# Safety requirements for cryogenic installations

# Safety requirements for the proper operation of cryogenic installations

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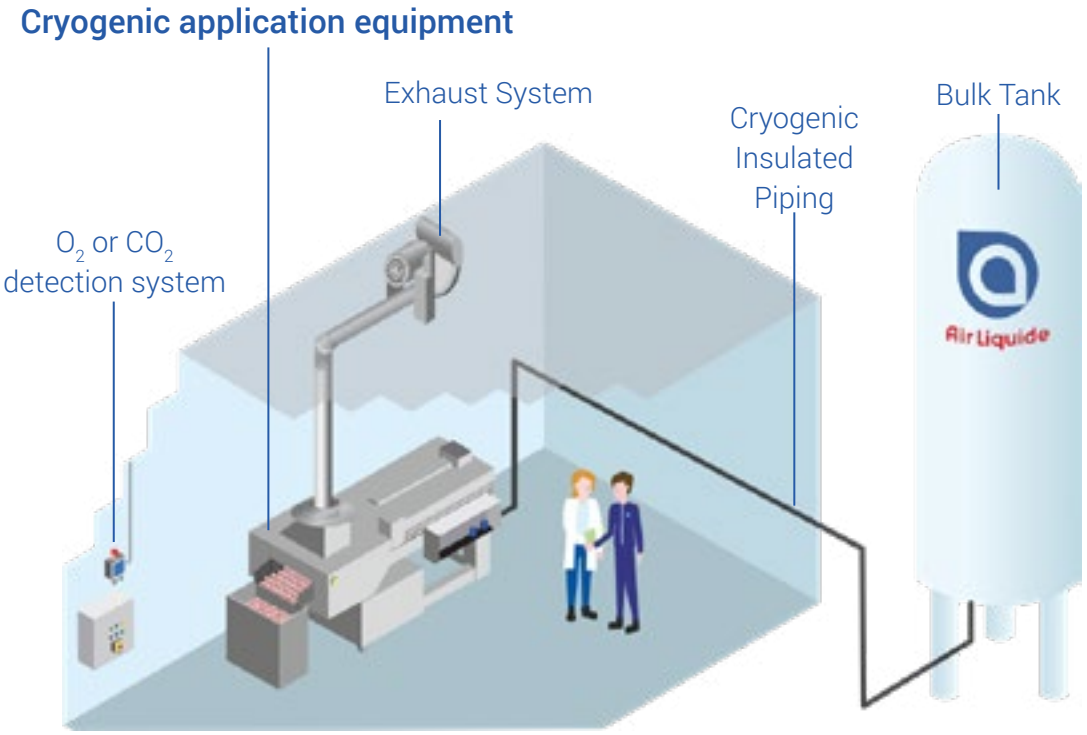
# 1. Introduction

The use of cryogenic installations requires the adoption of critical safety measures in order to ensure the safety of the staff exposed. This document outlines some of the key aspects to implement and master before operaing a cryogenic installation.

## 1.1 The cryogenic installation design

Cryogenic installation components:

- Cryogenic liquid storage tank
- Cryogenic pipeline connecting the storage tank to the cryogenic unit
- Cryogenic application equipment (using a cryogenic medium for operation)
- Exhaust system
- Atmosphere monitoring system (oxygen or carbon dioxide detection system)



# 2. General safety information

All personnel dealing with the cryogenic installation and its auxiliary components, especially related to operation, transportation and maintenance, must be familiar with the manufacturer's instruction and the other specific instructions and guidelines for health and safety at a particular workstation.

Detailed instructions should have been developed on the basis of applicable regulations, installation manufacturer's instructions, occupational risk assessment and others, and should include such information as (but not limited to):

- Basic safety conditions
- Pre-work activities
- Principles and methods of safe execution of work
- Post-work activities.
- Hazard emergency procedures (including first aid)
- Prohibited Activities

# 3. The main risks associated to the use of cryogenic installations

## 3.1 Extremely low temperatures

Cryogenic gases refers to extremely low temperatures. For example:

- **Liquid nitrogen: -196°C**
- **Solid carbon dioxide: -79°C**

This involves two direct risks:

- Freezing of human tissues, or "cryogenic burns"
- Brittleness or cold embrittlement of materials (carbon steel, plastic, rubber etc)

### 3.1.1 Freezing of human tissues, or "cryogenic burns"

This risk can be mitigated by the use of appropriate personal protective equipment (PPE) and following health and safety regulations when working with the cryogenic agent.

Personnel should not have to handle liquid cryogenic gases. Although they may be exposed to environments where liquid cryogenic gases are used or handle dry ice. In this case, the following Personal Protective Equipment (PPE) must be used:

The following is a set of required protective equipment that should be used when operating the installation:




- **Insulating gloves**

They must be worn at all times when handling anything that has been in contact with cryogenic gases and their vapors including deep frozen objects.
Most of the cryogenic equipment is insulated. Although some parts may be cold. Insulated gloves must be worn when coming in contact with the cryogenic equipment.

- **Safety shoes**

The cryogenic equipment is designed for maximal user safety. However safety shoes must be worn in case of failure of any heavy part, but also to protect for any (unlikely) cryogenic fluid projection.

- **Long trousers**

Those must be worn all all times, they should be cuffs-free and not tucked into shoes.

- **Jacket** coverings arms and chest
- **Glasses**, if there is a possibility for splashes

The occupational risk assessment carried out by the employer or user of the installation is an overarching document that determines the need for specific personal protective equipment. It should be carried out in accordance with current regulations and, on its basis, adapt protective equipment to the specifics of the job.

### 3.1.2 Cold embrittlement of materials (carbon steel, plastic, rubber etc)

Some materials, when exposed to cryogenic gases, can become brittle to the point where they can suddenly and easily break causing serious or even fatal hazards.
Many materials are unsuitable for cryogenic service, in particular carbon steel, low carbon steel and mild steel. Austenitic stainless steel is the material of choice for many applications. In case of doubt, contact Air Liquide.
In case of a customer-owned installation: the design of the installation and the choice of materials must be made compatible with the use of cryogenic liquid, from the liquid storage tank to the point(s) of use.

**Precautions**

It is highly recommended to have this reviewed by Air Liquide. We also strongly recommend to communicate any change to this installation, even minor, to Air Liquide prior to the execution (for example, changes in the position of walls).

To minimize the risk of cold embrittlement a few key principles must be followed:

- **Plant design and construction**
  Proper design and construction of the plant and the use of materials resistant to low temperature embrittlement are key. Consultation with cryogenics experts is recommended to avoid potential mistakes.
- **Operating procedures**
  Personnel should be trained to follow proper operating procedures. Guidelines for the safe handling of cryogenic liquids should be followed. Operating procedures should be adapted to the risk conditions at the installation site.

- **Labeling of equipment**
  Equipment working with cryogenic liquids should be labeled with appropriate warning signs. This helps increase worker awareness and mitigate the risk of hazardous situations.

With these measures, the risks associated with working with cryogenic liquids can be effectively minimised. Keep safety in mind and follow the safety recommendations!

## 3.2 Asphyxiation and poisoning

**Risk of anoxia and carbon dioxide poisoning**

Liquified cryogenic gases are inert gases. This means that they do not support life. Both nitrogen and carbon dioxide are naturally present in the air in the following proportions:

- **nitrogen ($N_2$)**: approx **78%**
- **carbon dioxide ($CO_2$)**: approx **0.04%**

Note that there are about 20.9% oxygen in the air. Oxygen is absolutely necessary to sustain human life.

All inert gases can cause asphyxiation by displacing breathable air. This is an increased risk especially indoor due to the high liquid-to-gas expansion rate. Inert gases are **odorless and colorless**, their presence cannot be detected without instrumentation. Workers can be asphyxiated before they realize that an asphyxiation atmosphere exists, making the use of a gas detector obligatory.

The asphyxiation risk related to the use of inert cryogenic gases can be mitigated by the appropriate design of the installation and use of protective devices. **The likelihood is increased by the high liquid-to-gas expansion rate of the liquid cryogenic gases**.

Carbon dioxide can also lead to poisoning. **Excess $CO_2$ in the air causes oxygen deficiency**, and the body cannot effectively remove the harmful gases. $CO_2$ poisoning can be just as dangerous as poisoning from carbon monoxide (CO).

### 3.2.1 Atmosphere monitoring

The hazards associated with **oxygen-deficient or $CO_2$-enriched** atmospheres and improper handling of cryogenic liquids are most often associated with the installation and operation of cryogenic application equipment that is used in confined or semi-confined spaces.

Buildings where application equipment is installed must be coupled with a gas monitoring system consisting of:

- A fixed oxygen detector for the nitrogen plant
- A fixed carbon dioxide detector for the carbon dioxide plant

Detectors should be installed in the same room as the point of use and carefully positioned by a professional to give best protection. **Those should have both visual and audible alarm signals**. These measures can be combined with the use of personal gas detectors.

It is recommended to place an alarm device from the gas detection system at the entrance to the room where the cryogenic equipment is installed. This signaling device should inform about the current air condition in the room. In addition, the signaling system should allow a test to be performed before each entrance to the room. The location of the button used to perform the test should be clearly labelled and described, for example: “Attention!”. Before starting work or returning after a long break, perform a signaling test each time. The gas detection system must also be equipped with an emergency power supply to ensure its operation for at least 30 minutes in the event of a main power failure.

**Cut off the supply of liquid gas to the cryogenic equipment**

ALWAYS make sure that anyone working in the surroundings of a cryogenic installation can locate the manual cut off valve located upstream of the cryogenic equipment and the remote emergency cut off button for the storage tank shut off valve.

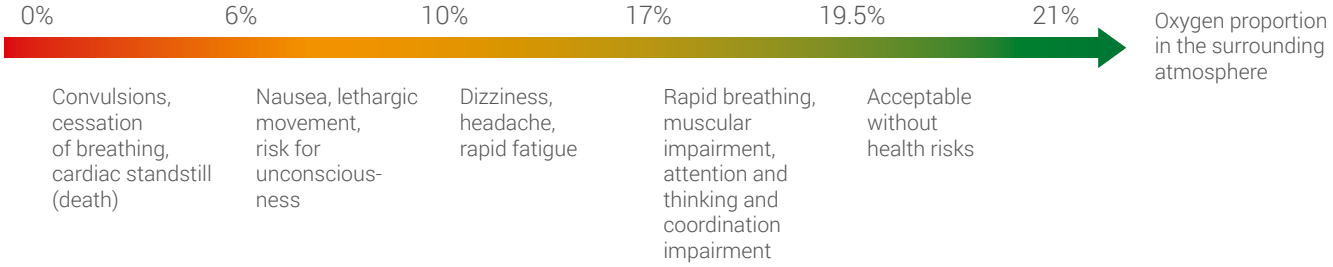
When the oxygen content drops or the carbon dioxide level rises above the set values, the atmospheric monitoring system must cut off the supply of liquid gas to the building by closing the automatic shut off valve at the storage tank and on the cryogenic unit.

## 3.2.2 Nitrogen, specific precautions

A fixed oxygen detector should be installed in each room where liquid nitrogen is used. This device should be located in the direct neighborhood of the nitrogen point of use. To ensure safety, the detector should be set to the following alarm levels:

- **Level 19.5%**: Activation of audio and visual alarm.
- **Below 19.5%**: The operation of the mechanical ventilation systems and the air exchange system in the room should be checked. In addition, the operation of the cryogenic unit should be verified.
- **Level 18%**: Automatically cut off of the nitrogen, exhaust boost and evacuation of the room or the entire plant.

It is also recommended that appropriate safety signage and operating instructions are placed in a prominent position next to fixed oxygen detectors.



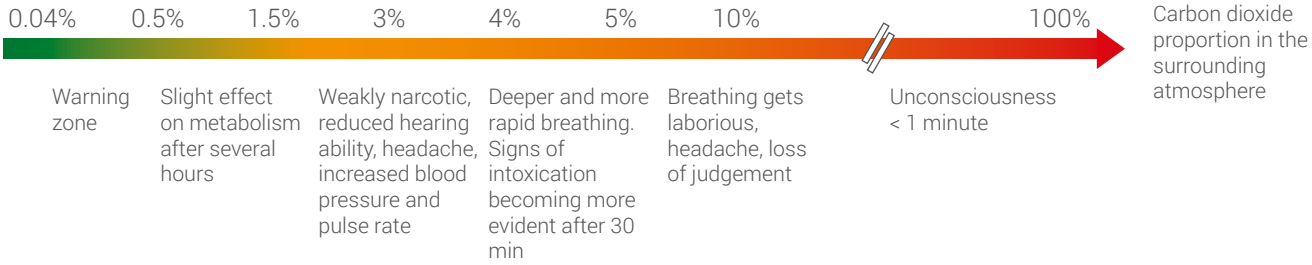
## 3.2.3 Carbon dioxide, specific precautions

Carbon dioxide is a normal product of human metabolism and takes place in pulmonary gas exchanges. As part of the body's natural chemical environment, it is involved in respiration, circulation and vascular response. However, exposure to increased levels of carbon dioxide will strongly perturb those reactions causing a progressive collapse of the human metabolism.

Therefore, a dedicated $CO_2$ detector must be installed in rooms where carbon dioxide is used. This detector should be set to detect certain concentration levels of the gas to prevent the risk of poisoning:

- **Level 0.5%**: Activation of audio and visual alarm.
- **Above 0.5%**: The operation of the mechanical ventilation systems and the air exchange system in the room should be checked. In addition, the operation of the cryogenic unit should be verified.
- **Level 1.5%**: Evacuation of the room.

It is also recommended that appropriate safety signage and operating instructions are placed next to fixed carbon dioxide detectors to facilitate rapid response in case of emergency.




## 3.2.4 Ventilation and air replenishment

To ensure good air quality in the room where the gas point of use is located, it is necessary to properly design and use an exhaust system that discharges vaporized gases to the outside of the building continuously during the operation of the cryogenic application equipment. **NEVER use cryogenic equipment without efficient exhaust system**. If in doubt, contact Air Liquide.

**Ventilation (air exchange)**

In most cases, the exhaust system removes some air from the production room in addition to the evaporated cryogenic fluid. There is therefore a need for a fresh air supply to compensate for the loss. The air exchange rate should be adapted to the volume of the room taking into account the type of installation.

## 3.3 Pressurization / explosion

Cryogenic liquids have a high liquid-to-gas expansion rate, at 1 atm.
For example:

- **1 liter of liquid nitrogen** evaporates into **700 liters** of nitrogen gas
- **1 liter of liquid carbon dioxide** is equivalent to **500 liter** of carbon dioxide gas

This causes a risk for piping rupture if cryogenic liquid was to be blocked inside a closed volume. This is a significant risk that must be taken into account when designing and operating systems using cryogenic fluids.

**Precautions**

The design of a cryogenic plant is a key element in ensuring safe and efficient operation with liquid gases. Here are some important issues to consider:

- **Design validation by a professional:** A cryogenics expert should be consulted before installation. A professional will assess the design for safety and compliance with standards.
- **Pressure relief valves:** It is recommended to install **two pressure relief valves** in every part of the installation if cryogenic liquids can be enclosed (such as a valve). This will prevent emergency situations and allow the installation to be shut down safely if necessary.
- **Discharge of safety valve vents:** Vents from relief valves should be piped to a **safe location**, away from the areas where they may pose a hazard. Gas discharge pipes should be properly labelled and secured.
- **Contact Air Liquide:** Always contact Air Liquide prior to modifying the installation (addition/removal of elbows, piping segments, valves etc). This will help avoid potential problems and risks.

A properly designed and maintained cryogenic plant is the key to working safely with liquid gases.

# 4. Contingency plan

Each user of the installation should develop their own plans for emergency situations. The following are important aspects to consider.

**In case of suspected asphyxiation**, high concentration carbon dioxide exposure, or suspected failure of any automatic safety system:

- Raise the alarm, if not already on, if sufficiently near
- Evacuate
- Cut off the supply of cryogenic liquid (by closing the valve at the tank)
- If possible, boost the exhaust and open doors and windows to allow fresh air to enter

**Anyone suffering from lack of oxygen**:

- Should be quickly moved to an area with a normal atmosphere if safe to do so
- If the victim is not breathing, artificial respiration or cardiopulmonary resuscitation (CPR) should be administered immediately in a safe zone

If anyone is lying **unconscious in a room and asphyxiation is suspected**:

- Do not enter inside to rescue or you may also lose consciousness
- Apply the previously stated evacuation procedure and await for help
- Close the main valve on the tank
- Cascade the safety valve settings

**In contact with liquid cryogenic gases**:

- Personnel should not come in direct contact with liquid cryogenic gases if all procedures are followed
- In the event of a cold burn, the following is to be immediately applied:
  - Search for medical assistance as soon as possible
  - Remove any clothing not frozen to the skin that could restrict blood circulation in frozen area. Do not intend to remove any frozen clothing or material. Await for medical intervention
  - Do not rub frozen tissues
  - Take the casualty to a warm room as soon as possible
  - If possible place the affected areas in a medium warm water bath with a temperature < 40°C: the use of cold tap water in the first 20 minutes is recommended
  - Do not use very warm water, do not dry heat
  - If prolonged exposure to low temperatures, prompt medical intervention and treatment against hypothermia should be administered

Note:

- Poviding the safety data sheets of the cryogenic gases in use to the medical staff can be beneficial

**In case of installation failure**:

- Immediately evacuate all personnel from the plant using the closest emergency exit
- Close the supply valve on the tank
- Never re-enter if the alarms are still on

*Recommended complementary reading:*
Guidelines for the safe installation and use of cryogenic food freezing and chilling equipment, Doc 174/21, from EIGA (available online, free of charge)
SDS Liquid Nitrogen, available on Air Liquide website
SDS Carbon dioxide, available on Air Liquide website

# 5. Labeling of the equipment and production rooms

## 5.1 Labels placed in front of the entrance to the production room with the cryogenic equipment

**Hazard labelling with definition**

Example:

| | RISKS |
|---|---|
|  | Cold burns<br>Frostbite |
|  | Danger of suffocation |

## 5.2 Labels placed on the cryogenic equipment

**Hazard signage (to be selected according to the hazard)**

Examples of pictograms:

## 5.3 Labels placed at the signal lamp and the control panel of the atmosphere detection system

Example:

### Carbon Dioxide Detector Indication

**Flashing lamp**

Carbon dioxide content higher than 0.5%

**Notify your supervisor**


**Flashing lamp and audio signal**

Carbon dioxide content higher than 1.5%

**IMMEDIATE EVACUATION**

**Notify your supervisor**

### Oxygen Detector Indication

**Visual alert**

Oxygen level below 19.5%

**Notify your supervisor**


**Visual and audio alert**

Oxygen level below 18%

**IMMEDIATE EVACUATION**

**Notify your supervisor**

## Contact Us

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