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

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As part of a programme of harmonisation of industry standards, the European Industrial Gases Association (EIGA) has published EIGA Doc 174, *Guideline for the Safe Installation of Cryogenic Food Freezing and Chilling Equipment*. This publication was jointly produced by members of the International Harmonisation Council.

This publication is intended as an international harmonised publication for the worldwide use and application by all members of the International Harmonisation Council whose members include the Asia Industrial Gases Association (AIGA), Compressed Gas Association (CGA), European Industrial Gases Association (EIGA), and Japan Industrial and Medical Gases Association (JIMGA). Regional editions have the same technical content as the EIGA edition, however, there are editorial changes primarily in formatting, units used and spelling. Regional regulatory requirements are those that apply to Europe.

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Amendments to 174/21

Section	Change
	DOC174 has been globally harmonised

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 refrigerated liquefied gases (liquid nitrogen and liquid carbon dioxide) as the cooling medium. This publication uses the expressions cryogenic and refrigerated liquefied gas when referring to both liquid nitrogen and liquid carbon dioxide. As the hazards of refrigerated liquefied gases may not be widely appreciated, specifically the differences between liquid nitrogen as a cryogen and liquid carbon dioxide, anyone installing or using this equipment is strongly advised to consult their liquefied cryogenic gas supplier and/or equipment supplier before installing or making any alteration to the system.

2 Scope and purpose

2.1 Scope

This publication covers the installation and operation of food freezing and chilling equipment and associated supply systems and the use of that equipment with refrigerated liquefied gases (nitrogen and carbon dioxide).Topics covered in this publication include but are not limited to safety, design, handling, storage, use, ventilation, maintenance, and monitoring of areas where these gases can accumulate and cause hazardous conditions. General safety guidelines or information within this publication are also applicable to non-food cryogenic applications.

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

This publication does not address food safety related to biological, chemical (including radiological), or physical contamination. These should be controlled through good manufacturing practices, materials of construction, and other risk-based controls identified in other publications.

2.2 Purpose

The purpose is to provide minimum requirements on the design, installation, and operation of food freezing and chilling equipment and the associated supply system so that they can be operated safely.

This publication will also inform about risks and their mitigation when refrigerated liquefied 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 Asphyxiation

To become unconscious or die from a lack of oxygen.

3.2.2 Automatic shutoff valve

Supply isolation valve that automatically closes when actuated by gas detection signal or activation switch, and in the event of a power failure.

3.2.3 Carbon dioxide intoxication

Carbon dioxide overexposure that is physiologically harmful.

3.2.4 Cryogenic liquid

See refrigerated liquefied gas.

3.2.5 Dilution air

Air that is mixed in with the cold exhaust gases from the food freezing and chilling equipment in order to warm them up as they are exhausted.

3.2.6 Exhaust system

Components utilized to remove the residual refrigerated gases and/or dilution air to an area where venting does not cause a hazard.

3.2.7 Food gases

Gases in solid, liquid, gaseous form intended to be used as a food additive, direct contact processing aid or ingredient in accordance with relevant regional regulatory requirements.

3.2.8 Fresh air

Having a composition that is indistinguishable from atmospheric air.

3.2.9 Food freezing and chilling equipment

Equipment that uses a liquefied gas (cryogenic or refrigerated) to freeze or chill.

3.2.10 Gas detector

Device designed to detect the concentration of a specific gas and is a component of a gas monitoring system.

3.2.11 Inert gas

Gas(es) that does not readily react chemically with other substances under normal conditions of temperature and pressure.

3.2.12 Life safety controls

Comprehensive safety systems consisting of elements that are designed to protect occupants during an emergency.

3.2.13 Operating company

Responsible company operating the food freezing and chilling equipment and that is accountable for personnel safety and maintaining the risk assessment.

3.2.14 Oxygen depletion

Reduction of oxygen concentration in normal atmospheric air (concentrations of less than 20.9%).

3.2.15 Refrigerated liquefied gas

Gas that when packaged is made partially liquid because of its low temperature.

3.2.16 Risk assessment

Overall process of risk identification, risk analysis, and risk evaluation.

3.2.17 Spray nozzle

Attachment that causes the refrigerated liquefied gas to be delivered as a spray.

3.2.18 Supply system

Assembly of dedicated equipment designed to store and distribute refrigerated liquefied gas.

4 Overall description of installation

Installations shall consist of five main parts as shown in Figure 1:

- storage vessel for the refrigerated liquefied gas complete with pressure control;
- pipeline to supply the food freezing and chilling equipment;
- food freezing and chilling equipment;
- exhaust system for the residual refrigerated gases and/ or dilution air; and
- gas monitoring system.

All these main parts shall be present to ensure a safe installation. The operating company shall ensure a risk assessment is performed.

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

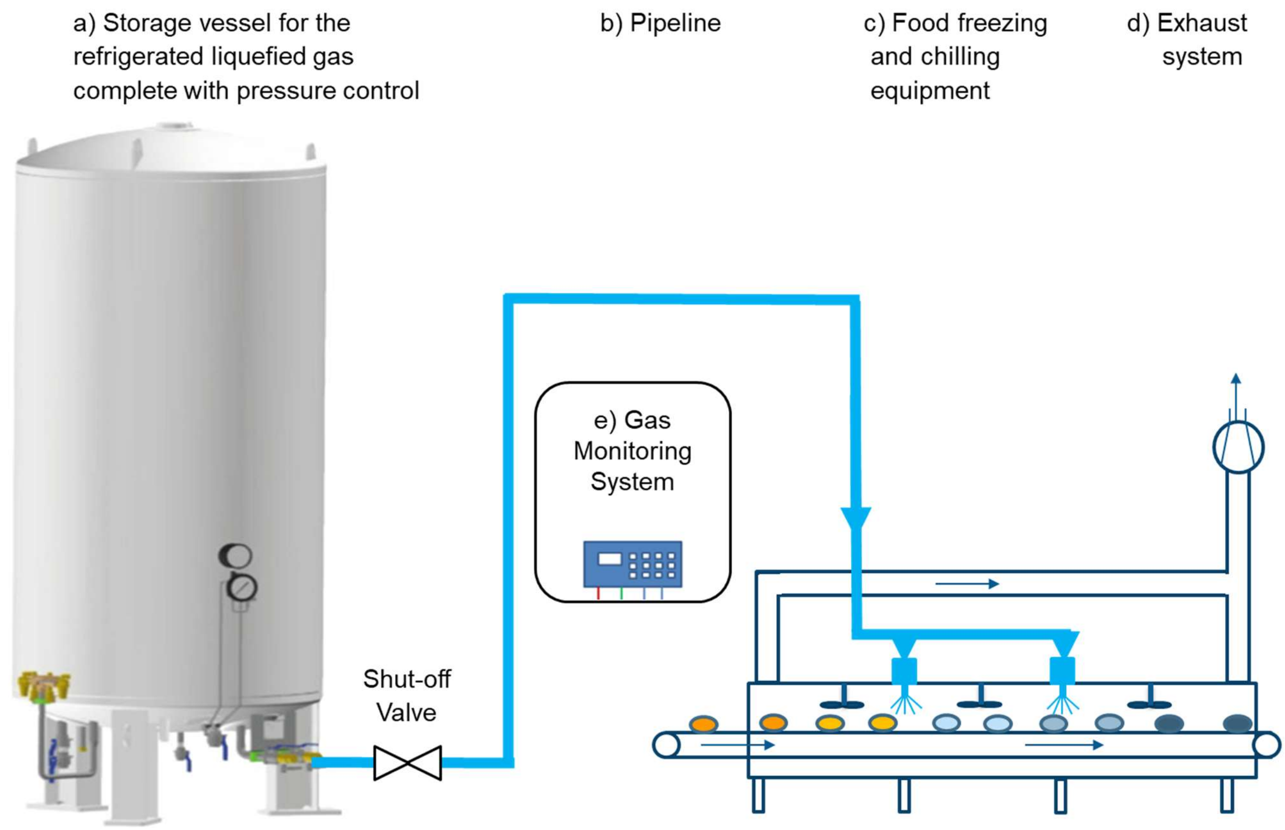


Figure 1—Example of a food freezing and chilling equipment installation using refrigerated liquefied gas

5 General refrigerated liquefied gas safety

5.1 Physical and chemical properties

Nitrogen, 78% of the air, is inert, chemically inactive, and non-corrosive at food freezing temperatures. It cannot be detected by humans by smell (odour), taste, visibility or any other natural senses. The operating company should refer to the supplier's safety data sheets (SDS) for the hazards of nitrogen. See CGA P-9, *The Inert Gases: Argon, Nitrogen, and Helium* or EIGA Doc 23, *Safety Training of Employees* [1, 2].[1]

Carbon dioxide, 0.04% of the air, is non-corrosive at food freezing temperatures. It cannot be a liquid under atmospheric conditions but can be in a solid or gaseous form. It can be undetectable by humans by smell (odour), taste, visibility, or any other natural senses. The operating company should refer to the supplier's SDS for the hazards of carbon dioxide. See CGA G-6, *Carbon Dioxide* or EIGA SI 24, *Carbon Dioxide Physiological Hazards - "Not just an Asphyxiant!"* [3, 4].

When at food freezing temperatures, both carbon dioxide and nitrogen are heavier than air and if there is a leak, they will tend to collect at the floor.

5.2 Skin or eye frostbite

Because of their extremely low temperatures refrigerated liquefied 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 refrigerated liquefied gases. The extremely cold metal will cause the flesh to stick, and tearing will occur

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

when removal is attempted. Even non-metallic materials at food freezing temperatures are hazardous to touch.

5.3 Asphyxiation and carbon dioxide intoxication

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

All other gases can cause asphyxiation in an enclosed workspace by displacing oxygen. 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) 3) 4)]
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 [5].

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.

3) A hazardous atmosphere oxygen concentration range as defined by the U.S. Occupational Safety and Health Administration (OSHA) is outside the range of 19.5% to 23.5% [5].

4) While the percentage of oxygen does not change with altitude, the partial pressure of the atmosphere decreases, which creates physiological effects similar to oxygen deficiency. These effects increase at higher altitudes. Working at altitudes above 2 438 m (8 000 ft) can have similar effects to working in a 15% oxygen atmosphere and working at altitudes of 4 267 m (14 000 ft) can have effects similar to a 12% oxygen atmosphere. Precautions such as supplemental oxygen and acclimatization shall be taken when working at altitudes to protect the employees against the effects of altitude sickness and other physiological effects similar to those experienced with decreasing oxygen concentrations. Consult knowledgeable medical and safety professionals regarding the specific precautions to take when working at high altitudes.

Consideration should be given to undertake a specific risk assessment aligned together with reference to EIGA Doc 44, *Hazards of Oxygen-Deficient Atmospheres* [6].

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 cause adverse physiological effects including fatality depending on exposure level and duration, see EIGA SI 24, and CGA G-6 [3, 4].

Carbon dioxide is naturally present in air at a level of approximately 350 ppm to_ 420 ppm (0.035% to 0.042%). Carbon dioxide at these concentrations is non-toxic. However, at elevated concentrations, carbon dioxide can be intoxicating and ultimately act as an asphyxiant. 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.

The response to carbon dioxide inhalation depends on the degree and duration of exposure, and it varies greatly even in healthy individuals. The medical term for the physiological effects of excess carbon dioxide in the blood is hypercapnia. Carbon dioxide can be intoxicating even when normal oxygen levels are present. Low concentrations of inhaled carbon dioxide can be tolerated for a considerable period of time without noticeable effect or can merely cause an unnatural feeling of shortness of breath. Sustained exposure to 5% carbon dioxide produces stressful rapid breathing. When the level of inhaled carbon dioxide exceeds 7%, the rapid breathing becomes labored (dyspnea) and restlessness, faintness, severe headache, and dulling of consciousness occur. Greater than 10%, unconsciousness accompanied by rigidity and tremors occurs in less than 1 minute, and in the 20% to 30% range it produces unconsciousness and convulsions in less than 30 seconds. The reason these effects occur quickly is that carbon dioxide diffuses in the tissue fluids at a rate approximately 20 times more rapidly than oxygen. High concentrations of carbon dioxide can cause asphyxiation quickly without warning and with no possibility of self-rescue regardless of the oxygen concentration.

Table 2—Carbon dioxide concentration and effects

Level of CO_2	**Likely Effects**
1% to 1.5%	Slight effect on chemical metabolism after exposures of several hours
1.5% to 4%	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% to 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% to 10%	Breathing becomes more laborious with headache and loss of judgement.
10% to 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

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 information in Table 2, this represents a significant hazard of intoxication to any people in the area. See EIGA SI 24 or CGA G-6 for more information [3, 4].*

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 time-weighted average [TWA]). Short-term exposure limits (STEL) can be higher, but there is no agreed international level. Local jurisdictions may establish other exposure limits.

5.4 High liquid to gas expansion ratio

All refrigerated liquefied gases produce large volumes of gas when they vaporise. For example, 1 L of liquid nitrogen at its boiling temperature at one atmosphere vaporises to approximately 700 L of nitrogen gas when warmed to room temperature. One litre of liquid carbon dioxide is equivalent to approximately 500 L of carbon dioxide gas. An unintended release of a refrigerated liquefied gas to the breathable air, given the expansion ratio, can create a hazardous environment and should be considered in the design of the safety features of the system.

If liquid nitrogen is vaporised or solid carbon dioxide is sublimated in a gas tight container or pipe, it will create a very high pressure. Therefore, pressurised refrigerated liquefied gas containers and pipes shall be protected with pressure relief devices.

5.5 Extremely low temperature

5.5.1 Material compatibility

Refrigerated liquefied gases are extremely cold, for example at atmospheric pressure liquid nitrogen is –196 °C (–320 °F) and solid carbon dioxide is –79 °C (–109 °F). Their cold temperature and their boil-off vapours can cause embrittlement to common materials such as certain types of carbon steel, plastic, and rubber. All materials shall be confirmed for compatibility.

5.5.2 Oxygen enrichment

Low pressure liquid nitrogen in poorly insulated containers or piping can condense the surrounding air into an oxygen-rich liquid.

5.6 Cryogenic fog

A visible fog or vapour cloud is usually produced by the cooling effect of refrigerated liquefied gases and cold vapour in ambient air causing moisture to condense. The density and extent of the vapour cloud is determined by the temperature and humidity of the air (dew point). The greater the humidity, the denser 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

Personnel safety is the obligation of the operating company. Training for emergencies is critical. An emergency preparedness plan shall be developed, maintained, and incorporated into existing safety management plans that the site maintains. This section outlines recommended key elements of an effective emergency preparedness plan. A risk assessment as referenced in 9.2 and in Appendix A is intended to support the plan development. The following sections offer guidance on details that might not be influenced by the risk assessment directly.

6.1 Safety training

Trained personnel are essential for ensuring safe operation. The operating company should contact the food freezing and chilling equipment supplier(s) and/or the refrigerated liquefied gas supplier for support in their development of training material and content. Training should include:

- information on the nature, risks and properties of the refrigerated liquefied gas in both the liquid and gaseous phase and, for carbon dioxide, the solid phase;
- information on the safe use, handling, and storage of nitrogen and/or carbon dioxide in all phases;
- full understanding of the gas monitoring systems in use, both fixed and portable and the visual and audible alarms that can be generated;
- operating and maintenance instructions for the complete installation, see Figure 1;
- knowledge of the food freezing and chilling equipment exhaust system and requirement for introduction of fresh air exchanges;
- use and care of protective equipment and clothing;

- review of the emergency preparedness plan and its execution; and
- when to activate any emergency shutdown buttons that are incorporated in the system in the case of an incident that does not appear to have triggered an alarm.

6.2 Additional considerations in the preparedness plan

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 refrigerated liquefied 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. See Appendix A for more information on alarms.

Anyone suffering from lack of oxygen or carbon dioxide intoxication should be quickly moved to an area with fresh air if safe to do so. Do not enter oxygen deficient or carbon dioxide rich atmospheres without suitable breathing apparatus and training. Once in a safe area, if the victim is not breathing, artificial respiration or cardiopulmonary resuscitation (CPR) should be administered immediately.

The emergency preparedness plan shall identify the process and personnel responsible for site safety. The plan shall also provide the process by which control of re-entry to an evacuated area shall be implemented.

6.3 First aid for cold contact burns

Cold contact burns can occur with incorrect handling of product, equipment, and other uninsulated surfaces.

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 possible, the individual should be taken to a warm room, and the affected area should be placed in a warm water bath that has a temperature less than 40 °C (104 °F) (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.

Also see CGA P-12, *Guideline for Safe Handling of Cryogenic and Refrigerated Liquids* [7].

6.4 Personal protective equipment

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* [8].

Residual liquid nitrogen or solid carbon dioxide can remain in the food freezing and chilling equipment after opening. Personnel shall be aware of the hazards of contact with liquid nitrogen or solid carbon dioxide.

The operator should use a personal gas detector based on a risk assessment of the individual hazard levels. See Appendix A for more information.

6.4.1 Insulating gloves

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

6.4.2 Trousers

Trousers (full length pants) should not have cuffs and should not be tucked into boots or work shoes.

7 Tank and pipeline requirements

7.1 Storage supply systems

Nitrogen supply systems shall comply with NFPA 55, *Compressed Gases and Cryogenic Fluids Code*, CGA P-18, *Standard for Bulk Inert Gas Systems (an American National Standard)*, and any additional requirements contained in this standard [9, 10].

Carbon dioxide supply systems shall comply with NFPA 55, CGA G-6.1, *Standard for Insulated Liquid Carbon Dioxide Systems at Consumer Sites*, and any additional requirements contained in this standard [9, 11].

7.2 Liquid supply to the food freezing and chilling equipment

The overall requirement is to deliver the required flow of refrigerated liquefied 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.

7.3 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 freezing and chilling equipment taking into account the pressure drop in the pipeline. Tank pressure affects the safe operation of the system. Adjustments to tank pressure control shall only be done under the management of change, see EIGA Doc 51, *Management of change* [12].

For liquid nitrogen, tank pressure in the region of 1.5 bar to 4 bar (22 psi to 60 psi) is generally preferred. Pressure control of the liquid in the tank is required to maintain this pressure.

Pressure control systems shall be installed on the storage tank to control vessel pressure within the desired range during normal operation. Control of the tank pressure is important to ensure proper flows to the flows to the food freezing and chilling equipment beyond the capacity of the exhaust system.

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 (74 psi) (preferably more than 6.5 bar (94 psi) to avoid pipeline blockage due to dry ice. [2]Typical tank pressure is in the region of 14 bar to 21 bar (203 psi to 304 psi) but should be verified with the gas supplier. For more information see, EIGA Doc 164, *Safe Handling of Liquid Carbon Dioxide Containers that have Lost Pressure* [13].

Pressure relief devices are required on storage tanks. They are not pressure control devices and should only function during abnormal operation or emergencies. Distribution piping and food freezing and chilling equipment shall be considered when determining the size and set point for the cryogenic vessel

[2] psi, bar, and kPa shall indicate gauge pressure unless otherwise noted as (psia; bar, abs; and kPa, abs) for absolute pressure or (psid; bar, dif; and kPa, dif) for differential pressure. All kPa values are rounded off per CGA P-11, *Guideline for Metric Practice in the Compressed Gas Industry*.

pressure relief devices see 7.5 in CGA S-1.3, *Pressure Relief Device Standards-Part 3-Stationary Storage Containers for Compressed Gases*, and ISO 21013-3, *Cryogenic vessels — Pressure-relief accessories for cryogenic service — Part 3: Sizing and capacity determination* [14, 15].

7.4 Cryogenic pipeline design

A pipeline is designed to transfer a given flow rate of refrigerated liquefied gas from the storage to the food freezing and chilling equipment 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, low, and as short as practical.

Piping shall be secured to prevent unintended movement, routed to protect against impacts, or located in a non-vulnerable area.

Pipelines shall be clearly identified by durable labels identifying the gas and direction of flow. Text should be easily readable by operator. Labels should be placed in locations to warn personnel and be spaced a maximum of every 6 m (20 ft) along the pipeline [16].

Avoid unnecessary rises in the pipeline: For example, a 10 m (30 ft) liquid nitrogen rise leads to a vaporisation of up to 3.5% of the liquid (by weight), which is more than 50% by volume.

A gas vent, phase separator, or subcooler may be installed to improve liquid quality at the food freezing and chilling equipment. The gas from these devices shall be vented to an area without creating a new hazard.

Pipelines shall be pressure rated to accommodate the required pressure of the refrigerated liquefied 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 food freezing and chilling 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 unless otherwise demonstrated by risk assessment. Vents from relief valves shall be piped to an area where venting does not cause a hazard. Considerations for venting pressure relief devices outdoors shall be given based on local regulations. For more information, see CGA P-18 and EIGA SA 39, *Risk of Indoor Low-Pressure Cryogenic Liquid Applications* [10, 17]. Where risk assessment has determined or regulations require a gas monitoring system that activates an automatic shutoff valve, the gas monitoring system shall be installed to activate the automatic shutoff valve. The automatic shutoff valve shall be located to isolate the leak. The automatic shutoff valve shall be designed to be fail-close.

7.5 Piping insulation

Insulation is typically 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 food freezing and chilling equipment and some connections may 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 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 should be insulated or otherwise protected.

When liquid nitrogen pressure is low (less than 0.7 bar [10 psi]) 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* [18].

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 refrigerated liquefied gas; the outer pipe forms the vacuum jacket. In order to avoid differential thermal contraction between the inner and outer pipe._For liquid nitrogen supply, the inner or outer pipe includes expansion bellows (around one every 6 m [18 ft]) 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 pipe(s)lines are composed of:

- carrier pipe made of stainless steel or copper;
- insulation made of one or more layers of foam; and
- 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;
- install 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 food freezing and chilling equipment design

All food freezing and chilling equipment and machines shall meet regional requirements, for example the *Machinery Directive* in Europe and OSHA requirements in the United States [19, 5].

The design of the food freezing and chilling equipment shall be suitable to be in contact with refrigerated liquefied gases (low temperature).

The food freezing and chilling equipment shall be supplied with an operating manual. The gas supplier shall provide a SDS about the gas supplied.

8.2 Exhaust

All food freezing and chilling equipment shall be fitted with a dedicated exhaust system designed to remove the maximum volume of gas produced including dilution air, from the supply of refrigerated liquefied gas to the food freezing and chilling equipment.

The exhaust system capacity shall be determined by calculation of the maximum possible flow of refrigerated liquefied gas to the food freezing and chilling equipment, after consideration of but not limited to the tank pressure, liquid head, degree of sub-cool, valves and spray nozzle size and pipe diameter.

Exhaust blowers should be mounted in an exterior location. Any exhaust discharge to the outside of the building shall be directed to an area that does not cause a hazard.

If the exhaust blower is installed in an interior location, then the discharge shall be piped to an area that does not cause a hazard with further consideration of gas monitoring adjacent to the blower and the downstream exhaust piping.

If the exhaust fails to operate, refrigerated liquefied gas shall not be supplied to the food freezing and chilling equipment.

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 concentration falls below a safe level or carbon dioxide concentration rises above a safe level, then the exhaust system shall continue to run. The exhaust system should be operated at full capacity. The refrigerated liquefied gas supply to the food freezing and chilling equipment shall be shut off, if it is safe to do so. Additionally, consideration shall be given to interlocking the room monitor to the food freezing and chilling equipment automatic shutoff valve.

Gas monitoring systems are described in Appendix A.

8.3 Other essential safety requirements

If the food freezing and chilling equipment is opened during its operation, the refrigerated liquefied gas supply shall be shut off.

Food freezing and chilling equipment shall be supplied with a dedicated safety circuit that automatically shuts off the refrigerated liquefied gas supply if a deviation is detected in the food freezing and chilling equipment. One such method is low temperature detection.

All hazardous energy sources shall be isolated before servicing to prevent personnel exposure. If items (i.e., conveyor belts) shall operate when food freezing and chilling equipment is open, rotating components and pinch points shall be guarded to prevent exposure.

The food freezing and chilling equipment shall be equipped with at least two independent valves that provide the following combined functionality:

- A clearly labelled, lockable isolation shutoff valve for the refrigerated liquefied gas; and
- an automatic fail close shutoff valve for the refrigerated liquefied gas.

8.4 Boiling and splashing

Food freezing and chilling 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 food freezing and chilling equipment 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 refrigerated liquefied gas_flow requirement for the food freezing and chilling equipment shall be determined including a contingency to allow for variations in customer requirements, supply pipe system, and process control.

Tank pressure, valve size, or spray nozzle size shall not be changed except by a management of change; see EIGA Doc 51, *Management of Change* [12].

9.2 Gas monitoring system and ventilation of the room

Fresh air should be delivered into the production facility enabling the room exhaust system to operate correctly. Fresh air intakes shall not be closer than (3.1 m) 10 ft from any exhaust. This should be independent of any ventilation provided to the food freezing and chilling equipment exhaust system. The number of fresh air changes will depend upon the size of the room, number of food freezing and chilling equipment, exhaust fans on the food freezing and chilling equipment etc. The operating company shall ensure that a risk assessment has been performed and documented. The risk assessment shall include consideration for the room size, ventilation rate, and credible leak rate. Once carried out, the risk assessment should be used to inform the operating company's development of the emergency planning and control measures implemented to reach an acceptable level of safety. (see EIGA Doc 44) [6].

Gas monitoring systems for nitrogen applications measure critical oxygen levels. Gas monitoring systems for carbon dioxide shall measure concentrations of carbon dioxide. While oxygen can be depleted by carbon dioxide, the critical levels for harm are reached for carbon dioxide intoxication well before oxygen depletion becomes a concern.

An oxygen monitoring system shall be installed the area of nitrogen food freezing and chilling equipment installations and operated continuously regardless of whether or not the food freezing and chilling equipment 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. The alarm level shall comply with local regulations. Alarms shall invoke emergency procedures that include area evacuation. The emergency procedures should additionally include but are not limited to:

- initiate general evacuation;
- shut off the supply at the tank;
- shut off the supply at the food freezing and chilling equipment ;
- limit access to the affected areas;
- turn on augmented ventilation; and

- initiate safe shutdown of the production process.

The operator of the food freezing and chilling equipment shall consider a pre-alarm notification that would allow for assessment of the situation and appropriate action. Actions should be documented and included in training. Instructions should be posted in an accessible area.

A carbon dioxide monitoring system shall be installed in the area of carbon dioxide food freezing and chilling equipment installations and operated continuously regardless of whether or not the food freezing and chilling equipment is in use. The carbon dioxide monitors shall be installed, operated, calibrated and maintained as prescribed by its manufacturer. Carbon dioxide monitors shall have an audible and visual alarm. The alarm level shall comply with local regulations. Alarms shall invoke emergency procedures that include area evacuation. The emergency procedures should additionally include but are not limited to:

- initiate general evacuation;
- shut off the supply at the tank;
- shut off the supply at the food freezing and chilling equipment ;
- limit access to the affected areas;
- turn on augmented ventilation; and
- initiate safe shutdown of the production process.

The operator of the food freezing and chilling equipment shall consider a pre-alarm notification. Actions should be documented and included in training. Instructions should be posted in an accessible area.

Where room ventilation systems need to be augmented, gas detection shall activate the augmented ventilation system at the evacuation detection level.

The position of the oxygen/carbon dioxide sensors shall be selected to ensure that any measurement of oxygen depletion and increases in 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 [6].

9.3 Electrical connection

The operator of the food freezing and 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 bonding for all parts of the food freezing and chilling equipment shall be provided.

The electrical installation shall only be performed by authorised personnel.

Electrical equipment shall be installed in accordance with local regulations.

Standby power requirements shall be evaluated for:

- mechanical room ventilation;
- gas monitoring system; and
- associated life safety controls.

9.4 Exhaust system design and construction

The exhaust duct construction:

- shall be designed, together with the exhaust fan, to extract the maximum capacity of the refrigerated liquified gas that can be supplied to the food freezing and chilling equipment and dilution air 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 and if bends are essential, they should be long radius, for example 1 m (3 ft) 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 refrigerated liquified gas can be released into the building;

- shall ensure that the residual refrigerated liquified gases are exhausted to areas that will not cause a hazard and away from any air intakes and building openings;

- flow restrictions during operations should be minimized. For example, the implications of using slide gates or other control equipment;

- ;

- shall have a discharge duct on the outlet of the exhaust fan at least 1 m (3 ft) long to prevent contact with the fan impeller and follow local regulations;

- shall not include any fixed physical obstructions or barriers in the exhaust discharge duct that can plug with ice, for example mesh screens with fine or medium sized openings to protect against birds;

- cold surfaces should be protected from contact by personnel;

- should be able to be cleaned; and

- should preferably be vertical ducts rather than horizontal ducts. Where horizontal ducts are used, they should be angled at least 1 degree downwards to the exit for water drainage.

Icing of fans should be prevented. Options to prevent icing of fans include, but are not limited to, the use of:

- 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

- air ingress system to warm the exhaust above 4 °C (39 °F) and ensure the required room make-up air is available; or

- heater to raise the exhaust temperature with a set-up to prevent overheating of the system and an overheat cut-off device, although this may not be practical .

The exhaust fan shall have:

- a means of ensuring the exhaust fan is rotating; and
- a locally mounted disconnect switch, within the line of sight of the exhaust fan, to prevent or ensure that it cannot be started during maintenance.

9.5 Other responsibilities of the installer

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

Food freezing and chilling equipment shall be installed in accordance with the manufacturer's instructions. If installation requires any modifications to the food freezing and chilling equipment, they shall be carried out in consultation with the manufacturer and without compromising safety or invalidating any food freezing and chilling equipment certification and shall follow the management of change procedure.

The cryogenic pipelines 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 food freezing and chilling equipment shall only be used if all services are connected and operational as defined by the manufacturer.

Operators and management shall be trained in the operation of the food freezing and chilling equipment and in the hazards of the refrigerated liquefied gas used. It should be recorded that training has been given.

A commissioning inspection for operational readiness should be conducted by competent personnel before handover and recorded to ensure that the safety, technical, equipment, and business requirements of the manufacturer, supplier, and customer are met.

10 Operating company responsibilities and continuing operation of the food freezing and chilling equipment

The operating company shall be familiar with all the safety and auxiliary requirements of the food freezing and chilling equipment. The operating company shall have an emergency preparedness plan in place and all affected personnel trained to carry it out.

Operation should not be at production rates greater than that specified by the food freezing and chilling equipment manufacturer and/or gas supplier nor should operating temperature be lower than that specified. The minimum temperature set points according to the operating instructions shall not be changed.

The operating company shall ensure that all guards and all life safety controls are in place and all interlocks are operational at all times that the food freezing and chilling 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 food freezing and chilling equipment shall be used only with liquid nitrogen and carbon dioxide food freezing and chilling equipment shall be used only with carbon dioxide. If injection systems for both refrigerated liquefied gases are installed on the food freezing and chilling equipment, simultaneous operation of both injections shall not be used.

Operators shall be aware of the hazards of damaged or failed food freezing and chilling equipment. In the case of excessive escaping gas, they shall stop the food freezing and chilling equipment, immediately seek assistance, and manually turn off the refrigerated liquefied gas to isolate and investigate the source of the issue.

Untrained personnel shall not use the food freezing and chilling equipment. Installation, repair, servicing and maintenance works shall only be carried out by trained and qualified personnel.

Component replacements shall be in accordance with the specifications in the maintenance manual or as agreed upon with the food freezing and chilling equipment manufacturer or the gas supplier and shall follow the management of change procedure.

The food freezing and chilling equipment should not be relocated without prior agreement from the manufacturer or the gas supplier and shall follow the management of change procedure.

The operating company should consult with the gas supplier prior to consideration of any significant changes in building layout that could affect the safe operation of the food freezing and chilling equipment (for example, changes in wall location). In any instance, the operating company shall ensure a risk assessment be carried out and shall follow the management of change procedure.

10.1 Operating company training for the event of refrigerated liquefied gas leakage

The operating company is responsible for the safe operation of their facility. In the event of a low oxygen level or high carbon dioxide level in the facility the room ventilation should be increased, see 9.2, and it is essential that:

- the room is immediately evacuated; and
- the supply system of the refrigerated liquefied gas is isolated manually if safe to do so or automatically shutting the supply valve(s).

If the reason for the escape of the refrigerated liquefied gas cannot be determined or resolved, the gas supplier and/ or the food freezing and chilling equipment manufacturer shall be informed at once.

Under no circumstances shall the food freezing and chilling equipment continue in operation unless the issue has been identified and repaired.

After the supply system is secured per the previous bullet point instructions in 10.1, if the gas detection or gas monitoring system is suspected to be malfunctioning, entry is only allowed after it has been validated to be safe. If it is believed that the gas detection or gas monitoring system is malfunctioning, entry is only allowed after verification with an alternate atmospheric monitor.

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, which can result in death or serious injury. An absorptive gas mask will not prevent asphyxiation.*

For additional guidance on PPE, see EIGA Doc 136 [8].

10.2 Food freezing and chilling equipment operation

The food freezing and chilling equipment shall be operated (starting, running, shut down) strictly in accordance with the manufacturer’s operating instructions. It shall be ensured that at every shutdown procedure (regular shutdown at end of production or at interruptions, emergency shutdown, automatic or manual shutdown) all supplied gas to the food freezing and chilling equipment is extracted by the exhaust system so that a fresh air atmosphere exists inside the food freezing and chilling equipment before switching off the exhaust. This requires a delay time between stopping the injection of refrigerated liquefied gas and shutting off the exhaust system. Special attention is required, if refrigerated liquefied nitrogen or solid carbon dioxide is collected inside the food freezing and chilling equipment. In these cases, the exhaust system shall run until all liquid or solid is transferred into its gaseous state and extracted.

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

Cleaning the food freezing and chilling equipment can expose the operator to hazards of cold and/or moving parts. Procedures shall be developed and implemented to eliminate or guard exposed moving parts and other energy sources when the food freezing and chilling equipment is open for cleaning.

10.3 Maintenance, inspection and repair

The operating company of the food freezing and chilling equipment and ancillary equipment such as gas monitoring system and exhaust system shall be responsible for its safe operation. Maintenance and inspection intervals recommended by the manufacturer in the user's manual shall be followed.

Maintenance, inspection, modifications, and repairs shall only be carried out by specifically trained personnel. When in doubt, consult the gas supplier or the manufacturer of the food freezing and chilling equipment. If required by regional requirements, a work permit system should be in place, see EIGA Doc 40, *Work permit systems* [20].

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

When working on the food freezing and chilling equipment, the main electrical power switch should 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.

The gas detectors shall be protected during cleaning and maintenance operations.

10.4 Disposal

Equipment shall be disposed of responsibly and recycled according to national and local regulations.

Until disposal, equipment that is no longer in operation shall be disconnected from all services and stored safely.

11 References

Unless otherwise specified, the latest edition shall apply.

[1] CGA P-9, *The Inert Gases, Argon, Nitrogen and Helium*, Compressed Gas Association, Inc. www.cganet.com

[2] EIGA Doc 23, *Safety Training of Employees,* European Industrial Gases Association. www.eiga.eu

[3] CGA G-6, *Carbon Dioxide,* Compressed Gas Association, Inc. www.cganet.com

[4] EIGA SI 24, *Carbon Dioxide Physiological Hazards - "Not just an Asphyxiant!"* European Industrial Gases Association, www.eiga.eu

[5] *Code of Federal Regulations*, Title 29 (Labor) Part 1910, U.S. Government Printing Office. www.gpo.gov

[6] EIGA Doc 44, *Hazards of Oxygen-Deficient Atmospheres,* European Industrial Gases Association. www.eiga.eu

NOTE—This publication is part of an international harmonisation programme for industry standards. The technical content of each regional document is identical, except for regional regulatory requirements. See the referenced document preface for a list of harmonized regional references.

[7] CGA P-12, *Guideline for Safe Handling of Cryogenic and Refrigerated Liquids*, Compressed Gas Association, Inc. www.cganet.com

[8] EIGA Doc 136, *Selection of Personal Protective Equipment*, European Industrial Gases Association. www.eiga.eu

NOTE—This publication is part of an international harmonisation programme for industry standards. The technical content of each regional document is identical, except for regional regulatory requirements. See the referenced document preface for a list of harmonized regional references.

[9] NFPA 55, *Compressed Gases and Cryogenic Fluids Code*, National Fire Protection Association, www.nfpa.org

[10] CGA P-18, *Standard for Bulk Inert Gas Systems (an American National Standard),* Compressed Gas Association, Inc. www.cganet.com

[11] CGA G-6.1, *Standard for Insulated Liquid Carbon Dioxide Systems at Consumer Sites*, Compressed Gas Association, www.cganet.com

[12] EIGA Doc 51, *Management of change*, www.eiga.eu.

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

NOTE—This publication is part of an international harmonisation programme for industry standards. The technical content of each regional document is identical, except for regional regulatory requirements. See the referenced document preface for a list of harmonized regional references.

[14] CGA S-1.3, *Pressure Relief Device Standards-Part 3-Stationary Storage Containers for Compressed Gases*, Compressed Gas Association, Inc. www.cganet.com

[15] ISO 21013-3, *Cryogenic vessels — Pressure-relief accessories for cryogenic service — Part 3: Sizing and capacity determination*, International Organization for Standardization, www.iso.org

[16] ANSI/ASME A13.1, *Scheme for the Identification of Piping Systems, ASME International. www.asme.org*

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

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

NOTE—This publication is part of an international harmonisation programme for industry standards. The technical content of each regional document is identical, except for regional regulatory requirements. See the referenced document preface for a list of harmonized regional references.

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

[20] EIGA Doc 40, *Work permit systems*, www.eiga.eu.

[21] NFPA 110, *Standard for Emergency and Standby Power Systems*, National Fire Protection Association. www.nfpa.org

[22] NFPA 111, *Standard on Stored Electrical Energy Emergency and Standby Power Systems*, National Fire Protection Association. www.nfpa.org

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 monitoring and related systems for nitrogen and carbon dioxide applications (Normative)

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

This publication does not cover the use of indoor or outdoor air quality monitors that measure the level of common air pollutants that are not hazardous gases. These air quality monitors shall not be used in applications where low oxygen levels and or high carbon dioxide levels may occur.

A.1 Fundamentals

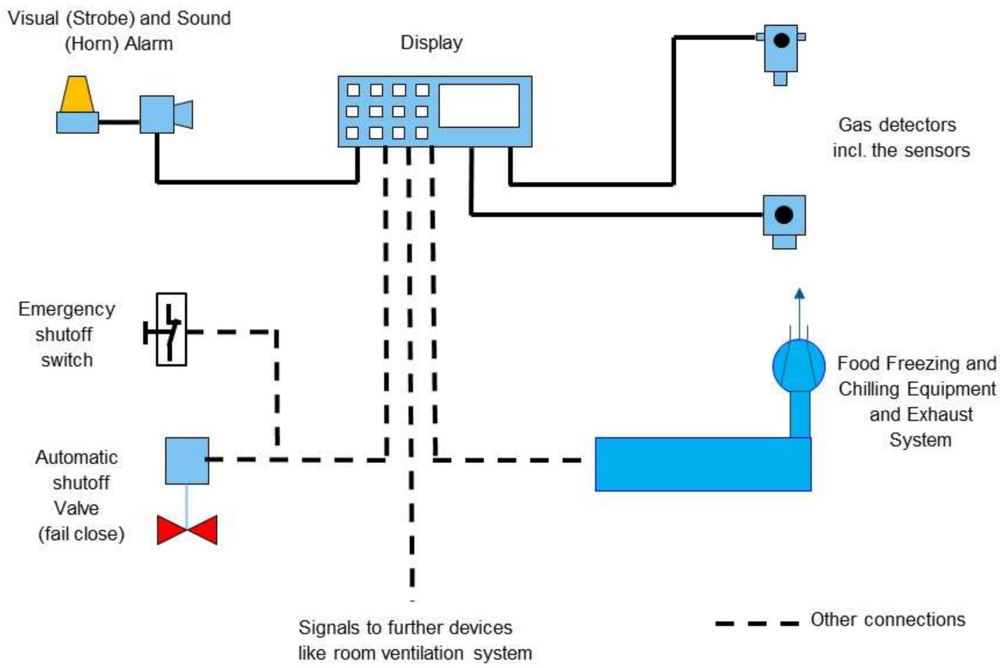
The purpose of this appendix is to inform and to recommend methods for implementation, use, maintenance and management of gas monitoring systems designed for the protection of workers where asphyxiation or intoxication can occur. It does not replace recommendations or instructions provided by gas monitoring systems manufacturer's/installer's or specific country regulation and does not replace operating company food freezing and chilling 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 oxygen. In addition to asphyxiation, carbon dioxide, can have intoxicating physiological effects – see 5.3.

A.3 Monitoring

The use of a gas monitoring system to detect leaks from, or failures of, the supply system and the food freezing and chilling equipment is essential. See Figure A1 and Table A1.



NOTE—Other configurations of a gas monitoring system may be available.

Figure A1—Example of gas monitoring system and other associated components

Table A1—Description of gas monitoring components

Part	Description	Typical Location as Prescribed
Components of gas monitoring system		
Power supply	Secured wall plug or hard-wired power from the buildings electrical system	Connected to the gas detector at the point of installation.
Sample inlet	The portion of the monitor that takes a sample of atmospheric air.	Install where leak accumulations are most likely, such as at use points and piping connections.
Gas detector	The component that contains the sensor(s) for the specific gas(es) to be measured.	Located where gases are expected to accumulate.
Display	The visual indicator of the gas detector's operation. It displays ppm or percent concentration of the gas being monitored. May also display temperature, barometric pressure, and LEDs of devices power and alarm statuses.	Connected to the detector and located at a position accessible to the operators.
Horn	An audible alarm signal triggered by the gas detector.	Inside the area being monitored and in any area with interior ingress to the monitored area.
Strobe	A visual alarm signal triggered by the gas detector.	Inside the area being monitored and in any area with interior ingress the monitored area.
Other associated components		
Automatic shutoff valve	A fail-close automatic shutoff valve triggered by the gas detector and also independently by an emergency shutoff switch.	Located in a position to isolate the leak.
Emergency shutoff switch	A marked switch provided to trigger the automatic emergency shutoff valve.	Marked with a sign and easily accessible at a mounted location in the use area.
Room exhaust System	Continuous mechanical exhaust ventilation during occupancy and augmented mechanical exhaust triggered by the gas detector at the evacuation limit.	Inlets placed to the exhaust system located at a "Keep Clear" area .3 meters (12 inches) from the floor.
Standby power or emergency power supply (if used)	Standby power supply provided to power the following devices in the event of a power outage: • Gas detector; • Alarm signals; and • Augmented mechanical exhaust ventilation. For a minimum of 90 minutes or otherwise as approved by the local authority having jurisdiction (AHJ).	Standby power provided in accordance with recognized national or local standards (in North America NFPA 110 and NFPA 111 [21,22].

A.4 Gas monitoring system components

A.4.1 Gas detector

Gas detectors shall have:

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

- water/humidity protection.

For carbon dioxide food freezing and chilling equipment systems, a carbon dioxide detector is required. For nitrogen cryogenic food freezing and chilling equipment systems, an oxygen detector to measure oxygen depletion is required. An oxygen detector is not an alternative for a carbon dioxide detector.

The gas detectors shall be protected during cleaning and maintenance operations. The use of personal gas detection should be in effect during cleaning operation when fixed gas monitoring has been temporarily disabled. Contact the gas monitoring manufacturer for details about its use during cleaning operations.

A.4.2 Signage

Proper signage, including manufacturer's signage, related to gas detection shall be posted per code and local regulatory requirements.

A.4.3 Choice and implementation of gas detector(s)

The following criteria shall be considered when choosing gas detectors for the monitoring systems:

- detector positioning (location/height);
- number of detectors;
- temperature of working area;
- barometric pressure compensation;
- humidity, including ingress protection;
- electrical classification of area;
- 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.4.4 Gas monitoring alarm settings

Setpoints shall conform with local regulations. Where no local regulation exists, Table A2 and Table A3 offer guidance on alarm settings:

Table A2—Oxygen monitoring

	Description	**Enunciation**	**Common setpoints**
Notification threshold	At a level prior to alarm to allow for assessment and potential correction	Visual notification to persons responsible for the	North America: 20% Europe: 19.5%

		operation. Audible notification is recommended	
Alarm threshold	At a level consistent with local regulation and acceptable to the AHJ	Audible and Visual Alarm to person that could be affected by the emergency. Alarms shall initiate the emergency plan that shall include at a minimum area evacuation.	North America: 19.5% Europe: 18%

NOTE—Local regulations can define different exposure levels.

Table A3—Carbon dioxide monitoring

	Description	Enunciation	Common Setpoints
Notification threshold	At a level prior to alarm to allow for assessment and potential correction	Visual notification to persons responsible for the operation. Audible notification is recommended	North America: 0.5% instantaneous-0.5% 8hr TWA (5 000 ppm) Europe: 0.5% instantaneous (5 000 ppm)
Alarm Threshold	At a level consistent with local regulation and acceptable to the AHJ	Audible and Visual Alarm to person that could be affected by the emergency. Alarms shall initiate the emergency plan that shall include at a minimum area evacuation.	North America: 0.5% 8hr TWA(5 000 ppm) 3% 15 min TWA (30000 ppm) Europe: 1.5% (15 000 ppm)

NOTE—Local regulations can define different exposure levels.

Main alarm (evacuation threshold):

- shall trigger an audible and visual alarm;
- shall initiate the emergency preparedness plan and proceed to evacuate the area;
- should automatically close refrigerated liquefied gas supply to the food freezing and chilling equipment;
- should increase the food freezing and chilling equipment exhaust to maximum possible capacity; and
- should increase ventilation of the room where required.

The operator of the food freezing and chilling equipment shall ensure that a risk assessment has been completed. The risk assessment shall determine the relevant actions to ensure worker safety and make sure the work area atmosphere is safe, such as:

- ventilation of the room;
- worker evacuation; and/or
- stopping of any food freezing and chilling equipment in use except its exhaust system.

When a pre-alarm notification is used, an action plan should be prepared, documented, personnel trained and responsibilities assigned. The following actions should 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 food freezing and chilling equipment is set-up correctly.

An action plan for evacuation shall be incorporated into the emergency preparedness plan that is initiated at the alarm, and should include:

- process responsibilities;
- training and practice drills;
- emergency procedures, i.e., close valve(s) to isolate any leaks, calling the emergency responders, etc;
- safe shutdown of the food freezing and chilling equipment;
- facility layout showing assembly locations and evacuation routes;
- head count register;
- re-entry plan; and
- first aid.

A.4.5 Maintenance of the gas monitoring system

See specific manufacturer's instructions for the maintenance of the device including recommendations for the cleaning operations of the gas monitoring system.

A.4.6 Power outage

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

When the risk assessment and emergency plan demand continuous power, an electrical backup supply to the system is recommended. The backup supply is recommended to provide power for 90 minutes or as dictated by local regulations. The components that need to be maintained with power may include the following:

- gas monitoring system, alarm signals and associated controls; and
- augmented mechanical room exhaust ventilation.

A.4.7 Risk assessment

The operating company shall ensure a risk assessment is performed. Refer to local regulations to ensure compliance with safety requirements.

The following parameters shall be considered but not limited to:

- 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;
- refrigerated liquefied gas flow and profiles (start-up, normal and peak);
- use of the food freezing and chilling equipment (permanent and number of shifts); and

- temperature and humidity of the work area.

Qualified personnel should be responsible for managing the risk assessment.

A.5 Portable monitoring devices

In addition to the fixed gas detection and monitoring systems, there are portable systems that are not a substitute for, but which provide data or personnel protection in areas where gas levels become unsafe or a fixed gas detection system might not be functioning. Portable systems can be divided into two groups, (1) personal wearable devices and (2) non-wearable devices. These portable systems should be used in accordance with manufacturer's instructions. The components of the portable system are similar to a fixed system.

A.5.1 Wearable devices

These devices are designed to be worn by an individual. These devices are designed to give wearers advanced notice of such unsafe levels. These devices are internally powered and include a detector assembly and appropriate alarms. These devices may send data to a remote display. Wearable devices should be checked for functionality by the operating company at regular intervals per manufacturer's recommendations.

A.5.2 Non-wearable devices

These portable devices are designed to measure gas levels and give personnel advanced notice of unsafe levels prior to entering an area. These devices are internally powered and will include a detector assembly and generate signals to a remote display. These devices may generate appropriate audible and visual alarms both locally and to remote displays. Non-wearable devices should be checked for functionality by the operating company at regular intervals per manufacturer's recommendations.