each installation will employ a lightning safety program with a two-tiered notification system to minimize personnel exposure to lightning hazards.

2.9.3.1.1. A *Lightning Watch* is in effect 30 minutes prior to thunderstorms being within 5 nautical mile (nm) radius of any predetermined location or activity as forecast by the BWS. ***NOTE****: Lightning is a direct product of a thunderstorm.* During a Lightning Watch accomplish the following:

- Operations or activities may continue, however all personnel must be prepared to implement Lightning Warning procedures without delay.
- Be alert for any lightning activity, to include audible thunder, and advise supervisory personnel of any observations.

2.9.3.1.2. A *Lightning Warning* is in effect whenever any lightning is occurring within 5 nm radius of the predetermined locations and activities. Personnel in affected locations or engaged in affected activities will take the following actions:

- Cease all outside activity and seek shelter. Recommended locations that provide safe shelter and locations to avoid are listed in paragraph 2.9.2.

2.9.3.2. If lightning does not occur within 5 nm at the valid (forecast) time of the Lightning Watch then BWS will reassess the Lightning Watch and amend as needed. Lightning warnings will be canceled when the thunderstorms have passed beyond the 5 nm radius of the location or activity. A Lightning Watch will not be canceled if there is potential for more thunderstorms within 30 min.

2.9.3.3. All aircraft fuel service maintenance activities (including liquid oxygen (LOX) servicing) will cease whenever a Lightning Warning is in effect.

FRANCIS C. GIDEON, JR., Maj General, USAF
Chief of Safety

Attachment 1

GLOSSARY OF REFERENCES, ABBREVIATIONS, ACRONYMS, AND TERMS

References

Air Force Instruction (AFI) 23-201, *Fuels Management.*

AFI 91-301, *Air Force Occupational and Environmental Safety, Fire Protection and Health (AFOSH) Program.*

Air Force Manual (AFMAN) 20-203V2, *Chemical Rocket/Propellant Hazards* (formerly designated as Air Force Manual (AFM) 161-30).

Air Force Occupational Safety and Health (AFOSH) Standard 91-31, *Personal Protective Equipment* (formerly designated as AFOSH Standard 127-31).

AFOSH Standard 91-66, *General Industrial Operations*.

Occupational Safety and Health Administration (OSHA) Standard 29 Code of Federal Regulations (CFR) 1910.103, *Oxygen.*

Safety With Cryogenics, M. G. Zabetakis, Plenum Press, 1967.

Technical Order (TO) 00-25-172, *Ground Servicing of Aircraft and Static Grounding/Bonding.*

TO 00-35D-54, *USAF Material Deficiency Reporting System.*

TO 33D2-10-34-1, *Cosmodyne Cryogenics Gas Sample*.

TO 33D2-10-60-1, *Cryogenic Sampler Model #FCS200l.*

TO 35-1-3, *Corrosion Prevention, Painting, and Marking USAF Support Equipment.*

TO 36Gl-2-9-1, *Oxygen/Nitrogen Generating Plant, Model J665.*

TO 36Gl-2-9-11, *Oxygen/Nitrogen Generating Plant, Model D LON-150(M*).

TO 36G1-2-9-21, *Oxygen/Nitrogen Generating Plant, Model J79122.*

TO 36Gl-2-11-1, *Oxygen/Nitrogen Generating Plant, Model J79123.*

TO 36G1-3-8-1, *Oxygen/Nitrogen Generating Plant, Model DLON-500(M).*

TO 37C2-8-17-1, *Oxygen/Nitrogen Storage Tank, Model TMU-7A/E.*

TO 37C2-8-20-1, *Oxygen/Nitrogen Storage Tank, Model 16290.*

TO 42B6-1-1, *Quality Control of Aviators Liquid Breathing Oxygen.*

TO 42B7-3-1-1, *Quality Control of Nitrogen.*

Aircraft -2's Technical Orders.

Abbreviations and Acronyms

AC—Alternating Current

AFI—Air Force Instruction

AFM—Air Force Manual (outdated designation)

AFMAN—Air Force Manual (new designation)

AFOSH—Air Force Occupational Safety and Health

AFSC—Air Force Safety Center

ASME—American Society of Mechanical Engineers

BWS—Base Weather Station

BX—Base Exchange

CO—Carbon Dioxide

CFR—Code of Federal Regulations

DoD—Department of Defense

DOT—Department of Transportation

DRU—Direct Reporting Unit

F—Fahrenheit

FOA—Field Operating Agency

HQ—Headquarters

LIN or LN2—Liquid Nitrogen

LOX—Liquid Oxygen

MAJCOM—Major Command

nm—Nautical Mile

NSN—National Stock Number

OSHA—Occupational Safety and Health Administration

PDO—Publishing Distribution Office

POL—Petroleum/Oil/Lubricant

PPE—Personal Protective Equipment

psi—Per Square Inch

psia—Per Square Inch Absolute

TO—Technical Order

WWW—World-Wide Web

Terms

Combustible—Capable of catching fire and burning.

Critical Pressure—The vapor pressure of a liquid at the critical temperature.

Critical Temperature—The temperature above which a gas cannot be liquefied by pressure alone.

Cryogen—A cryogenic liquid. As used in this standard, refers to LIN (LN2) or LOX.

Cryogenics—The science of refrigeration, with reference to methods for producing very low temperatures.

Cryotainer—A double-walled, insulated container (tank) for storage of a cryogenic fluid.

May—Indicates an acceptable or satisfactory method of accomplishment

Oxygen Displacement—The reduction of the gaseous oxygen content of air.

Oxygen Enrichment—The increase of the gaseous oxygen content of air.

Phase Change—The passing of a substance from one phase (state) to another (liquid to gas, solid to liquid, etc.).

Shall—Indicates a mandatory requirement.

Should—Indicates a preferred method of accomplishment.

Will—Is also used to indicate a mandatory requirement and in addition is used to express a declaration of intent, probability, or determination

Attachment 2

PERSONAL PROTECTIVE EQUIPMENT (PPE) FOR LIN (LN_2) AND LOX OPERATIONS

This information should be used in conjunction with AFOSH Standard 91-31 which contains more details on types of PPE, recommended usage, national stock numbers (NSNs), and other relevant information. The PPE listed below are to be worn in conjunction with head covering, cuffless trousers, long sleeve shirt, jacket, or CMU-3/P coveralls (MIL-C-27845C), and shoes which fit closely around the top with rubber soles and heels.

Operation	Required PPE
Operating LIN (LN_2) and LOX Generating Plant	Thermal Gloves Face Shield Ear Protection (Consult installation bioenvironmental engineer)
Cleaning LIN (LN_2) and LOX Generating Plant	Eye Protection Face Shield Chemical Gloves Chemical Apron Respirator (Consult installation bioenvironmental engineer)
Mixing Chemicals	Eye Protection Face Shield Chemical Gloves Chemical Apron
Moving Chemicals	Eye Protection Face Shield Chemical Gloves Chemical Apron
Storage and Transfer of LIN (LN2) and LOX	Thermal Gloves Face Shield Chemical Apron

Servicing of Aircraft	Consult TO 00-25-172

Attachment 3

CHECKLIST -- LIQUID NITROGEN AND OXYGEN SAFETY

This is not an all-inclusive checklist. It simply highlights some critical items in this standard. Other requirements exist that are not included in the checklist. Where appropriate, MAJCOMs, DRUs, FOAs, local safety personnel, and supervisors will add to this checklist to include command or individual shop-unique requirements or situations.

A3.1. Are all high-pressure lines secured with brackets, braces, or other devices to prevent whipping due to a failed line? (Reference paragraph 2.1.5.)

A3.2. Are painting, welding, cutting, and brazing, solvent use, and any operation producing toxic or noxious gases or vapors prohibited during LIN (LN_2) or LOX production runs? (Reference paragraph 2.1.6.)

A3.3. Are cryogenic facilities sited by minimum separation distances or greater as prescribed by AF 32-Series and TO 00-25-172 criteria? (Reference paragraph 2.2.1.)

A3.4. Do LIN (LN_2) and LOX production facilities and storage locations have permanent danger signs posted indicating “OXYGEN-NO SMOKING-NO OPEN FLAMES” or an equivalent warning? (Reference paragraph 2.2.2.)

A3.5. Are joint sealers LOX-compatible where spills are likely to occur in LOX handling and storage areas? Does this area normally cover a 25-foot radius from LOX cart fill points during servicing? (Reference paragraph 2.2.2.)

A3.6. Is the area around the LIN (LN2) and LOX plant itself made of concrete? (Reference paragraph 2.2.2.)

A3.7. Is personal protective equipment (PPE) provided and used by workers handling solvents and chemicals for cleaning? (Reference paragraphs 2.3.1. and 2.4.1.)

A3.8. Is guidance requested from and provided by the installation bioenvironmental engineer on hazards, precautions, PPE, and ventilation required for working with solvents and chemicals? (Reference paragraph 2.3.1.)

A3.9. Are personnel prohibited from using the same PPE for cryogenic operations as used for chemical protection? (Reference paragraph 2.4.1.)

A3.10. Do personnel who handle LIN (LN2) and LOX wear all required, clean PPE properly? (Reference paragraph 2.4.1.)

A3.11. Is PPE always worn when an uninsulated cryogenic surface could be touched? (Reference paragraph 2.4.2.)

A3.12. Do workers avoid using cryogenics in small unventilated rooms? (Reference paragraph 2.4.4.)

A3.13. Is proper ventilation provided for workers handling solvents and chemicals? (Reference paragraph 2.4.4.)

A3.14. Do personnel ensure that no oil or grease is present on clothing, PPE, equipment, or tools when working with or around LOX? (Reference paragraph 2.4.5.)

A3.15. Do workers wear only approved clothing to prevent static electricity generation around LOX operations? (Reference paragraph 2.4.5.)

A3.16. Do workers ground themselves prior to beginning LOX operations? (Reference paragraph 2.4.5.)

A3.17. Is the use of LOX for cooling prohibited? (Reference paragraph 2.4.5.)