

# Liquid nitrogen

Liquid nitrogen is inert, colorless, odorless, noncorrosive, nonflammable, and extremely cold. Nitrogen makes up the major portion of the atmosphere (78.03% by volume, 75.5% by weight). Nitrogen is inert and will not support combustion; however, it is not life supporting.

Nitrogen is inert except when heated to very high temperatures, where it combines with some of the more active metals, such as lithium and magnesium, to form nitrides. It will also combine with oxygen to form oxides of nitrogen and, when combined with hydrogen in the presence of catalysts, will form ammonia.

Since nitrogen is noncorrosive, special materials of construction are not required to prevent corrosion. However, materials of construction must be selected to withstand the low temperature of liquid nitrogen. Vessels and piping should be designed to American Society of Mechanical Engineers (ASME) specifications, Department of Transportation (DOT) codes, or locally applicable pressure vessel code for the pressures and temperatures involved.

Although used more commonly in the gaseous state, nitrogen is commonly stored and transported as a liquid, affording a more cost-effective way of providing product supply.

Liquid nitrogen is a cryogenic liquid. Cryogenic liquids are liquefied gases that have a normal boiling point below  $-130^{\circ}\text{F}$  ( $-90^{\circ}\text{C}$ ). Liquid nitrogen has a boiling point of  $-320^{\circ}\text{F}$  ( $-196^{\circ}\text{C}$ ). The temperature difference between the product and the surrounding environment, even in winter, is substantial. Keeping this surrounding heat from the product requires special equipment to store and handle cryogenic liquids.

A typical system consists of the following components: a cryogenic storage tank, one or more vaporizers, and a pressure and temperature control system. The cryogenic tank is constructed like, in principle, a vacuum bottle. It is designed to keep heat away from the liquid that is contained in the inner vessel. Vaporizers convert the liquid nitrogen to its gaseous state. A pressure control manifold controls the pressure at which the gas is fed to the process. Processes that use nitrogen as a liquid do not require the vaporizers and pressure control manifold.

Physical and chemical properties are listed in Table 1.

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## Manufacture

Nitrogen is produced at air separation plants by liquefaction of atmospheric air and separation of the nitrogen by continuous cryogenic distillation. The nitrogen is then recovered as a cryogenic liquid and/or as a warm gaseous product.

## Uses

Nitrogen is the largest volume inorganic chemical sold in the world, supporting a multitude of commercial and technical applications. In its liquid state, nitrogen is used for food freezing, plastic and rubber deflashing and grinding, cooling, metal treating, biological sample preservation, pulverization, and other temperature-related applications.

## Health effects

Being odorless, colorless, tasteless, and nonirritating, nitrogen has no warning properties. Humans possess no senses that can detect the presence of nitrogen. Although nitrogen is non-toxic and inert, it can act as a simple asphyxiant by displacing the oxygen in air to levels below that required to support life. Inhalation of nitrogen can cause dizziness, nausea, vomiting, loss of consciousness, and death. Death may result from errors in judgment, confusion, or loss of consciousness that prevents self-rescue. At low oxygen concentrations, unconsciousness and death may occur in seconds and without warning.

**Personnel, including rescue workers, should not enter areas where the oxygen concentration is below 19.5%, unless provided with a self-contained breathing apparatus or air-line respirator.**

For more information on oxygen-deficient atmospheres, consult Air Products' Safetygram #17, "Dangers of Oxygen-Deficient Atmospheres."

Extensive tissue damage or burns can result from exposure to liquid nitrogen or cold nitrogen vapors.

**Table 1: Liquid Nitrogen Physical and Chemical Properties**

Chemical Formula	N <sub>2</sub>
Molecular Weight	28.01
Boiling Point @ 1 atm	-320.5°F (-195.8°C)
Freezing Point @ 1 atm	-346.0°F (-210.0°C)
Critical Temperature	-232.5°F (-146.9°C)
Critical Pressure	492.3 psia (33.5 atm)
Density, Liquid @ BP, 1 atm	50.47 lb/scf (808.5 Kg/m <sup>3</sup> )
Density, Gas @ 68°F (20°C), 1 atm	0.0725 lb/scf (1.16 Kg/m <sup>3</sup> )
Specific Gravity, Gas (air=1) @ 68°F (20°C), 1 atm	0.967
Specific Gravity, Liquid (water=1) @ 68°F (20°C), 1 atm	0.808
Specific Volume @ 68°F (20°C), 1 atm	13.80 scf/lb (0.861 m <sup>3</sup> /kg)
Latent Heat of Vaporization	85.6 Btu/lb (199.1 kJ/kg)
Expansion Ratio, Liquid to Gas, BP to 68°F (20°C)	1 to 694

## Containers

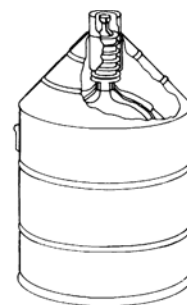
Liquid nitrogen is stored, shipped and handled in several types of containers, depending upon the quantity required by the user. The types of containers in use are the dewar, cryogenic liquid cylinder, and cryogenic storage tank. Storage quantities vary from a few liters to many thousands of gallons. Since heat leak is always present, vaporization takes place continuously. Rates of vaporization vary, 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

Figure 1 illustrates a typical, vacuum-jacketed dewar. 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 a nonpressurized container. The unit of measure for the capacity of a dewar is typically the liter. Five- to 200-liter dewars are available. Product may be removed from small dewars by pouring, while larger sizes will require a transfer tube. Cryogenic liquid cylinders that are pressurized vessels are sometimes incorrectly referred to as dewars.

**Figure 1: Typical Dewar**



### Cryogenic liquid cylinders

Figure 2 shows a typical cryogenic liquid cylinder. Cryogenic liquid cylinders are insulated, vacuum-jacketed pressure vessels. They come equipped with safety relief valves and rupture discs to protect the cylinders from pressure buildup. These containers operate at pressures up to 350 psig and have capacities between 80 and 450 liters of liquid.

Product may be withdrawn as a gas by passing liquid through an internal vaporizer or as a liquid under its own vapor pressure. For more details on the construction and operation of cryogenic liquid cylinders, consult Air Products' Safetygram #27, "Cryogenic Liquid Containers."

Figure 2a: Typical Cryogenic Liquid Cylinder, side view

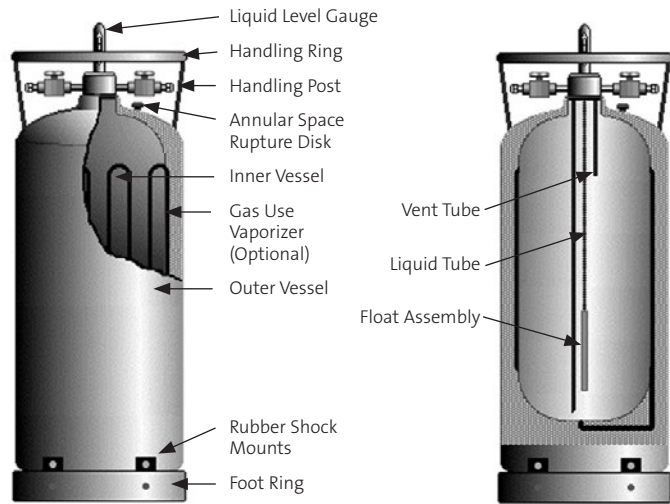
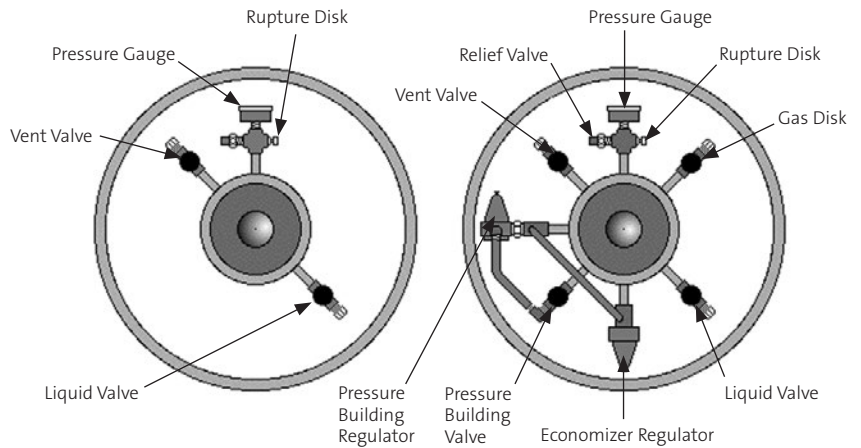


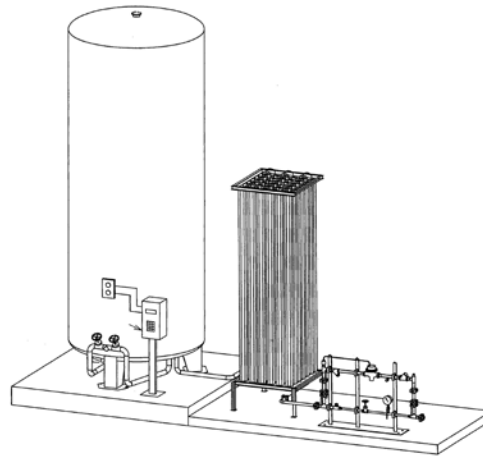
Figure 2b: Typical Cryogenic Liquid Cylinder, top view



## Cryogenic storage tanks

A typical customer installation (see Figure 3) includes a tank, a vaporizer, and a pressure control manifold. Tanks may be spherical or cylindrical in shape. They are mounted in fixed locations as stationary vessels or on railroad car or truck chassis for easy transportation. Typical sizes range from 500 to 420,000 gallons, and most tanks are powder- and vacuum-insulated in the annular space. Tanks are equipped with various circuits to control product fill, pressure buildup, pressure relief, product withdrawal, and tank vacuum. Tanks are designed to ASME specifications for the pressures and temperatures involved.

Figure 3: A Typical Customer Station with a Cryogenic Storage Tank



### Transfer lines

A liquid transfer line is used to safely remove liquid product from dewars or cryogenic liquid cylinders. A typical transfer line for dewars is connected to a bayonet that provides a means of using product vapor pressure buildup or an external pressure source to remove the liquid. For cryogenic liquid cylinders, the transfer line is connected to the cylinder's liquid withdrawal valve.

Liquid product is typically removed through insulated withdrawal lines to minimize the loss of liquid product to gas. Insulated flexible or rigid lines are used to withdraw product from storage tanks. Connections on the lines and tanks vary by manufacturer.

**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 are different than the connections used for gaseous withdrawal. This is to prevent cross connections between processes using liquid or gaseous product.

## Shipment of liquid nitrogen

Containers used for transporting liquid nitrogen at less than 25 psig (40 psia) pressure are UN/DOT authorized containers. These are containers built to other than DOT specifications but are authorized by the DOT for use in the transport of approved products. Containers used for transporting liquid nitrogen at pressures greater than 25 psig (40 psia) need to be designed, manufactured, and tested to DOT specifications.

For air shipments, all packages must be in compliance with International Air Transport Association/ International Civil Air Organization (IATA/ICAO) Dangerous Goods Regulations, as well as DOT regulations.

**Hazard Class:** 2.2

**Shipping Label:** Nonflammable Gas except none for cargo tanks under 23 psig

**Identification Number:** UN1977

**Proper Shipping Name:** Nitrogen, Refrigerated Liquid, 2.2, UN1977

## Safety considerations

The hazards associated with liquid nitrogen are exposure to cold temperatures, which can cause severe burns; overpressurization due to expansion of small amounts of liquid into large volumes of gas in inadequately vented equipment; and asphyxiation due to displacement of oxygen in the air in confined work areas.

If oxygen-deficient atmospheres are suspected or can occur, use oxygen monitoring equipment to test for oxygen-deficient atmospheres. Review the liquid nitrogen Safety Data Sheet (SDS).

## Buildings

Because of the large expansion ratio of liquid to gas, it is very important to provide adequate ventilation in areas using liquid nitrogen. A minimum of six air changes per hour is suggested in these areas.

Provide monitoring for areas where oxygen displacement may occur. It is recommended that emergency or normal vents be routed to a safe location outside of any buildings.

U.S. regulations have established 19.5% oxygen concentration as the minimum for working without supplied air.

**Remember, nitrogen has no warning properties!**

## Storage and handling

Store and use liquid containers with adequate ventilation. Do not store containers in a confined area or in an area unprotected from the extremes of weather. Cryogenic containers are equipped with pressure relief devices designed to control the internal pressure. Under normal conditions these containers will periodically vent product. Do not plug, remove or tamper with any pressure relief device.

Cryogenic containers must be stored, handled and transported in the upright position. When moving, never tip, slide or roll containers on their side. Use a suitable hand truck for moving smaller containers. Move larger containers by pushing, not pulling. Avoid mechanical and thermal shock. Never allow any unprotected part of the body to come in contact with uninsulated pipes or equipment containing cryogenic product. The extreme cold will cause flesh to stick fast and potentially tear on withdrawal.

If there is any difficulty in operating the container valve or container connections, discontinue use and contact the vendor. Do not remove or interchange connections. Use only the properly assigned connections. **Do not use adapters.**

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.

On gas withdrawal systems, use check valves or other protective apparatus to prevent reverse flow into the container. On liquid systems, pressure relief devices must be used in lines where there is the potential to trap liquid between valves. It is recommended that all vents be piped to the exterior of the building.

Liquid containers should not be left open to the atmosphere for extended periods. Keep all valves closed and outlet caps in place when not in use. If restriction results from freezing moisture or foreign material present in openings and vents, contact the vendor for instructions. Restrictions and blockages may result in dangerous over-pressurization. Do not attempt to remove the restriction without proper instructions. If possible, move the cylinder to a remote location.

For additional information on the storage and handling of cryogenic liquids refer to Air Products' Safetygram-16, "Safe Handling of Cryogenic Liquids," and CGA Pamphlet P-12, "The Safe Handling of Cryogenic Liquids."

## Personal protective equipment (PPE)

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

Eyes are most sensitive to the extreme cold of liquid nitrogen and its vapors. The recommended personal protective equipment when handling or using liquid nitrogen is a full faceshield over safety goggles; loose-fitting thermal insulated or leather gloves; and long-sleeved shirts and pants without cuffs, especially whenever the possibility of exposure or a spill exists. In addition, safety shoes are recommended for those involved with the handling of liquid nitrogen containers.

In emergency situations, self-contained breathing apparatus (SCBA) must be used.

## First aid

People suffering from lack of oxygen should be moved to fresh air. If the victim is not breathing, administer artificial respiration. If breathing is difficult, administer oxygen. Obtain immediate medical attention.

**Self-contained breathing apparatus (SCBA) may be required to prevent asphyxiation of rescue personnel.**

For skin contact with cryogenic liquid nitrogen, remove any clothing that may restrict circulation to the frozen area. Do not rub frozen parts, as tissue damage may result. As soon as practical, place the affected area in a warm water bath that has a temperature not in excess of 105°F (40°C). Never use dry heat.

Frozen tissue is painless and appears waxy with a possible yellow color. It will become swollen, painful, and prone to infection when thawed. If the frozen part of the body has been thawed, cover the area with a dry sterile dressing with a large bulky protective covering, pending medical care.

In the case of massive exposure, remove clothing while showering the victim with warm water. Call a physician immediately.

If the eyes are exposed to the extreme cold of the liquid nitrogen or its vapors, immediately warm the frostbite area with warm water not exceeding 105°F (40°C) and seek immediate medical attention.

## Fighting fires

Since nitrogen is nonflammable, special fire fighting equipment and instructions are not needed. As a note of caution, however, water streams must not be directed toward venting nitrogen, as the water will freeze and plug the pressure relief vent and may result in a container failure.

### Emergency Response System

T 800-523-9374 (Continental U.S. and Puerto Rico)

T +1-610-481-7711 (other locations)

For regional ER telephone numbers, please refer to the local SDS 24 hours a day, 7 days a week for assistance involving Air Products and Chemicals, Inc. products

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### Technical Information Center

T 800-752-1597 (U.S.)

T +1-610-481-8565 (other locations)

Monday–Friday, 8:00 a.m.–5:00 p.m. EST

F 610-481-8690

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