

Product Safety Assessment

Liquid Nitrogen

General

Nitrogen is colorless, odorless and tasteless. It is nonflammable, will not support combustion and is not life-supporting. The gas is slightly lighter than air and is only slightly soluble in water. When liquid nitrogen is vaporized and then heated it consumes a large amount of heat, making it an ideal coolant.

Nitrogen is present in the atmosphere at a concentration of 78.1%. Nitrogen is recovered from air in an Air Separation Unit (ASU) where it is drawn off as a cryogenic liquid at about -321 °F. Nitrogen can then be distributed as a cryogenic liquid or as a gas in cylinders. Nitrogen can also be generated onsite, using various techniques.

The major uses of nitrogen are based on its inerting and or cooling attributes. This would include food freezing and providing an inert atmosphere in process that are adversely affected by oxygen or moisture.

Liquid nitrogen is a cryogenic, extremely cold, liquid. Cryogenic liquids are liquefied gases that have a normal boiling point below -238 °F (-150 °C). Liquid nitrogen has a boiling point of -320.5 °F (-295.8 °C).

Manufacture

Oxygen, nitrogen and argon are recovered from air using a cryogenic method developed by Carl von Linde more than 100 years ago. Particulates are removed from the incoming air, which is then repeatedly compressed and cooled. Water, hydrocarbons and carbon dioxide are then removed. With further processing, the air eventually becomes a liquid and the individual gases are separated by distillation. These plants are called air separation units, or Air Separation Units (ASU). Many of the world's ASUs have been built by Linde's engineering division.

Applications

Nitrogen has many commercial and technical applications. Liquid nitrogen's cooling properties are used to freeze food, blood and other materials; modify metal properties; control reaction temperatures; cool concrete and simulate cold operating conditions. Nitrogen gas is used to blanket, purge or stir many chemicals or molten metals. The gas can also be used to pressurize devices or pneumatically convey materials, while keeping out contaminants like oxygen or water.

Health Effects

Nitrogen is odorless, colorless, tasteless, and nonirritating, which means it has no warning properties. Humans possess no senses that can detect the presence of nitrogen.

Contact with rapidly expanding nitrogen near the point of release may cause frostbite, with redness, skin color change to gray or white, and blistering.

No adverse ingestion effects are anticipated, but nitrogen is a simple asphyxiant. Effects of oxygen deficiency resulting from simple asphyxiation may include rapid breathing, diminished mental alertness, impaired muscular coordination, faulty judgment, depression of all sensations, emotional instability, and fatigue. As asphyxiation progresses, nausea, vomiting, prostration, and loss of consciousness may result, eventually leading to convulsions, coma, and death.

At low oxygen concentrations, unconsciousness and death may occur in seconds and without warning.

Oxygen deficiency during pregnancy has produced developmental abnormalities in humans and experimental animals.

First aid measures are not required for gas. If frostbite is suspected, flush eyes with cool water for 15 minutes and obtain immediate medical attention. For frostbite, immerse skin in lukewarm water. DO NOT USE HOT WATER. Obtain medical attention.

Ingestion is unlikely since nitrogen is a gas at room temperature. In cases of inhalation and overexposure, prompt medical attention is required. Rescue personnel should be equipped with self-contained breathing apparatus. Victims should be assisted to an uncontaminated area and inhale fresh air. Quick removal from the contaminated area is most important. Unconscious persons should be moved to an uncontaminated area, and if breathing has stopped, administer artificial resuscitation and supplemental oxygen. Further treatment should be symptomatic and supportive.

Contact with liquid nitrogen may cause freeze burns to exposed tissue.

Table Liquid Nitrogen Properties

Chemical Formula	N ₂
Boiling Point @ 1 atm	-320.5°F (-195.8°C)
Melting Point @ 1 atm	-346°F (-210°C)
Critical Temperature	-232.5°F (-146.9°C)
Critical Pressure	492.3 psia (33.5 atm)
Density, Gas @ 68°F (20°C), 1 atm	0.0725 lb/scf
Specific Volume @ 68°F (20°C), 1 atm	13.8 scf/lb
Density, Liquid, @ Boiling Point, 1 atm	50.45 lb/scf
Heat of Vaporization	92 Btu/lb
Expansion Ratio, Liquid to Gas, BP to 68°F (20°C)	1 to 694
Molecular Weight	28

Containers

Several types of containers, depending upon the quantity, is used to store, ship, and handle liquid nitrogen. Containers utilized are dewars, cryogenic liquid cylinders, and cryogenic storage tanks, and storage volumes vary from a few gallons to many thousands of gallons. Vaporization takes place continuously to maintain cold temperature. The vaporization rate varies depending on the design of the container and the volume of stored product.

Containers are designed and manufactured according to the applicable codes and specifications for the temperatures and pressures involved.

Dewars

A typical, vacuum-jacketed dewar is shown below. A loose-fitting dust cap over the outlet of the neck tubes prevents atmospheric moisture from plugging the neck and allows gas produced from vaporized liquid to escape. This type of container is non-pressurized. The most common unit of measure for the capacity of a dewar are liters, which range from 5 - to 200-liters. Liquid nitrogen may be removed from small dewars by pouring, while larger sizes will require a transfer tube. *Cryogenic liquid cylinders which are pressurized vessels are sometimes incorrectly referred to as dewars.*

Cryogenic Liquid Cylinders

A cryogenic liquid cylinder is an insulated, vacuum-jacketed, pressure vessel. They are equipped with pressure-relief valves and rupture disks to protect the cylinders from pressure buildup. Liquid containers operate at pressures up to 350 psig and have capacities between 80 and 450 liters of liquid. Nitrogen may be withdrawn as a gas or liquid, depending upon valve use for withdrawal.

NOTE: Liquid cylinders designed to dispense gaseous nitrogen have valves equipped with standard Compressed Gas Association (CGA) outlets. Suitable pressure-regulating equipment may be attached. Valves provided for the withdrawal of liquid product are also equipped with standard CGA outlets but differ from connections used for gaseous withdrawal. This prevents cross connections between processes using the liquid or gaseous product.



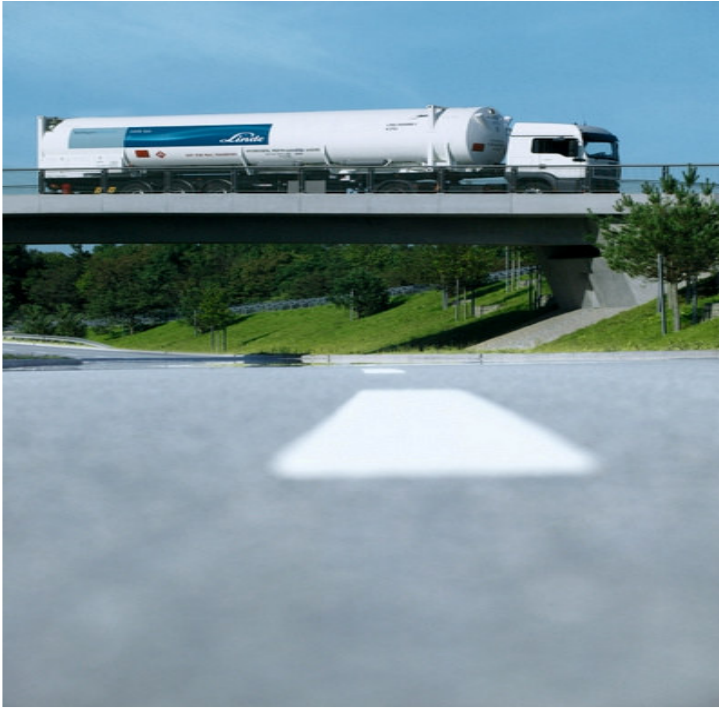
Cryogenic Storage Tanks

Cryogenic storage tank installations generally include a tank, vaporizer, and pressure control manifold. Tanks are mainly cylindrical in shape and mounted in fixed locations as stationary vessels. Sizes range from 500 to 420,000 gallons. All tanks are vacuum insulated, and may contain other insulating materials in the annular space. Tanks are designed to ASME specifications.

Typical Cryogenic Storage Tanks



Shipment of Liquid Nitrogen

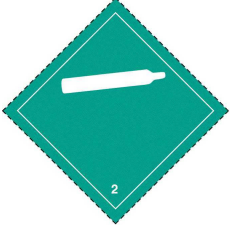


All shipments of nitrogen, refrigerated liquid (liquid nitrogen), must comply with DOT regulations. This applies to motor freight, rail, air, and water shipments. Air shipment of nitrogen, refrigerated liquid is restricted depending upon amounts. Water vessel shipments must also be prepared in accordance with the International Maritime Organization (IMO) regulations. All packaging used to transport nitrogen must be either "UN/DOT Specification" or "UN/DOT Authorized" and in proper condition for transport. DOT Code of Federal Regulations, Title 49, also specifies the following labeling and identification requirements:

DOT Shipping Name: Nitrogen, Refrigerated Liquid

DOT Hazard Class: 2.2

DOT Shipping Label: Nonflammable Gas



Identification Number: UN1077

Safety Considerations

Liquid nitrogen **cannot** be handled in carbon or low alloy steel. 18-8 and 18-10 stainless steel are acceptable as are copper and its alloys, nickel and its alloys, brass bronze, silicon alloys, Monel®, Inconel® and beryllium. Teflon®, Teflon® composites, or Kel-F® are preferred non-metallic gasket materials.

Stationary customer site vessels should operate in accordance with the manufacturer's and Linde's instruction. Do not attempt to repair, adjust or in any other way modify the operation of these vessels. If there is a malfunction or other type of operations problem with the vessel, contact the closest Linde location immediately.

Nitrogen, refrigerated liquid is delivered to a customer into stationary, vacuum-jacketed vessels at the customer's location or in portable vacuum-jacketed "liquid" cylinders. Post "NO SMOKING OR OPEN FLAMES" signs in storage and use areas. There should be no sources of ignition in storage and use areas. Containers of liquid nitrogen can be stored with flammable gas or toxic containers.

Liquid nitrogen vessels should be used only in well ventilated areas in accordance with manufacture and Linde's instructions. Cylinders must always be kept upright. Specialized trucks are needed for their movement. Do not tip, drag, slide, or roll cylinders. Full and empty cylinders should be stored away from flammable and combustible products. Valve protection caps must remain in place unless container is secured with valve outlet piped to use point. If user experiences any difficulty operating container valve discontinue use and contact supplier. Do not insert any object (i.e.: screwdriver) into valve cap openings as this can damage the valve causing leakage. Use a pressure reducing regulator when connecting cylinder to lower pressure piping or systems. Do not heat containers by any means to increase the discharge rate of product from the cylinder. Use a check valve or trap in the discharge line to prevent hazardous back flow into the system.

Protect containers from physical damage. Store in cool, dry, well-ventilated area, away from heavily trafficked areas, and emergency exits. Containers should be stored upright and firmly secured to prevent falling or being knocked over. Full and empty cylinders should be segregated. Use a "first in-first out" inventory system to prevent full containers being stored for excessive periods of time.

Never allow any unprotected part of the body to touch uninsulated pipes or vessels containing cryogenic fluids. The extremely cold metal will cause the flesh to stick and tear when you attempt to remove it.

For additional recommendations, consult Compressed Gas Association Pamphlets P-1, G-10.1, P-8.1, P-8.2, P-9, P-16, P-18, and Safety Bulletin SB-2.

Never carry a compressed gas cylinder or a container of a gas in cryogenic liquid form in an enclosed space such as a car trunk, van or station wagon. A leak can result in a fire, explosion, asphyxiation or a toxic exposure.

Also, review the Material Safety Data Sheet (MSDS) and follow all recommendations.

Buildings

Liquid Nitrogen has a large expansion ratio of liquid-to-gas (694 to 1), it is very important to provide adequate ventilation in areas where liquid nitrogen is in use.

NOTE: nitrogen has no warning properties!

Storage & Handling

- Liquid nitrogen vessels should be used only in well ventilated areas in accordance with manufacture and Linde's instructions.
- Cryogenic containers are equipped with pressure relief devices designed to control the internal pressure by venting periodically. Do not plug, remove or tamper with any pressure relief device.
- "No Smoking" and "No Open Flames" signs need to be posted.
- Storage locations must be installed in accordance with the Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids National Fire Protection Association (NFPA) Standard 55.
- Cylinders must always be kept upright. Specialized trucks are needed for their movement.
- Do not tip, drag, slide, or roll cylinders.
- Full and empty cylinders should be stored away from flammable and combustible products.
- Valve protection caps must remain in place unless container is secured with valve outlet piped to use point.
- Do not use adaptors.
- Use only transfer lines and equipment designed for use with cryogenic liquids. Some elastomers and metals, such as carbon steel, may become brittle at extremely low temperatures and may easily fracture. These materials must be avoided in cryogenic service.
- It is recommended that all vents be piped to the exterior of the building.
- On liquid systems pressure relief devices must be used in lines where there is the potential to trap liquid between valves.

Personal Protective Equipment (PPE)

Individuals must be thoroughly familiar with properties and safety considerations before being allowed to handle liquid nitrogen and its associated equipment.

Wear chemical goggles with face shields where contact with liquid is possible.

Protective gloves made of any suitable material appropriate for the job. Insulated gloves recommended for cryogenic liquids. Gloves must be clean and free from oil and grease.

Safety shoes, emergency eyewash station are also recommended

In emergency situations only trained and certified emergency responders should respond to emergency situations.

First Aid

Never introduce ointment or oil into the eyes without medical advice! In case of freezing or cryogenic "burns" caused by rapidly evaporating liquid, DO NOT WASH THE EYES WITH HOT OR EVEN TEPID WATER!

Remove victim from the source of contamination. For contact with small amounts of liquid, open the eyelids wide to allow the liquid to evaporate. For contact with large amounts, rinse with a low pressure stream of cool water for 15 minutes. Refer the victim to an ophthalmologist for treatment and follow up. If the victim cannot tolerate light, protect the eyes with dark glasses. The use of bandages is not recommended as keeping the eyelids closed or exerting pressure on the eyelid may cause further damage.

SKIN:

For dermal contact or frostbite: Remove contaminated clothing and flush affected areas with lukewarm water.

DO NOT USE HOT WATER. A physician should see the patient promptly if contact with the product has resulted in blistering of the dermal surface or in deep tissue freezing.

INGESTION:

A physician should see the patient promptly if the cryogenic "burn" has resulted in blistering of the dermal surface or deep tissue freezing.

INHALATION:

PROMPT MEDICAL ATTENTION IS MANDATORY IN ALL CASES OF OVEREXPOSURE WHEN NITROGEN IS INHALED UNDER PRESSURE (i.e.: as in scuba diving). Conscious persons should be removed from exposure and inhale fresh air. Quick removal from the source of exposure or contaminated area is most important. Further treatment should be symptomatic and supportive.

Fire Fighting

Nitrogen is nonflammable. A cylinder may vent rapidly or rupture violently from pressure when involved in a fire situation.

Although most cylinders are designed to vent contents when exposed to elevated temperatures, note that pressure in a container can build up due to heat and it may rupture if a pressure relief device should fail to function.

Firefighters should wear respiratory protection (SCBA) and full turnout or Bunker gear. Continue to cool fire-exposed containers until well after flames are extinguished.

FIRE FIGHTING INSTRUCTIONS:

DO NOT SPRAY WATER DIRECTLY ON TO LIQUID NITROGEN SINCE THIS WILL INCREASE THE RATE OF VAPORIZATION AND CAUSE FREEZING OF THE WATER.

If possible, stop the flow of nitrogen which is supporting the fire. Immediately cool containers with water spray from maximum distance. Do not direct water spray at container vent. Move cooled containers from fire area if it can be done without risk. Firefighters should wear respiratory protection (SCBA) and full turnout or Bunker gear. Continue to cool fire-exposed cylinders until well after flames are extinguished.

ACCIDENTAL RELEASE MEASURES:

Eliminate all ignition sources. Use appropriate protective equipment. Stop the flow of gas or remove cylinder to outdoor location if this can be done without risk.

Ventilate enclosed areas. To increase vaporization rate, spray large amounts of water onto the spill from an upwind position. If leak is in user's equipment, be certain to purge piping with inert gas prior to attempting repairs.

If leak is in container or container valve, contact the appropriate emergency telephone number listed below or call your closest Linde location.

Emergency Response System

Product Safety Information

- Call: 1-800-424-9300 (Continental U.S. and Puerto Rico)
- Call: 1-703-527-3887 (other locations)
- 24 hours a day, 7 days a week

For assistance involving Linde, Inc. products

For MSDS, Product Safety Assessment, and Product Safety Information,
www.linde.com

Information Sources

- www.us.lindegas.com
- Compressed Gas Association (CGA)
www.cganet.com

For More Information

Linde,
575 Mountain Ave
Murray Hill, NJ 07974-2082

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