

# Cryogenic liquid containers

Cryogenic liquid containers, also referred to as liquid cylinders, are double-walled vacuum vessels with multilayer insulation in the annular space. They are designed for the reliable and economic transportation and storage of liquefied gases at cryogenic temperatures, typically colder than  $-130^{\circ}\text{F}$  ( $-90^{\circ}\text{C}$ ). There are two primary advantages of a liquid container. The first is that it contains a large volume of gas at a relatively low pressure compared to a compressed gas cylinder. The second is that it provides a source of cryogenic liquids which can be easily handled. Cryogenic liquid containers are often incorrectly referred to as dewars. Dewars are open, nonpressurized vessels for holding cryogenic liquids.

The cryogenic products normally found in liquid containers are liquid nitrogen (LIN), liquid argon (LAR), liquid oxygen (LOX), and liquid helium (LHE). Carbon dioxide and nitrous oxide are also available as refrigerated liquids in similar containers.

Although these containers are well insulated, heat will continuously leak into the product, due to the extremely large temperature difference between the cryogenic liquid and the ambient environment. The heat leak will cause some vaporization to occur. Vaporized product, if not used, will collect in the vapor space above the liquid and build pressure. This is referred to as head pressure. The head pressure will build in the container and periodically vent via the pressure relief valve. Vaporization rates will vary and may be as low as 0.4% or as high as 3% of the container's volume per day. This is a normal and safe function of the container.

The user of any cryogenic liquid container should be thoroughly familiar with the product and the mechanical workings of the container before using the product.

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## General safety precautions

The potential hazards for handling cryogenic liquids, in addition to those observed for their respective gases, stem from two properties: extremely cold temperature and the expansion ratio.

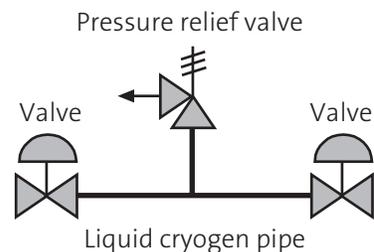
The extremely cold temperatures of cryogenic liquids can rapidly freeze human tissue. Leather or insulated gloves and other protective clothing should be worn when operating valves or when the potential exists for contact with product or exposed cold piping. This includes long cuffless pants, long-sleeved shirt, safety glasses, and full face shield.

All cryogenic liquids produce large volumes of gas when they vaporize. The expansion ratio is the amount of gas generated from a given amount of liquid. Table 1 shows the liquid-to-gas expansion ratios for the common cryogenic fluids. If a sufficient amount of liquid is vaporized within a closed container, it will produce enormous pressures that could rupture the vessel. For this reason, cryogenic liquid containers are protected with multiple pressure relief devices. Similarly, any system for the storage and delivery of cryogenic liquids should be carefully designed to avoid trapping cryogenic liquid at any point in the system by installing a relief device as depicted in Figure 1.

If liquid nitrogen, argon or helium is accidentally released in a confined space, a dangerous oxygen-deficient atmosphere could be created. Use and store liquid containers in well-ventilated areas. The released gas will displace the oxygen concentration in the air. A small spill of liquid will produce a large volume of gas, which can and will change the conditions of the ambient environment in a confined space very quickly. For example, a spill of one cubic foot of liquid nitrogen will vaporize to 696 equivalent volumes of gas at 70°F. An oxygen-deficient atmosphere can lead to rapid asphyxiation (suffocation). This can cause loss of consciousness and may result in serious injury or death. Never enter an area where oxygen levels are below 19.5% without the use of supplied air. The dangers of oxygen-deficient environments are discussed more fully in Air Products' Safetygram-17, "Dangers of Oxygen-Deficient Atmospheres."

If liquid oxygen is released, an oxygen-enriched atmosphere could result. An oxygen-enriched atmosphere is dangerous due to the increased potential for a fire to occur. Although oxygen itself is nonflammable, ordinary combustible materials will burn more vigorously. Materials that normally do not burn in air may burn in an oxygen-enriched atmosphere.

**Figure 1: Avoid Trapping a Cryogen**

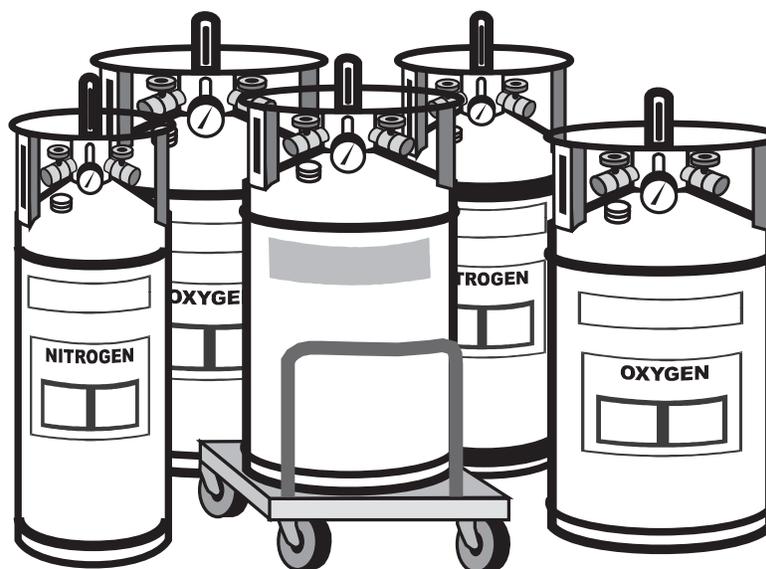


**Table 1: Expansion Ratios at 70°F of Common Cryogenic Fluids (Liquid to Gas\*)**

Cryogenic Liquid	Expansion Ratio
Argon	1 to 841
Helium	1 to 754
Hydrogen	1 to 848
Nitrogen	1 to 696
Oxygen	1 to 861

\* For example, 1 cubic foot of liquid argon will create 841 cubic feet of gaseous argon at 70°F.

**Figure 2: Containers May Be Supplied with Various Wheel Configurations**



## Handling and storage

Liquid containers are supplied in different sizes. A typical 180-liter unit weighs approximately 260 pounds (118 kg) when empty and as much as 774 pounds (351 kg) when filled with liquid argon. Table 2 lists nominal empty and full weights for common liquid containers. Due to their weight and bulkiness, care must be taken when handling and storing liquid containers. Mechanical handling devices should always be used to move them if they are not already equipped with wheels.

### Handling

Liquid containers must only be unloaded from or loaded onto a delivery vehicle by means of a crane, fork truck, or a power-assisted tailgate. Liquid containers may be moved using a forklift if they are secured on a pallet, in a cradle, or some other device designed for this purpose. When the container is removed from a pallet, it should only be moved using a specially designed four-wheel handcart. Liquid containers should only be transported in an upright position and should never be laid on their side. See Figure 3 for proper ways to handle a liquid container. Never roll these containers on their side.

Liquid containers equipped with wheels should always be moved by pushing the container, never pulling it. This reduces the possibility of the container falling on you or a coworker in the event it becomes unstable. Figure 4 depicts how to properly move a liquid container. Pushing the liquid container up any type of grade will increase the force necessary to move it. A grade as low as 5% (5-inch rise in 10 feet of travel) will increase the force necessary to start to push the container by as much as 50%.

**Table 2: Average Full and Empty Weights of Different Liquid Containers**

Nominal Volumetric Capacity (liters)	160	180	230
<b>Physical Dimensions</b>			
Empty Weight (lbs)	250	260	310
Filled Weight (lbs)			
Nitrogen	513	556	667
Oxygen	622	672	825
Argon	695	753	936
Diameter (inches)	20	20	24
Height (inches)	61	63.5	61.5
<b>Liquid Storage Capacity, SCF*</b>			
Nitrogen	3637	4088	4939
Oxygen	4500	4680	6224
Argon	4310	4775	6056
Gas Delivery Rate, SCFH	325	325	350

\* DOT MAX @ 235 PSIG Safety

### Elevator transport

Care must be exercised when transporting liquid containers in elevators. If possible, transport the container only on a freight elevator that is not generally used for personnel transport. After the container is placed in the elevator, the elevator should be locked out to all other users. The sender should remain outside the elevator and activate it. Another person should be available on the receiving floor to take the liquid container off the elevator at its destination. If a freight elevator is not available, a passenger elevator can be used provided it is locked out to all other users. If it is absolutely necessary to have an attendant in the elevator with the container, an escape pack supplemental breathing apparatus must be carried in the elevator. Do not transport a liquid container at any time in an elevator with any other personnel in the car.

### Storage

Liquid containers should always be stored in an upright position. Despite the superinsulation used in liquid containers, some heat leak is unavoidable. As a result, when product is not being withdrawn, pressure within the container will gradually increase, due to the small amount of liquid product vaporized by the heat leak. Pressure builds up until the pressure relief device functions and then reseats. This type of venting is usually normal and indicates the container is being protected from over-pressurization. Therefore, it is recommended that liquid containers are stored and used in well-ventilated areas or areas with forced ventilation. If this is not possible, monitoring of the area for oxygen concentration is essential. Storage areas, in addition to being well ventilated, should be secure and protected from the weather. Containers should be stored away from air intakes, high traffic areas, floor drains, and other underground openings. The escaping cold gas will be heavier than the surrounding air and will accumulate in low-lying areas.

## Cylinder tipping or damage

Always keep liquid containers upright and as near to their correct orientation as possible during storage, transportation, and use. If a liquid container falls over, allow 15 minutes for the container to settle. Assess its structural integrity before approaching it. A minimum of two persons are required to return it to an upright position. They should utilize a mechanical lifting device (e.g., block and tackle, hoist, or crane) secured to an overhead support, such as a portable tripod, capable of supporting the weight. Immediately notify the supplier of this situation.

The team should wear full face shields and gloves and return the container to the upright position. Vent any excess pressure. If there is no buildup of pressure or visible external damage, the container may be returned to service. Notify the supplier of the incident.

Container damage may create a hazardous condition and may not be immediately evident. If the container rapidly builds pressure or shows any signs of malfunction, vent it carefully into a well-ventilated, safe area and call your supplier for further instructions.

Figure 3: How to Handle Liquid Containers

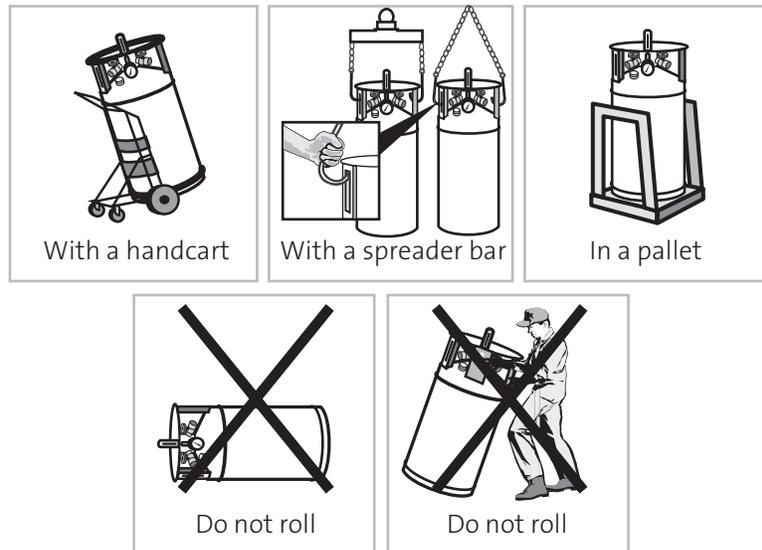
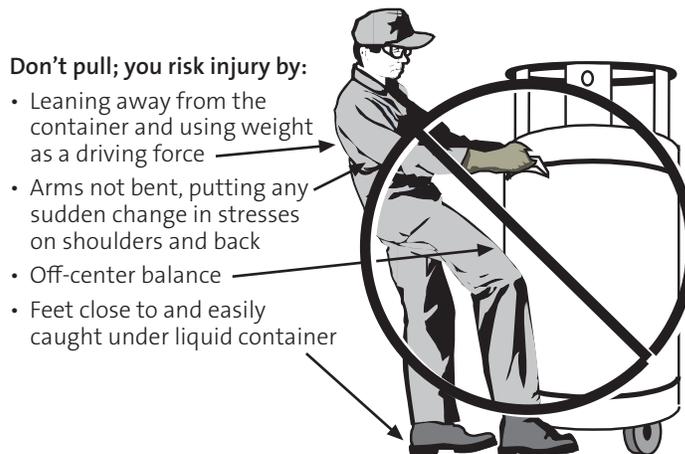
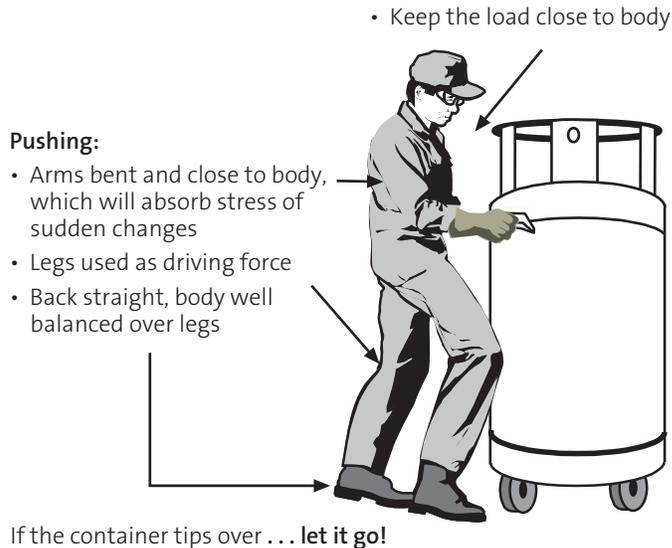


Figure 4: Moving Liquid Containers: Push, Don't Pull



## Container design and operation

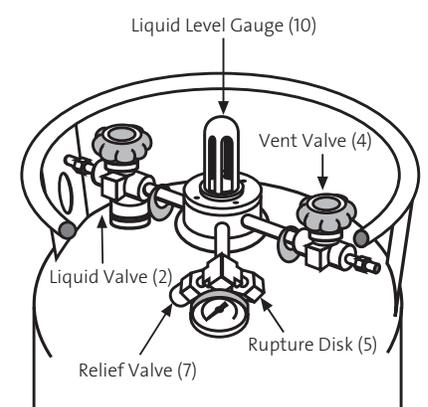
In order to safely withdraw gas or cryogenic liquid from a liquid container, it is important to be familiar with the container design and proper functioning of the components. Low-pressure liquid containers (Figure 5) are designed for cryogenic liquid withdrawal only, whereas high-pressure liquid containers (Figure 6) provide economic, efficient gaseous withdrawal in addition to liquid withdrawal. These containers are designed to operate under pressure and contain automatic pressure building to maintain delivery pressure. These containers could be used for all cryogenic liquids except hydrogen and helium. Refer to Safetygram-22, "Liquid Helium," for more safety and operating information.

Low-pressure liquid containers operate at pressures up to 22 psig, while high-pressure liquid containers operate at pressures up to 230 psig. Super-high-pressure containers that operate at pressures up to 350 psig are also available. Always ensure regulator and container pressure compatibility prior to making connections.

The most common liquid container sizes are 160-liter, 180-liter and 230-liter. Storage volumes and gas delivery rates vary. Table 2 provides nominal storage capacities in standard cubic feet (SCF) and gas delivery rates in standard cubic feet per hour (SCFH).

There are a number of operating components outside and inside the container. These features are illustrated in Figures 5, 6 and 7. They are as follows (numbers in parentheses refer to the index on Figure 7).

Figure 5: Low-Pressure Liquid Container Components

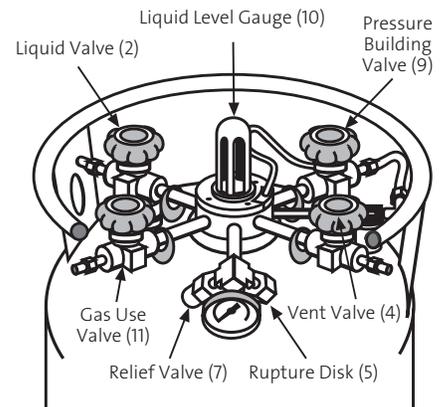


**Gas Withdrawal Valve (11):** This valve allows gaseous product withdrawal through the internal vaporizer and/or the economizer. It has the recommended Compressed Gas Association (CGA) connection that matches the gas service for which the container is configured. **Never remove or exchange this connection, or use adapting fittings.** If the fittings mismatch, contact your supplier immediately for assistance. (See Table 3 for recommended CGA fittings for inert gas and oxygen service.)

**Economizer (3):** When the head pressure is near the relief setting, an economizer circuit preferentially directs gas from the vapor space to the gas use valve when it is open. This minimizes the loss of gas to over-pressurization venting. Excess pressure in the vapor space of the container is relieved to the gas use valve outlet while preserving normal operating pressure. The economizer requires no operator attention and will function automatically.

**Liquid Withdrawal Valve (2):** Liquid product is added or withdrawn from the container through the connection controlled by this valve. It has a CGA connection specified for the appropriate cryogenic liquid. **Never remove or exchange this connection.**

Figure 6: High-Pressure Liquid Container Components



**Pressure Gauge (6):** The pressure gauge displays the internal container pressure. It does not indicate the volume of product in the container.

**Contents Gauge (10):** This is a float-type liquid level gauge. This is used to indicate the approximate amount of container contents.

**Vent Valve (4):** This controls a line into the vapor space of the container. It is primarily used in the fill process to vent the vapor space while filling and can be used to vent unwanted pressure during storage and use.

**Relief Devices (5 and 7):** To protect the container from over-pressurization, it is equipped with two relief devices. The first is a reseating spring-loaded relief valve that, depending on the setting, will relieve pressure at 22 psig, 230 psig, or 350 psig. The second is a burst disk rated to protect the inner vessel. **Never plug, restrict, or remove any relief device. Never attempt to cap or seal a venting relief device in any way.** Notify your supplier about any container that continuously vents through any of the relief devices.

**Caution:** Some liquid containers may be equipped with a threaded connection on the outlet of the relief device. This is only for users to connect vent piping to the relief device to safely exhaust venting gas. It is recommended that vent lines be exhausted outdoors or to a safe, well-ventilated location. **Never place a cap or plug on this device as this will defeat the container's pressure relief capability.**

**Pressure Building Valve (9):** The pressure building circuit is used to create sufficient operating pressure. It is controlled by a regulator that opens to allow liquid to flow from the bottom of the container through a vaporizer, where it becomes a gas. The gas then collects in the vapor space at the top of the container. The vaporization of the liquid into gas increases the pressure in the container.

**Internal Vaporizer (1):** This is an internal heat exchanger that functions as a gas vaporizing coil to convert liquid product to gas.

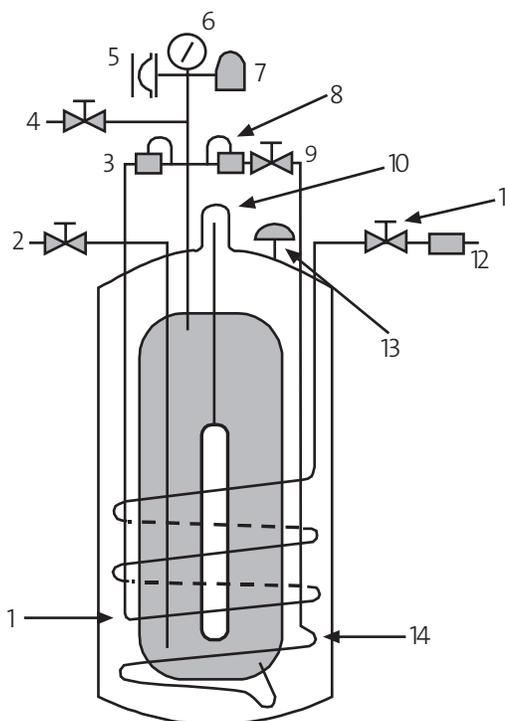
**Outlet Restraints:** These restraints, as illustrated in Figure 8, are to prevent the dangerous practice of changing outlet connections at user sites. Removal of these restraints will void all product warranties. Changing outlet connections is an extremely dangerous practice and can result in serious injury or death if an incompatible product is introduced into a user's system!

### Operation

**Caution:** Before use, always confirm that the CGA fittings are appropriate for the product identified on the cylinder label. If a mismatch appears, do not attempt to use the container. Contact your supplier for assistance immediately.

**Figure 7: Flow Diagram**

1. Gas withdrawal vaporizer
2. Liquid withdrawal valve
3. Economizer regulator
4. Vent valve
5. Inner tank rupture disk
6. Pressure gauge
7. Safety relief valve
8. Pressure building regulator
9. Pressure building valve
10. Liquid level gauge
11. Gas withdrawal valve and integral check valve
12. Check valve in house line
13. Outer tank rupture disk
14. Pressure building vaporizer



Cryogenic liquid containers are available in a variety of designs to allow for a variety of product withdrawal modes. Most containers allow either gas or liquid withdrawal, although some allow for only gas or liquid withdrawal. Users must be familiar with the type of container they are using for their application and must ensure that the proper connections for that container are in place.

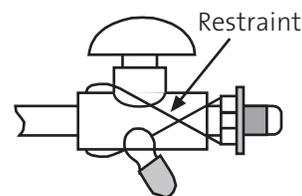
### Gas Withdrawal:

To withdraw gas from the container, connect the inlet of a suitable pressure regulator or control valve to the gas withdrawal valve, and the outlet of the regulator or valve to the system receiving the gas. Open the withdrawal valve and the pressure building valves until the container pressure reaches the desired pressure, for example, 125 psig. At this point you may begin withdrawing gas.

**Table 3: Recommended Connections for Liquid Containers**

Oxygen	Inert Gas
Gas Withdrawal CGA-540	CGA-580
Liquid Withdrawal CGA-440	CGA-295

**Figure 8: Do Not Remove Outlet Restraints**



(continued on page 8)

## Troubleshooting Liquid Containers

Due to the variability in process requirements and ambient conditions, circumstances may arise which call for some adjustment to the operation of the liquid container installation. The table below offers some suggestions for remedial action (numbers in parentheses refer to Figure 7) for Air Products-owned liquid containers. For customer-owned containers, refer to vendor's manual for instructions.

Issue	Possible Cause	Recommended Activity
Gas vents intermittently through safety relief valve (7) when container is not in use.	Probably normal operation. Gas generated due to heat leak into cylinder causes head pressure to build.	Ensure inactive containers are stored in well-ventilated area. Rotate inventory.
Gas vents continuously through safety relief valve (7).	Possible relief valve failure or excessive heat leak.	Remove container or vent exhaust to a well-ventilated area. Relieve product through vent valve (4). Check to see if safety relief valve (7) is frozen open. Call supplier for assistance.
Gas vents during use through the safety valve (7).	Set point on regulators (3) or (8) exceeds safety relief valve setting.	Reduce set point on pressure building relief regulator (8).
Pressure in the container is low.	Leak from container.	Use appropriate leak detection fluid to check for leaks in connections. Examine container for signs of frost. If leaks on container itself, contact supplier.
	Pressure building valve (9) is not fully opened.	Open valve fully.
	Pressure building regulator (8) not set high enough.	Adjust to increase pressure.
	Gas withdrawal rate exceeds design capability of container. Pressure building regulator (8) may not be functioning properly.	Refer to 2 for system capabilities. Manifold multiple containers together if necessary.
	Incorrect container may have been ordered or delivered.	Contact supplier for assistance.
Pressure in the container is too high.	Pressure building valve (9) is open.	Close the valve if frost is visible on the pressure building vaporizer (14) near the bottom of the tank.
	Leak in or improper setting of pressure building regulator (8).	Reduce regulator setting to achieve desired pressure level. If pressure building vaporizer is frosted and the safety relief valve pressure setting is exceeded, call supplier to service regulator.
	Gas withdrawal rate is low.	Utilize and store in a well-ventilated area. Increase product withdrawal rate or bleed excess pressure through vent valve (4) into a well-ventilated area.
	Vacuum integrity failing.	If container walls covered with frost, contact supplier.
Pressure fails to change when pressure building valve (9) adjusted.	Excessive product in container.	Vent or use product.
	Problem with vaporizer coil. Pressure building valve (9) is stuck in closed position.	Call supplier. Call supplier.
Container wall covered with frost less than 8" from the bottom.	Pressure building vaporizer (14) in use to increase pressure.	If pressure building valve (9) is open, this is normal. If it is not, call supplier.
Container wall covered with frost to height of >10" from the bottom.	Gas withdrawal vaporizer (1) is in use.	Normal operation if gas withdrawal valve (11) is open. If not, call supplier.
Container top covered with frost.	High product use. Leak in fittings such as sight glass.	Normal operation. Call supplier.
Container has isolated spots of frost.	Container may have been damaged, compromising integrity of insulation.	Call supplier.
Container surface is uniformly covered with frost.	Vacuum integrity compromised.	If accompanied by high rate of product venting through safety relief valve (7), or high rate of pressure increase, call supplier.
Gaseous product is too cold.	Product withdrawal rate is greater than the design delivery rate of the container.	Reduce product withdrawal rate or manifold multiple containers together to achieve desired flow rate.

Air Products does not recommend the removal or attempted repair of any component supplied by Air Products as part of the liquid container package. If in doubt about the functionality of any part of the liquid container, please contact Air Products for assistance.

**Caution:** When withdrawing gas from the container, the capacity of the internal vaporizer can be exceeded. If gas is withdrawn at a rate greater than the vaporizer capacity, liquid or very cold gas will be discharged. Severe damage to external equipment or injury to personnel could occur from the extremely cold temperature of the product being withdrawn.

If a higher product withdrawal rate is desired, two or more containers can be manifolded together. This will reduce the draw on each container to a safe rate. If two or more containers are manifolded, the vent valves should also be connected together to ensure pressure equilibration between all the containers.

### Liquid Withdrawal:

**Note:** For liquid use requirements, the container should normally be specified with the 22 psig relief valve. Minimizing the pressure reduces the product loss due to flash-off.

Connect a transfer line from the liquid valve to the user's system or vessel being filled. Open the liquid valve to obtain the desired rate of flow. Close the liquid valve when finished. To prevent back-contamination in the container, all valves should be closed when the container has been emptied.

If high withdrawal rates require additional pressure, open the pressure building valve only until the required pressure is obtained, then close the valve. (This feature is not available on 22 psig containers equipped for liquid withdrawal only.)

**Caution:** Always wear a full face shield and gloves when transferring liquid product. Transfer of liquid at pressures higher than 22 psig into open vessels such as small dewars can lead to excessive splashing of the product, which may come in contact with the operator or nearby personnel. Care should be exercised to avoid skin or other tissue contact with any cold surface. Always read product labels before using.

### Emergency Response System

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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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