GUIDELINES FOR THE SAFE INSTALLATION AND USE OF CRYOGENIC FOOD FREEZING AND CHILLING EQUIPMENT

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Prepared by WG-8 Food Gases and CO_2

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5.5	Updated information on carbon dioxide
5.6	Clarify cryogenic fogging
6	Clarified actions and responsibilities in response to incidents
7	Addition of references to references to other EIGA documents and information on low pressure nitrogen
8	Additional information on exhaust system
9.2	Changed recommended carbon dioxide alarm setting to 1.5%
9.2	Changed information on room ventilation requirements
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10	Updated information on gas monitoring and user responsibilities
Appendix A	New appendix with information on gas detection systems

NOTE Technical changes from the previous edition are underlined

1 Introduction

This publication has been prepared to cover the safety requirements and best practices for the installation and use of equipment for the chilling and freezing of food using liquefied cryogenic gases (liquid nitrogen) or refrigerated liquefied gases (liquid carbon dioxide) as the cooling medium. This publication uses the expression liquefied cryogenic gas when referring to both liquid nitrogen and liquid carbon dioxide. As the hazards of liquefied cryogenic gases may not be widely appreciated, anyone installing or using these machines is strongly advised to consult their liquefied cryogenic gas supplier before installing or making any alteration to the machine or the freezing process.

2 Scope and purpose

2.1 Scope

This publication covers the installation and operation of food chilling and freezing equipment as well as liquid nitrogen (N_2) and carbon dioxide (CO_2) installations intended for liquid application. Much of this publication is equally applicable to non-food cryogenic applications but concentrates on food applications.

This publication does not replace any risk assessment required by the operating company or employer.

2.2 Purpose

The purpose is to provide guidelines on the design, installation and operation of chilling and freezing equipment so that they can be operated safely.

This publication will also inform about risks and their mitigation when liquefied cryogenic gases are used for freezing and chilling. These specific risks are:

- asphyxiation (oxygen deficiency);
- elevated carbon dioxide concentration;
- pressure build up due to confined evaporation / sublimation (bursting / leaking); and
- hazards due to low temperatures

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

3.2 Technical definitions

3.2.1 Pressure

In this publication bar shall indicate gauge pressure unless otherwise noted i.e., (bar, abs) for absolute pressure and (bar, dif) for differential pressure.

4 Overall description of installation

Figure 1 shows a typical installation consisting of five main parts:

a) storage vessel for the liquefied cryogenic gas complete with pressure control;

b) pipeline to supply the freezing and chilling equipment;

c) cryogenic freezer or chiller;

d) exhaust system for the used gas; and

e) gas detection system.

From an engineering perspective, the complete installation should be treated as a single entity even though the individual components may be supplied from different sources.

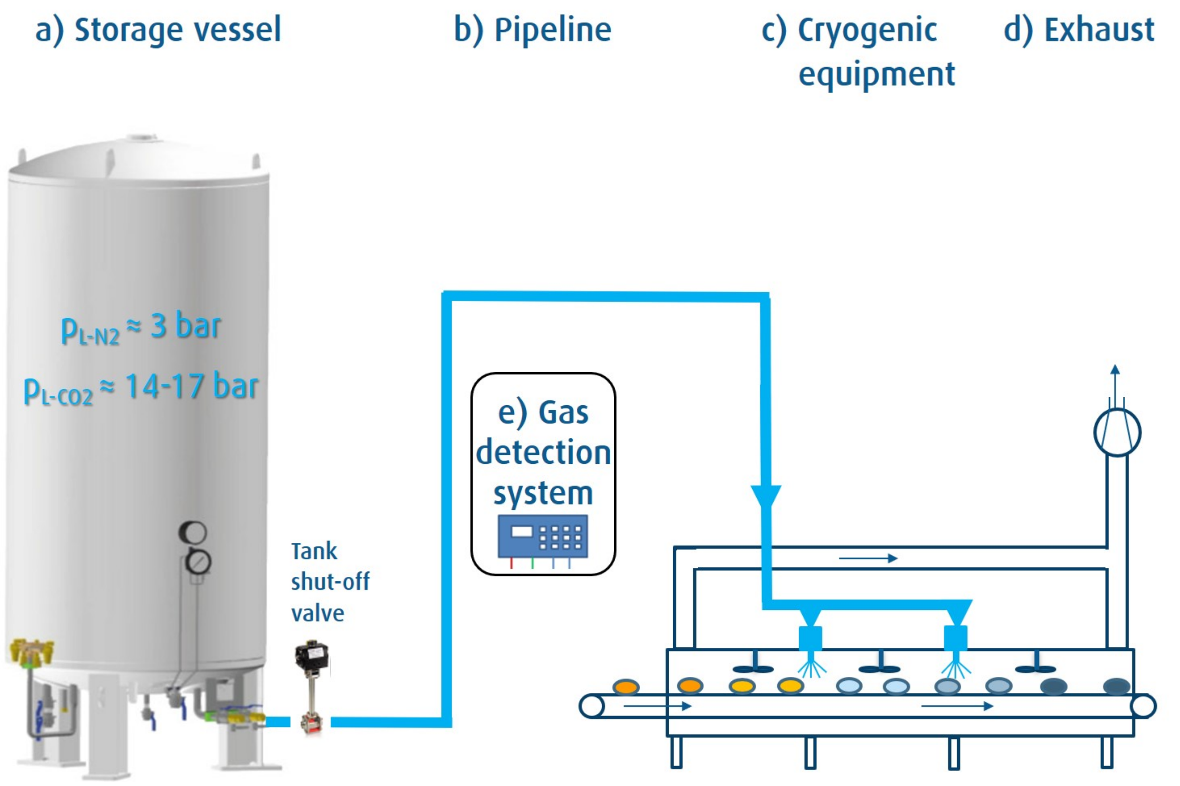

Figure 1: Example of a food freezer installation using liquified cryogenic gas

5 General liquefied cryogenic gas safety

5.1 Physical and chemical properties

Nitrogen and carbon dioxide are inert, chemically inactive, and non-corrosive at cryogenic temperatures. Users should refer to the supplier's safety data sheets for the particular product used.

NOTE Carbon dioxide cannot be a liquid under atmospheric conditions but can be in a solid or gaseous form.

5.2 Extremely low temperatures

Liquefied cryogenic gases are extremely cold, for example at atmosphere pressure liquid nitrogen is –196 °C and solid carbon dioxide is –79 °C. Their cold temperature and their boil-off vapours can rapidly freeze human tissue and cause many common materials such as carbon steel, plastic, and rubber to become brittle. Low pressure liquid nitrogen (less than 1.7 bar, abs) in poorly insulated containers or piping can condense the surrounding air into a liquid. This liquid will be oxygen-rich and should be treated as liquid oxygen.

5.3 Skin or eye frostbite

Because of their extremely low temperatures liquefied cryogenic gases, whether liquid, solid or gas, can cause frostbite on exposed skin. Delicate tissues such as eyes can be damaged by exposure to these cold gases, even when the contact is too brief to affect the skin of the hands or face.

Do not allow any unprotected part of the body to touch uninsulated pipes or vessels that contain liquefied cryogenic gases. The extremely cold metal will cause the flesh to stick, and tearing will occur when removal is attempted. Even non-metallic materials at cryogenic temperatures are hazardous to touch.

5.4 High liquid to gas expansion ratio

All liquefied cryogenic gases produce large volumes of gas when they vaporise. For example, one litre of liquid nitrogen at its boiling temperature at one atmosphere vaporises to approximately 700 litres of nitrogen gas when warmed to room temperature. One litre of liquid carbon dioxide is equivalent to approximately 500 litres of carbon dioxide gas. If liquid nitrogen is vaporised or solid carbon dioxide is sublimated in a gas tight container, it will create a very high pressure. Therefore, pressurised cryogenic containers and cryogenic lines shall be protected with pressure relief devices.

5.5 Asphyxiant

Oxygen is the only gas that supports life. The normal oxygen concentration in air is about 21% by volume.

All inert gases can cause asphyxiation in an enclosed workspace by displacing breathable air. The hazards of reduced oxygen levels are given in Table 1.

Table 1: Oxygen concentration and effects

Oxygen percent at sea level (atmospheric pressure = 760 mmHg)	Effects [1) 2)]
20.9	Normal (below 19.5% is considered oxygen deficient)
19.5 – 10	Increased breathing rates; accelerated heartbeat; and impaired attention, thinking, and coordination
10 – 6	Nausea, vomiting, lethargic movements, and perhaps unconsciousness
<6	Convulsions, then cessation of breathing, followed by cardiac standstill (death). These symptoms can occur immediately.

NOTES

1) Adapted from Title 29 of the U.S. Code of Federal Regulations, Parts 1910 and 1926 [2].

2) These indications are for a healthy average person at rest. Factors such as individual health (being a smoker), degree of physical exertion, and high altitudes can affect these symptoms and the oxygen levels at which they occur.

For further information see EIGA Doc 44, *Hazards of Oxygen-Deficient Atmospheres* [1].[1]

The presence of inert gases cannot be detected without instrumentation. Therefore, workers can be asphyxiated before they realise an asphyxiating atmosphere exists.

In addition to asphyxiation, carbon dioxide can have some physiological effects above a 1.5% concentration in air, see EIGA SI 24, *Carbon Dioxide Physiological Hazards - "Not just an Asphyxiant!"* [3].

Carbon dioxide is naturally present in air at a level of approximately 400 parts per million (0.04%). Carbon dioxide is a non-toxic gas, but at elevated concentrations acts as an asphyxiant as it causes oxygen depletion. However, carbon dioxide hazards and physiological effects are much more complex compared to other gases classified as asphyxiants. Namely, in contrast to other asphyxiant gases, carbon dioxide is a normal product of metabolism in human beings and takes an active part in pulmonary gas exchange principle when people breathe. It forms a part of the human body's normal chemical environment as an active messenger substance in the linking of respiration, circulation, and vascular response to the demands of human metabolism.

Individual tolerances can vary widely, depending on the physical condition of the person and the temperature and humidity of the air, but as a general guide, the effects of inhaling varying concentrations of carbon dioxide are likely to be as in Table 2.

Table 2: Carbon dioxide concentration and effects

Level of CO_2	Likely Effects
1 – 1.5 %	Slight effect on chemical metabolism after exposures of several hours
3 %	The gas is weakly narcotic at this level, giving rise to deeper breathing, reduced hearing ability, coupled with headache, an increase in blood pressure and pulse rate.
4 – 5 %	Stimulation of the respiratory centre occurs resulting in deeper and more rapid breathing. Signs of intoxication will become more evident after 30 minutes exposure.
5 – 10 %	Breathing becomes more laborious with headache and loss of judgement.
10 – 100 %	When the carbon dioxide concentration increases above 10%, unconsciousness will occur in under one minute and unless prompt action is taken, further exposure to these high levels will eventually result in death

[1] References are shown by bracketed numbers and are listed in order of appearance in the reference section.

WARNING: *Carbon dioxide intoxication is entirely independent of the effects of oxygen deficiency (i.e. asphyxiation), therefore the oxygen content in the air is not an effective indication of the danger of intoxication. For example, a reduction of "only" 2% oxygen results in a concentration of 9.5% carbon dioxide and according to the table above, this represents a significant hazard of intoxication to any people in the area. See EIGA SI 24 for more information [3].*

Due to the health risks associated with carbon dioxide the average exposure of a healthy employee during an eight-hour working shift should not exceed 0.5% (5000 ppm). Short term exposure limits can be higher, but there is no agreed international level. Local legislation may require lower exposure limits.

5.6 Cryogenic Fog

A visible fog or vapour cloud is usually produced by the cooling effect of cryogenic liquids or gases in ambient air causing moisture to condense. The extent of the vapour cloud is determined by the temperature and humidity of the air (dew point), the higher the humidity, the more dense the vapour cloud. The increased concentration of inert gases in air can extend beyond the visible vapour cloud since the warmed gas will continue to mix with the air even though it can no longer condense moisture. This mixing effect results in a reduced concentration of oxygen extending from the source to some distance away.

The presence or absence of a vapour cloud is therefore not a reliable way of establishing the degree of oxygen depletion; the extent of the hazardous zone from nitrogen and carbon dioxide release should be determined by ambient air monitoring for the relevant gas.

6 Personnel safety

6.1 Safety training

Trained personnel are essential for ensuring safe operation. Training should include:

- information on the nature, risks and properties of the liquefied cryogenic gas in both the liquid and gaseous phase and, for carbon dioxide, the solid phase;
- specific instructions for the equipment;
- use and care of protective equipment and clothing; and
- handling emergency situations.

6.2 Action to be taken in case of incident

In the case of an incident:

- raise alarm;
- do not enter a room where the oxygen / carbon dioxide level is unknown;
- monitor the level of oxygen / carbon dioxide in the room before entry; and
- request medical assistance if required.
-

In the event of suspected asphyxiation / high carbon dioxide concentration or suspected failure of any automatic safety system, the first action after raising the alarm should be to isolate the liquefied cryogenic gas supply (by closing the tank's shut off valve that feeds the system) and, if possible, boost the exhaust system and / or open windows and doors 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.

6.3 First aid for cold contact burns

Personnel will rarely come in direct contact with a liquefied cryogenic gas if correct handling procedures are used. In the event of a cold contact burn immediate professional medical advice should be obtained.

The following emergency treatment should be taken for a cold contact burn:

- obtain medical assistance as soon as possible;
- remove any clothing not frozen to the skin that could restrict circulation to the frozen area;
- do not rub frozen areas as tissue damage can result;
- as soon as practicable, the casualty should be taken to a warm room, if possible and the affected area should be placed in a warm water bath that has a temperature less than 40 °C (use of cold tap water in the first 20 minutes is recommended), do not use dry heat; and
- if there has been prolonged exposure and the general body temperature is abnormally low, prompt medical attention is imperative, and treatment administered for hypothermia.

NOTE Frozen tissue is painless and appears waxy with a slightly yellow colour. It becomes swollen, painful, and prone to infection when thawed. If the frozen area thaws before medical attention is obtained, cover the area with a dry sterile dressing and a large, bulky protective covering.

6.4 Personal protective equipment

Residual liquid nitrogen or solid carbon dioxide can remain in a freezing or chilling equipment after opening. Personnel shall be aware of the hazards of contact with these liquefied cryogenic gases. However, food freezer operators do not normally handle liquefied cryogenic gases directly but may have to remove CO_2 snow.

Long duration exposures to very low temperatures, even when wearing appropriate Personal Protective Equipment (PPE), can result in cold burns and frostbite. See also EIGA Doc 136, *Selection of Personal Protective Equipment*, [4].

6.4.1 Insulating gloves

Insulating gloves should always be worn when handling anything that could have come into contact with liquefied cryogenic gases and vapours or when handling deep frozen objects.

6.4.2 Trousers

Trousers should not have cuffs and should not be tucked into boots or work shoes.

7 Tank and pipeline requirements

7.1 Liquid supply to the freezer

The overall requirement is to deliver the required flow of liquefied cryogenic gases, with minimum loss of quality to the use point. Loss of quality is defined as an increase in temperature and / or an increase in the proportion of gas.

7.2 General requirements of cryogenic storage

Standard designs of cryogenic storage tanks are acceptable and should be installed in accordance with local regulations. Ideally, tanks should be situated as close to the use point as possible and, if possible, be higher than the use point. Liquid offtake should be directly from the bottom of the tank and not by means of a dip tube.

The operating pressure of the tank should be suitable for the design operating pressure of the food freezer taking into account the pressure drop in the pipeline.

For liquid nitrogen, tank pressure in the region of 3 bar is generally preferred. Pressure control of the liquid in the tank is required to maintain this pressure.

For liquid carbon dioxide the tank pressure should be sufficient to ensure pressure anywhere in the system and at the point of use is more than 5.1 bar (preferably more than 6.5 bar) to avoid pipeline blockage due to dry ice. Typical tank pressure should be in the region of 14-20 bar. For more information see EIGA Doc 164, *Safe Handling of Liquid Carbon Dioxide Containers that have Lost Pressure* [5].

Pressure relief devices are required on storage tanks. They are not pressure control devices and should only function during abnormal operation or emergencies.

Burst discs shall not be installed on carbon dioxide installations due to the risk of the formation, in case of rupture, of solid carbon dioxide in the storage tank.

7.3 Standards

Under the requirements of the Pressure Equipment Directive (PED), nitrogen and carbon dioxide are classified as Group 2 gases [6]. Storage tanks shall be designed according to the PED or an equivalent appropriate design code for the age of the storage tank. Small diameter pipelines (less than or equal to DN32) may be built according to Sound Engineering Practice (SEP) and should not be CE marked.

7.4 Cryogenic Pipeline design

A pipeline is designed to transfer a given flow rate of liquefied cryogenic gas from the storage to the application with minimum loss of quality. It should be insulated to maintain quality and to prevent injury and protected from mechanical impact.

Pipelines should be as straight and as short as possible.

Avoid unnecessary rises in the pipeline: For example, a ten metre liquid nitrogen rise leads to a vaporisation of up to 3.5% of the liquid (by weight).

Fit a gas vent if liquid is required instantaneously when the application valve is opened. Install this vent at the highest point of the line, upstream of the application valve. The gas shall be vented to a safe location.

Add a phase separator to the pipeline only if pure liquid and no vapour are essential at the use point.

Pipelines shall be pressure rated to accommodate the required pressure of the liquefied cryogenic gas.

Install a thermal pressure relief valve where appropriate (for example when liquid can be trapped between two valves).

Where relief valves are installed on freezing equipment or on pipelines inside buildings, they shall be set higher than the set pressure of the tank relief valves and higher than any relief valves outside the building. Vents from relief valves shall be piped to an area where venting will not cause a hazard. For more information, see EIGA SA 39, *Risk of Indoor Low-Pressure Cryogenic Liquid Applications* [7].

7.5 Insulation technologies

Insulation can be achieved either with a vacuum jacket or with foam insulation. Vacuum jacketed insulation has a better insulation performance than foam.

Short pipeline sections, valves and accessories at the tank and freezer and some connections should be insulated with foam to allow access for maintenance or replacement and to reduce heat ingress.

Long sections should be preferably insulated with vacuum jacketed piping in order to reduce heat ingress and subsequent gaseous phase generation. Vacuum line is also more hygienic for use inside food factories. However, foam insulation can be used for long sections in the case of liquid carbon dioxide.

The final choice is a compromise between cost and performance.

Sections of pipeline that are accessible to operators shall be insulated or otherwise protected.

When liquid nitrogen pressure is low (below 1.7 bar, abs) in the pipeline, there is a risk of condensing ambient air and creating an oxygen rich condition within the insulation material. This shall be considered in the selection of insulation material (see EIGA Doc 04, *Fire Hazards of Oxygen and Oxygen Enriched Atmospheres*) [8].

7.5.1 Vacuum insulated pipe

Vacuum insulated pipeline is usually supplied by specialist manufacturers. It can be rigid or flexible, although rigid is preferred.

It is made of two concentric stainless steel pipes. The inner pipe conveys the liquefied cryogenic gas; the outer pipe forms the vacuum jacket. For liquid nitrogen supply, the inner pipe includes expansion bellows (around one every 6 metres) in order to avoid differential thermal contraction between the inner and outer pipe.

Vacuum lines are generally manufactured in prefabricated straight sections. Alternatively, they can be fabricated on site. Ensure that vacuum lines have an adequate pressure rating for the service required.

7.5.2 Foam insulated pipe

Foam insulated lines are composed of:

- the carrier pipe made of stainless steel or copper;
- the insulation made of one or more layers of foam; and
- insulation protection by a jacket of metal or plastic protecting the insulation against mechanical impact and from moisture condensing from air.

Foam should have as low a thermal conductivity as possible; this depends on its density.

CAUTION: *When polyurethane foam insulation burns it releases toxic gases.*

Where open cellular foam insulation is used, consideration of oxygen compatibility should be given where the possibility of air liquefaction and oxygen concentration exists for liquid nitrogen pipelines.

7.6 Commissioning of pipelines (vacuum and foam insulation)

When commissioning pipelines:

- ensure dust, moisture and other contaminants are removed by purging the line with a dry inert gas;

- ensure that there are signs on the pipelines indicating the fluid and flow direction and that they comply with the applicable local regulations for pipeline signage;
- isolate or remove relief valves, pressure gauges and other components rated lower than the proof pressure for the pressure test;
- pressure test or leak test according to design code, company or national standards;
- fit relief valves set to the design pressure;
- create a pressure test / leak test certificate, if required; and
- repeat the purge to ensure no contaminants have been introduced into the line, check nozzles and strainers for contamination.

8 Food freezing and chilling equipment requirements

8.1 General safety requirements for equipment design

All food freezing and chilling equipment and machines shall meet the requirements of European and national legislation, in particular the Machinery Directive, [9].

The freezing and chilling equipment shall be supplied with an operating manual. The gas supplier shall supply a safety data sheet (SDS).

8.2 Exhaust

All cryogenic equipment shall be fitted with an exhaust system designed to remove the maximum volume of gas produced from the supply of liquefied cryogenic gas to the equipment.

The exhaust system capacity shall be determined by calculation of the maximum possible flow of liquefied cryogenic gas to the freezer, after consideration of the tank pressure, degree of sub-cool, valve and nozzle size and duct diameter.

If the exhaust fails to operate, liquefied cryogenic gas shall not be supplied to the freezer.

There shall be a method of ensuring that there is a flow in the exhaust duct in the correct direction during installation or maintenance, such as rotation indication on the exhaust fan.

If room oxygen falls below a certain level or carbon dioxide rises above a certain level, then the exhaust system shall be boosted and the liquefied cryogenic gas supply to the freezing or chilling equipment shall be automatically shut off. Additionally, consideration shall be given to shutting an automatic valve at the tank.

Gas detection monitoring is described in Appendix A.

8.3 Other essential safety requirements

If the freezer is opened during its operation, the liquefied cryogenic gas supply shall be shut off.

The freezer shall be supplied with a second independent temperature circuit which shuts off the liquefied cryogenic gas supply if a very low temperature is detected in the freezer.

The equipment shall also be equipped with:

- A clearly labelled, safely accessible manual shut-off valve for the liquefied cryogenic gas;
- an automatic shut off valve for the liquefied cryogenic gas, and

- a flow control valve for the liquefied cryogenic gas.

8.4 Boiling and splashing

Freezing equipment that immerses food into liquid nitrogen shall be designed to protect personnel from the effects of boiling or splashing of the liquid nitrogen. Personnel shall be prevented from reaching into the machine and coming into contact with liquid nitrogen.

8.5 Embrittlement

Many materials including rubber and plastics objects that are soft and pliable at room temperature become hard and brittle at cryogenic temperatures and are easily broken. Many metals are unsuitable for cryogenic service, in particular mild steel. Austenitic stainless steel is the metal of choice for many cryogenic applications.

9 Installation requirements

9.1 General

The liquefied cryogenic gas flow requirement for the application shall be determined including a contingency to allow for variations in customer requirements and process control.

The tank pressure shall be specified and valve and nozzle sizes on the freezer calculated for this pressure and flow assuming saturated (boiling) liquefied cryogenic gas at the tank. The tank shall operate at this pressure to avoid higher liquefied cryogenic gas flow than the exhaust can remove. Tank pressure, valve size, nozzles shall not be changed except by a management of change; see EIGA Doc 51, *Management of Change*, [10].

The exhaust shall be sized assuming a certain amount of sub-cool and tank over-pressure, calculating the maximum possible cryogen flow in these circumstances.

Pressure control systems shall be installed on the storage tank to avoid an increase in the tank pressure that would lead to flows to the freezer beyond the capacity of the exhaust system. To ensure that the pressure in a cryogen tank does not rise above a certain level, two independent methods of pressure control are recommended, for example a back pressure regulator and an actuated valve.

NOTE Pressure relief valves are not pressure control devices.

9.2 Ventilation of the room

Fresh air should be delivered into the production facility enabling the extraction system to operate correctly so that the composition is indistinguishable from atmospheric air. This should be independent of any ventilation provided by the freezing and chilling equipment exhaust system. The number of air changes will depend upon the size of the room, amount of equipment, exhaust fans on the equipment etc. and requires an installation specific review (see EIGA Doc 44) [1].

A minimum of one oxygen monitor shall be installed and operated continuously in nitrogen food freezer installations regardless of whether or not the freezer is in use. The oxygen monitors shall be installed, operated, calibrated and maintained as prescribed by its manufacturer. Oxygen monitors shall have an audible and visual alarm at 19.5% oxygen. A second alarm level shall initiate evacuation of personnel, see Appendix A for more details.

At an oxygen level of 18%, the nitrogen supply shall be automatically shut off, the exhaust system shall run at maximum speed and the room evacuated.

For carbon dioxide equipment, a minimum of one carbon dioxide monitor shall be provided. The monitors shall have an audible and visual alarm at 0.5% carbon dioxide, 5000 ppm. A second alarm level to indicate short term higher carbon dioxide levels shall initiate evacuation of personnel, see Appendix A for more details. The carbon dioxide monitor shall be installed, operated, calibrated and maintained as prescribed by its manufacturer.

At 1.5% carbon dioxide, the carbon dioxide supply shall be automatically shut off, the exhaust system shall run at maximum speed and the room evacuated.

NOTE Local regulations can define different short-term exposure levels.

The position of the oxygen / carbon dioxide sensors shall be selected to ensure that any measurement of oxygen depletion and carbon dioxide concentration is representative of the potential hazardous atmosphere in the workplace.

Additional floor level ventilation for carbon dioxide should be considered, see Appendix A for more details.

NOTE For more information on the risks of asphyxiation see the EIGA campaign on asphyxiation and EIGA Doc 44, [1].

9.3 Electrical connection

The installer of the freezing or chilling equipment shall ensure that the electrical power supply is suitable for the service required and that it is suitably protected against overcurrent.

Grounding and equipotential bonding for all parts of the freezer shall be provided.

The electrical installation shall only be performed by authorised personnel.

9.4 Exhaust duct construction

The exhaust duct construction:

- shall be designed, together with the exhaust fan, to be able to extract all the cryogen gas that can be supplied to the freezer and separate from any other ventilation system;
- should be made from materials that are suitable for low temperature and compatible with food processing environment, for example stainless steel;
- should be straight except for the necessary 90 degree bend at a radial fan, if bends are essential, they should be long radius, for example 1 metre radius;
- smooth ducting should be used rather than spiral ducting;
- transitions in diameter, where required, should have a transition angle of 15 degrees or less to minimise snow and ice build-up;
- downstream of the exhaust fan and inside the building shall be leak-proof to ensure that no cryogenic gas can be released into the building;
- shall ensure that the cryogenic gas is exhausted to well-ventilated areas at safe locations outside the building and away from ay air intakes and building openings;
- shall not be able to be closed;
- shall have a discharge duct on the outlet of the exhaust fan (at least 1 metre long) to prevent contact with the fan impeller, and to improve its efficiency;
- shall not include any fixed physical obstructions or barriers in the exhaust duct, for example mesh screens to protect against birds; and
- should be able to be cleaned.

Vertical ducts are preferred over horizontal ducts. Where horizontal ducts are used they should be angled at least 1 degree downwards to the exit for water drainage.

To prevent icing of fans:

- use radial blade fans where possible (radial blade fans are ice shedding and tend to have fewer problems with ice build-up on the blades); or
- use an air ingress system which warms the exhausted cryogen to above 4 °C and calculate the required make-up air and design for this duty; or
- use a heater to raise the exhaust temperature with a system to prevent overheating of the system and an overheat cut-off device, although this may not be practical due to cost.

The exhaust fan shall have:

- a means of ensuring the movement of gas in the correct direction in the duct; and
- a locally mounted disconnect switch at the fan to ensure that it cannot be started during maintenance and an auxiliary signal to the control panel to prevent operating with an isolated exhaust.

9.5 Other responsibilities of the installer

Transport, assembly and installation of the freezing or chilling equipment shall be carried out by suitably qualified personnel authorised and supervised by the gas supplier or the equipment supplier.

If installation requires any modifications to the equipment, they shall be carried out without compromising safety or invalidating any CE certification.

The cryogenic pipelines, machine and exhaust duct shall be installed away from personnel or guarded against impact, for example by installation of a barrier where necessary. They should be labelled to indicate the contents of the pipe.

The equipment shall be installed level or at the angle specified by the manufacturer. In the event of an uneven floor, adjustable feet shall be used. The equipment shall be secured against movement.

The freezing or chilling equipment shall only be used if all services are connected, i.e. liquefied cryogenic gas, exhaust, electricity, compressed air, hydraulics, water for cleaning.

Operators and management shall be trained in the operation of the equipment and in the hazards of liquid nitrogen and carbon dioxide. It should be recorded that training has been given.

An operational readiness inspection should be conducted before handover and recorded to ensure that the safety, technical and business requirements of the supplier and customer are met.

10 User responsibilities and continuing operation of the freezing equipment

The user shall be familiar with all the safety requirements of the liquefied cryogenic gas and the machine.

The freezing and chilling equipment is to be exclusively used for purposes stipulated by the manufacturer, that is, for chilling and freezing of foods and other permitted products. Operation should not be at production rates greater than that specified by the machine manufacturer nor should operating temperature be lower than that specified.

The user shall ensure that all guards are in place and all interlocks are operational at all times that the equipment is in operation. Where gas monitors are installed, they shall be calibrated as per the manufacturer's instructions. Responsibility for calibration and maintenance of gas monitors shall be clearly defined.

Nitrogen freezers shall be used only with liquid nitrogen and carbon dioxide freezers shall be used only with carbon dioxide. If injection systems for both liquefied cryogenic gases are installed on the machine, simultaneous operation of both injections shall not be used.

The minimum temperature set points according to the operating instructions shall not be changed.

Operators shall be aware of the hazards of damaged or failed equipment. In the case of escaping gas, they shall stop the machine and manually turn off the liquefied cryogenic gas at the storage tank.

Untrained personnel shall not install, use or maintain the equipment. Repair, servicing and maintenance works shall only be carried out by trained and qualified personnel.

Components replacements shall be agreed with the freezer manufacturer or the gas supplier.

The freezer shall not be moved without prior agreement from the manufacturer or the gas supplier.

The user shall inform the gas supplier of any significant changes in building layout involving the freezing and chilling equipment (for example changes in wall location).

10.1 Customer training for the event of liquefied cryogenic gas leakage

The customer is responsible for the safe operation of their factory. In the event of a low oxygen level or high carbon dioxide level in the factory it is essential that:

- the room ventilation is increased;
- the room is immediately evacuated; and
- supply valves at the storage tank are closed.

If the reason for the escape of the liquefied cryogenic gas cannot be determined, the gas supplier or the freezer manufacturer shall be informed at once.

Under no circumstances shall the freezing and chilling equipment continue in operation.

If it is necessary to enter a work area that could have an oxygen-deficient or carbon dioxide rich atmosphere, self-contained breathing apparatus (SCBA) shall be used by trained users.

WARNING *Do not enter oxygen deficient or carbon dioxide rich atmospheres without suitable breathing apparatus. An absorptive gas mask will not prevent asphyxiation.*

For additional guidance on personal protective equipment see EIGA Doc 136 [4].

10.2 Freezer operation

The freezing and chilling equipment shall be operated and cleaned strictly in accordance with the manufacturer's operating instructions. The user is responsible for developing cleaning method procedures and frequency.

Cleaning the machine can expose the operator to hazards of cold and / or moving parts. Wherever possible, exposed moving parts should be eliminated or guarded when the machine is open for cleaning.

10.3 Maintenance, inspection and repair

The user of the freezing or chilling equipment is responsible for the safe operation of the machine. Maintenance and inspection intervals recommended by the manufacturer in the user's manual shall be followed.

Maintenance, inspection, modification and repair shall only be carried out by specifically trained personnel. In case of doubt, consult the gas supplier or the manufacturer of the equipment. A work permit system should be in place, see EIGA Doc 40, *Work permit systems* [11].

Before working on the equipment, pipeline or exhaust, the supply line for the liquefied cryogenic gas shall be locked closed and any residual pressure released.

When working on the freezing or chilling equipment, the main electrical power switch shall be locked in the off position.

Prior to start-up after installation or maintenance, all pipelines, components, injection nozzles and the exhaust duct shall be checked for tightness and cleanliness (see 7.6).

Leaking or improperly set relief valves shall be reported to the gas supplier or tank owner so steps can be taken to replace or reset them by authorised personnel. Frosting, ice formation, or excessive corrosion on pressure relief valves shall be reported to the gas supplier or tank owner, as these conditions can render the valves inoperative.

Visible frost on the storage tank can mean a loss of insulation and should be reported.

10.4 Disposal

Equipment with no economic value and unwanted equipment shall be disposed of responsibly and recycled as far as possible according to national and local regulations.

Until final disposal, unused equipment shall be stored safely.

11 References

Unless otherwise specified, the latest edition shall apply.

[1] EIGA Doc 44, *Hazards of Oxygen-Deficient Atmospheres*, www.eiga.eu.

[2] Code of Federal Regulations, Title 29 (Labor), Government Printing Office. www.gpo.gov.

[3] EIGA SI 24, *Carbon Dioxide Physiological Hazards - "Not just an Asphyxiant!"*, www.eiga.eu.

[4] EIGA Doc 136, *Selection of Personal Protective Equipment*, www.eiga.eu.

[5] EIGA Doc 164, *Safe Handling of Liquid Carbon Dioxide Containers that have Lost Pressure*, www.eiga.eu.

[6] Directive 2014/68/EU, *relating to the making available on the market of pressure equipment (PED)*, www.europa.eu.

[7] EIGA SA 39, *Risk of Indoor Low-Pressure Cryogenic Liquid Applications*, www.eiga.eu.

[8] EIGA Doc 04, *Fire Hazards of Oxygen and Oxygen Enriched Atmospheres*, www.eiga.eu.

[9] Directive 2006/42/EC *on machinery (Machinery Directive)*, www.europa.eu.

[10] EIGA Doc 51, *Management of Change*, www.eiga.eu.

[11] EIGA Doc 40, *Work Permit Systems*, www.eiga.eu.

[12] EN 60529, *Degrees of protection provided by enclosures (IP Code)*, www.cen.eu.

[13] ATEX Directive 2014/34/EU, *on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres*, www.eiga.eu.

12 Additional references

EIGA Doc 224, *Static Vacuum Insulated Cryogenic Vessels Operation and Inspection*, www.eiga.eu.

EIGA Doc 66, *Refrigerated CO2 Storage at Users' Premises*, www.eiga.eu.

Appendix A Gas detection for nitrogen and carbon dioxide applications

The purpose of this appendix is to give guidance on gas detection and related warning systems and the risk mitigation measures for nitrogen and carbon dioxide applications. The appendix is intended for cryogenic freezing and chilling equipment in food and other industries where large amounts of expanded gas are created from liquefied cryogenic gas and exhausted outside the building. These large volumes present a risk of forming asphyxiant atmospheres inside the building.

A.1 Fundamentals

The goal of this appendix is to inform and to recommend methods for implementation, use, maintenance and management of gas detection systems designed for the protection of workers where asphyxiation can occur. It does not replace recommendations or instructions provided by gas detection manufacturer's / installer's or specific country regulation and does not replace customer / user equipment responsibility.

A.2 Hazards

Inert gases cannot be detected by humans by smell (odour), taste, visibility or any other natural senses. Inert gases can cause asphyxiation by displacing breathable air. In addition to asphyxiation, carbon dioxide, can have some negative physiological effects – see 5.5.

A.3 Monitoring

The use of a gas detection system to monitor leaks from, or failures of, the freezing and chilling equipment is essential.

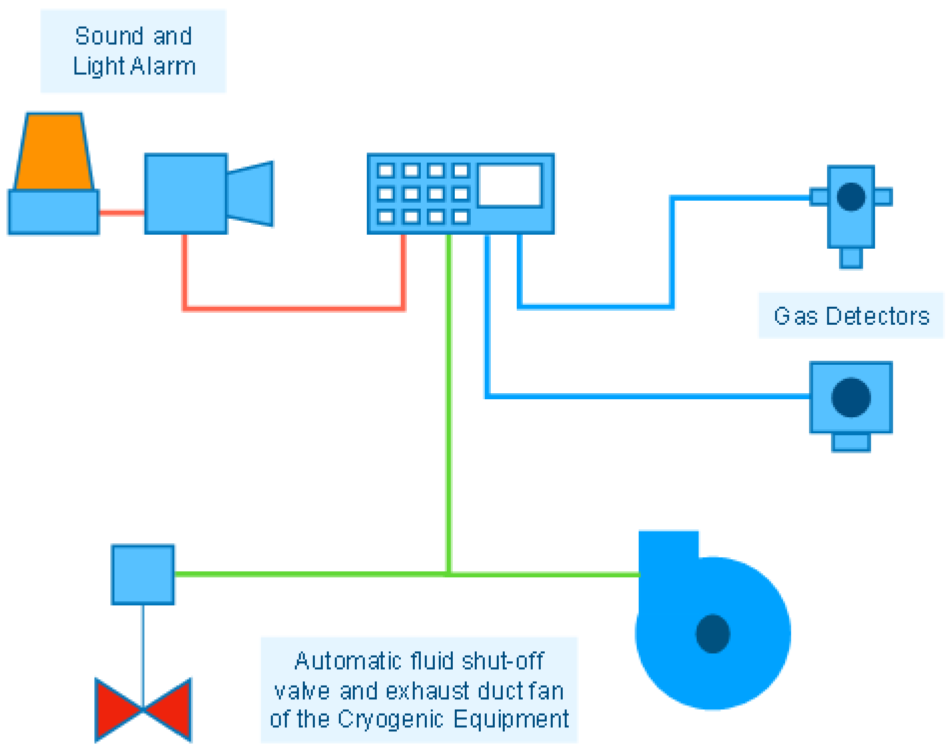

Figure 2: Typical gas detection system

A.4 Gas detection system components

A.4.1 Gas detector

Devices are commonly electrochemical sensor type for oxygen detection and infrared type for carbon dioxide.

Gas detectors shall have:

- stainless steel or polycarbonate enclosures compatible with aggressive cleaning agents used in food production environments; and

- water / humidity protection for example IP 65, 67 as per standard EN 60529, *Degrees of protection provided by enclosures (IP Code)* [12].

NOTE Gas detectors shall be suitable for explosive atmospheres when installed in an ATEX classified area (reference ATEX directive 2014/34/EU) [13].

When carbon dioxide is used a CO_2 detector is required, an additional oxygen detector is optional. A carbon dioxide detector shall not be replaced by an oxygen detector.

The gas detectors shall be protected from the water jets when operators are cleaning the production area, it is recommended to enclose within a stainless steel wash down box with appropriate aperture allowing ambient atmosphere monitoring, see Figure 3.

Figure 3: Stainless steel washdown box for gas detection monitors

A.4.2 Atmosphere monitoring station

This atmosphere monitoring station (measurement, data acquisition and process control) shall be placed in a convenient area outside the hazard area in accordance with the site risk analysis.

Monitoring stations shall have:

- stainless steel or polycarbonate enclosures compatible with aggressive cleaning agents used in food production environments; and

- water / humidity protection for example IP 65, 67 as per standard EN 60529 [12].

NOTE Monitoring stations shall be suitable for explosive atmospheres when installed in an ATEX classified area (reference ATEX directive 2014/34/EU) [13].

A.4.3 Audible and visual alarm

Equipment dedicated to alert the working staff about threat of low oxygen or high carbon dioxide concentration shall consist of sound and visual alarms. It shall be placed in order to be visible and / or audible to anyone in the working room and as well from outside the working room in order to be warned in case of alarm.

A.4.4 Choice and implementation of gas detector(s)

The following criteria shall be considered when choosing gas detection systems:

- detector positioning (location / height);
- number of detectors;
- temperature of working area;
- pressure of workplace;
- humidity, including ingress protection;
- explosive atmospheres
- electromagnetic interferences;
- accuracy;
- response time;
- detector shelf life;
- maintenance;
- calibration frequency; and
- reliability / repeatability.

NOTE There are differences in response time from one detector to another. When choosing the detector, response time shall consider working area size, small working areas require short response times.

Gas detector and atmosphere monitoring station shall be calibrated by the qualified manufacturer, installer or maintenance contractor. Refer to the device supplier for the maintenance and calibration frequency.

A.4.5 Gas detection alarm settings

Where no local regulation exist, the following alarm settings are recommend:

	Oxygen	Carbon dioxide
Pre-alarm threshold	19.5%	0.5%
Evacuation threshold	18%	1.5%

A pre-alarm threshold shall trigger an audible and visual alarm.

Main alarm (evacuation threshold) shall trigger:

- audible and visual alarm;
- emergency evacuation;

- liquefied cryogenic gas supply automatic shutdown; and
- running exhaust fan at full speed.

A customer risk assessment shall determine the relevant actions to ensure worker safety and make the work area atmosphere is safe, such as:

- ventilation of the room;
- worker evacuation; and /or
- stopping of any cryogenic freezing and chilling equipment in use.

An action plan for immediate relevant actions at pre-alarm shall be prepared, documented, personnel trained and responsibilities assigned. The following actions shall be taken into account:

- check that the exhaust system is running as designed and not blocked or partly blocked;
- check the gas supply system to ensure no leakage and correct operation; and
- check cryogenic freezing and chilling equipment is set-up correctly.

A.4.6 Power outage

The liquefied cryogenic gas supply shall be stopped immediately in case of power outage.

An electrical backup supply to the gas monitoring system is recommended for 30 minutes minimum, normally provided by integral batteries.

A.4.7 Risk analysis

A risk assessment shall be done by the user. Refer to local regulations to ensure compliance with safety requirements.

The following parameters shall be considered:

- human presence (number, location, working time etc.);
- natural and forced ventilation in the work area (dimensions, flow rates, number and size of openings, air exchange etc.);
- volume of the work area, liquefied cryogenic gas flow and profiles (start-up, normal and peak);
- use of the equipment (permanent and number of shifts); and
- temperature and humidity of the work area.

Professional consultants or trained specialists should be used to manage the risk assessment.

A.5 Personal gas detectors

Portable personal gas detectors are recommended for spot checking correct operation of gas monitoring system and checking of potential localised leaks.