



STATIC VACUUM INSULATED CRYOGENIC VESSELS OPERATION AND INSPECTION

Doc 224/20

Revision of Doc 224/19

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STATIC VACUUM INSULATED CRYOGENIC VESSELS - OPERATION AND INSPECTION

Prepared by WG-6 Cryogenic Vessels

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Amendments to 224/19

Section	Change
6.1, 6.9	Change references to Section 5 and Section 9
Table 2	Correction of references and removal of shell and tube vaporisers
9.4.3	Removal of incorrect reference
9.4.4	Correction of section titles

NOTE Technical changes from the previous edition are underlined

1. Introduction

Static vacuum insulated cryogenic vessels are used for the storage of cryogenic (refrigerated liquefied) industrial and medical gases and are part of the customer's gas supply system.

Static vacuum insulated cryogenic vessels are installed at a customer's premises and are normally owned by a gas company and filled using road tank vehicles.

Vessels used for the storage of cryogenic liquids consist of an inner pressure vessel, insulation, an outer jacket (not required to be a pressure vessel) and the auxiliary equipment. The space between the inner vessel and the outer jacket (annular space) is under vacuum.

Refrigerated liquefied gases including carbon dioxide, can be stored in a vessel suitable for cryogenic liquids, or in a vessel that consists of a pressure vessel with foam insulation.

The gases are supplied in a liquid or gaseous phase to the customer's point of use. The liquid or gas flow is normally achieved by pressure difference where the inner vessel and its contents are at a higher pressure than the customer's point of use. To achieve this, the vessels are fitted with a vaporizer, normally called the pressure build up unit and a pressure regulator. The pressure cycling operating range of static cryogenic vessels is limited, see EN 13458-2, *Cryogenic vessels. Static vacuum insulated vessels. Design, fabrication, inspection and testing* [1].¹

The properties of cryogenic gases require precautions to be taken and safety rules to be followed. Ignoring the precautions and safety rules can lead to accidents.

Cryogenic vessels shall be submitted to periodic inspections and testing.

The Pressure Equipment Directive (PED) [2] covers design, manufacturing, placing on the market and commissioning of the equipment. It does not specify the requirements for the in-service inspection of pressure equipment.

Because periodic inspection is not covered by the PED, local regulations apply in this context regarding inspection intervals. These regulations for periodic in-service inspection and testing of pressure equipment vary considerably between European Countries (for similar vessels/similar gas service).

EN ISO 21009-2 *Cryogenic vessels – Static vacuum insulated vessels – Part 2: Operational requirements* gives recommendations for the interval for the periodic inspection of cryogenic vessels [3].

Static cryogenic vessels are replaced or relocated from time to time because the gas consumption pattern of the customer changes and a different size of vessel required or the contract between gas-company and customer has ended. Industry experience shows that a cryogenic vessel is relocated every 6 years on average.

This publication is intended to be used as guidance for persons involved in the operation, maintenance and inspections of cryogenic liquid storage installations.

Local regulations take precedence over the recommendations in this publication.

This publication replaces EIGA Documents, Doc 114, *Operation of Static Cryogenic Vessels*, Doc 115 *Storage of Cryogenic Gases at Users' Premises* and Doc 119 *Periodic Inspection of Static Cryogenic Vessels* [4,5,6].

2. Scope

This publication describes the operation and required inspections of static vacuum insulated cryogenic vessels at user premises, designed for a maximum allowable working pressure (MAWP) of more than

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

0.5 bar. This is in accordance with the definition of pressure equipment in the Pressure Equipment Directive [2].

It may also be used as a guideline for vessels designed for a maximum allowable working pressure of less than 0.5 bar.

It covers installations of vessels with an individual water capacity up to 125 000 litres.

For installations in excess of 125 000 litres, this publication can also be used as guidance. In this situation local regulations can require different safety distances.

Subjects covered in this publication include:

- general information on cryogenic equipment;
- layout and design features for installation;
- putting into service / commissioning (documents, installation, checking);
- maintenance and repair, taking out of service;
- inspections (daily, filling and periodic); and
- training of personnel.

The cryogenic vessels described in this publication are used for the storage of for liquid oxygen, nitrogen argon and helium. The principles are also applicable for other cryogenic gases including carbon dioxide, nitrous oxide and flammable gases. Toxic gas service is excluded from this publication. This publication does not address the vessels used in the production of cryogenic gases or vessels used for transport, which are covered by the Transportable Pressure Equipment Directive (TPED) or transport of dangerous goods regulations [7].

This publication applies to new installations and may be used as guidance for existing installations.

For liquid hydrogen installations see EIGA Doc 06 *Safety in Storage, Handling and Distribution of Liquid Hydrogen* and for cryogenic ethylene see EIGA Doc 208 *Safety in Storage, Handling and Distribution of Cryogenic Ethylene* [8, 9].

This publication does not address equipment connected to the vessel, such as vaporisers, gas mixers and applications equipment.

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 Accessories

Components to the structural/basic elements of the vessel and piping, required to make the cryogenic vessel a functional whole, including for example regulators, valves, safety devices, indicators/gauges (pressure, temperature, flow), couplings and pressure build-up unit.

NOTE: This is also referred to as auxiliary equipment within the industry.

NOTE: In some countries, the process heat exchangers are considered as accessories.

3.2.2 Authorised representative

Any natural or legal person established within the Union who has received a written mandate from a manufacturer to act on his behalf in relation to specified tasks.

3.2.3 Competent person

Individual who is trained, qualified and authorised by the vessel owner for the intended task.

3.2.4 Confined area

Area where gas accumulation can occur due to lack of ventilation.

NOTE: This includes pits, ducts, walls in close proximity, an area with no roof bordered by three or more walls. A risk assessment could be required to determine if an area is considered as confined.

3.2.5 Indoor

Enclosed area in a building or structure that is bordered by a floor, a roof/ceiling and three or more walls. This area can be entered and left via a door, rolling door, hatches or gates.

3.2.6 Inner vessel

Pressure vessel intended to contain the cryogenic fluid.

3.2.7 Interspace

Volume between the inner vessel and outer jacket of the cryogenic vessel.

This volume is filled with isolating material, for example perlite, and evacuated to minimise heat transfer. Alternative/additional insulating techniques can be used.

NOTE: Interspace is also referred to as annular space

3.2.8 Outer jacket

Air tight enclosure which supports the inner vessel, holds the insulation and enables the vacuum to be established.

NOTE: This is not required to be a pressure vessel.

3.2.9 Placing on the market

According to PED means first making available of pressure equipment or assemblies on the Union market [5].

3.2.10 Pressure

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

3.2.11 Pressure relief valves

Safety device designed to open at a pre-set pressure and discharge fluid until the pressure drops to a predetermined level, for example to protect a cryogenic vessel.

3.2.12 Putting into service/commissioning

Operation and activities by which a vessel is prepared for service, including the first use. It applies to either a new vessel used for the first time or a vessel which has been taken out of service and brought back into service.

3.2.13 Static vacuum insulated cryogenic vessel

Thermally insulated vessel intended for use with cryogenic fluids, consisting of an inner vessel, an outer jacket, the associated piping system and auxiliary equipment, forming a functional whole, ready to put into service.

NOTE: This vessel is intended for on-site use only.

3.2.14 Thermal relief valve

Safety device designed to relieve excess pressure in a section of closed piping, for example between isolation valves.

3.2.15 User

User is considered to be the customer who uses the product contained in the cryogenic vessel, for their process.

4. General information

4.1 Cryogenic gases

Gaseous oxygen, nitrogen, helium and argon are colourless, odourless and tasteless. They are non-corrosive, non-toxic and non-flammable gases. Nitrogen, helium and argon are asphyxiants. Oxygen is not a flammable gas but is oxidising and accelerates combustion at high concentrations. Oxygen is slightly denser than air. Breathing pure oxygen at atmospheric pressure is not dangerous although exposure for several hours can cause temporary functional disorders to the lungs.

4.2 Properties of nitrogen, oxygen, argon and helium

Table 1 gives some physical properties of nitrogen, oxygen argon and helium.

Table 1 Properties of nitrogen, oxygen, argon and helium

		Nitrogen	Oxygen	Argon	Helium
Content in air	Vol %	78.1	21	0.9	5.10 ⁻⁴
Gas density at 1.013 bar abs and 15°C	kg/m ³	1.19	1.35	1.69	0.169
Boiling temperature at 1.013 bar abs	°C	-196	-183	-186	-269
Liquid density at 1.013 bar abs and boiling temperature	kg/m ³	808.5	1141	1394	125
Gas Volume (@1.013 bar abs and 15°C) of the vaporized liquid (@ boiling point and 1.013 bar abs)	ratio $\rho_{\text{liquid}}/\rho_{\text{gas}}$	682 (808.5/1.185)	843 (1141/1.354)	824 (1394/1.691)	740 (125/0.169)

4.3 Precautions

The properties of cryogenic gases require that a number of specific precautions are taken.

4.3.1 Oxygen deficiency or enrichment of the atmosphere

The atmosphere normally contains 21% by volume of oxygen. Enrichment, for example to only 23% can give rise to a significant increase in the rate of combustion. Many materials including some common metals which are not flammable in air, can burn in oxygen, when ignited. Further information on the hazards from oxygen enrichment or deficiency can be found in EIGA Doc 04 *Fire Hazards of Oxygen and Oxygen Enriched Atmospheres*, EIGA Doc. 44 *Hazards of Inert Gases and Oxygen Depletion* and EIGA SL 02 *Dangers of Asphyxiation* [10,11,12].

Ventilation shall always be provided in places where liquid cryogenic gases are stored and/or transferred.

4.3.2 Cryogenic burns

Severe damage to the skin can be caused by contact with liquid cryogenic gases, and cold gases or with uninsulated pipes or receptacles containing liquid cryogenic gases. For this reason, gloves and eye protection shall be worn when handling equipment in liquid cryogenic gases service.

4.3.3 Air condensation (air liquefaction) pipework

During the filling with or withdrawal of liquid helium ambient air can condense (air liquefaction) on exposed un-insulated pipework and equipment, causing local oxygen enrichment, though usually this pipework is vacuum insulated. Therefore, measures shall be taken to account for the oxygen rich air condensation, for example, insulation with compatible materials or catch trays to vaporize the liquid.

4.3.4 Air condensation on inner vessel shell

For liquid helium vessels it shall be taken into account that in case of the loss of interspace vacuum air will condense on the outside of the inner vessel. This effect shall be considered when determining the pressure relief device sizing and when selecting insulation material used in the interspace.

NOTE: For liquid nitrogen operating at less than 0.5 bar vapour pressure, there is a risk of an oxygen rich environment due to air condensation.

4.4 Cryogenic equipment

4.4.1 Cryogenic vessel

Static vacuum insulated cryogenic vessels at users premises usually have a capacity of less than 125 000 litres. The inner vessel contains the liquefied gas under pressure and represents the actual pressure vessel, and is designed to withstand internal pressure, external vacuum and cryogenic temperatures. The inner vessel is surrounded by an enclosure in the form of a jacket within which a vacuum is maintained to achieve the necessary degree of insulation between the surface of the jacket and the enclosed vessel. The inner vessel is of simple cylindrical shape with dished or spherical heads. The inter space is filled with an insulating material. The outer jacket acts as insulation containment and the support structure for the inner vessel and is manufactured from carbon steel, and is usually not classified as a pressure vessel. In the event the inner vessel leaks the pressure relief device placed in the outer jacket operates to avoid damage. These vessels are installed at customer premises and together with other equipment are known as cold converters, or customer stations. For the purposes of this publication they are referred to as vacuum insulated cryogenic vessels.

Vacuum insulated cryogenic vessels usually operate working pressures that vary by a relatively small amount with only very occasional total depressurisation and re-pressurisation.

The inner vessel temperature remains almost constant during operation. Only small external loads are applied to the inner vessel from pipework as it is designed to avoid stresses occurring due to contraction or expansion on cool-down or warm-up. Supports and anchor points from the inner vessel to the outer jacket are designed to provide minimum heat transfer.

The loss of vacuum in the interspace is not normally a safety problem. If vacuum loss occurs during tank operation the insulation material is sufficient to keep the vessel contents evaporation rate within the inner vessel relief valves normal rating. Any loss of vacuum should be investigated as this could affect the integrity of the vessel and support system.

4.4.2 Cryogenic vaporisers

Cryogenic vaporisers are of tubular construction and transfer heat to obtain vaporisation of the cryogenic liquid using ambient air, water, steam or other hot liquids or gases

The most commonly used vaporisers are ambient air vaporisers comprising tube bundles or tube assemblies of aluminium alloy, copper or stainless-steel tubes, equipped with fins for improved heat transfer. External visual inspections are possible at accessible parts of the assembly.

In water immersed vaporisers the tubes are manufactured in corrosion resistant materials such as copper or austenitic stainless steel, but depending on the quality of the water, corrosion attack from the water side is possible. External visual inspection is possible by emptying the water bath, but internal inspection is limited due to the small tubular construction.

The operating pressure can be up to 40 bar but is usually much less. External loads shall be considered such as ice, snow, wind and, vibrations.

Some mechanical problems due to vibrations have occurred in service but these have only involved operational inconvenience, not safety, and can be detected by carrying out visual external examinations.

4.5 Materials

The materials of construction used for cryogenic vessels are, austenitic stainless steel, and other suitable steels containing nickel for the inner vessel and carbon steel for the outer jacket.

The materials for vaporisers and accessories are aluminium and copper and their alloys.

These materials are resistant to brittle fracture at low operating temperatures and quick extension of cracking and have been proven over many years of service. For carbon dioxide and nitrous oxide, with their higher operating temperatures, carbon steels are sometimes used and their resistance to brittle fracture shall be considered. These materials are also more resistant to corrosion than other materials used for vessels in general service.

Mechanical tensile strength properties of the above materials are enhanced at cryogenic operating conditions. The enhanced strength is not always taken into account for the stress calculation of wall thickness according to the pressure vessels codes. This provides an additional safety margin at the operating condition, for example 4.5% Mg aluminium alloy increases in strength by 9% (0.2% proof) or 49% (UTS), 9% nickel steel increases in strength by 38% (0.2% proof) or 60% (UTS), and austenitic stainless steel increases in strength by 10% to 70% (0.2% proof) or 120% to 150% (UTS) from values at +20°C to -196°C.

4.6 Construction

Cryogenic vessels operate at pressures at or above atmospheric pressure and are designed, manufactured, tested and inspected to pressure vessels standards.

Vacuum insulated vessels are manufactured and tested to ensure and maintain a vacuum of typically less than 0.05 mbara for multilayer insulation and 0.2 mbara for perlite insulation in the interspace between the outer shell and the inner vessel.

Vessel components, piping and fittings, are connected by welding or brazing. Flanged and screwed connections are eliminated as far as possible to avoid leaks of gas or liquid which if they occurred at any connection could damage the vessel foundations or insulation containment. In the case of vacuum insulated vessels, such leaks would badly affect the properties of the insulation. This is one reason why cryogenic vessels normally have no manholes as access into the inner vessel, and, have the final seams welded from the outside. This practice is in accordance with the codes and is approved by pressure vessel approval authorities.

4.7 Corrosion

The wall of the inner vessel in contact with the cryogenic fluid is not subject to corrosion as the cryogenic fluids are dry and clean. Corrosion is non-existent at such low temperatures. The outside wall of the inner vessel is protected from corrosion by the vacuum in the interspace.

4.8 Insulation

Due to the extremely low temperatures specific types of insulation are necessary. This usually consists of either perlite or a wound fibre/aluminium foil, in the inter space, along with the vacuum. Typically, the insulation thickness is 0.2 metres, though could be less for tanks that use multilayer insulation.

4.9 Cleanliness

The need for very high standards of cleanliness for equipment used in oxygen service requires particular attention during manufacture and construction. This includes taking care during pressure testing by using clean media (gases or water). Experience shows that the service conditions, during normal operation, ensure that the equipment retains its required standard of cleanliness.

Care shall be taken when for example replacing a valve to not contaminate the inner vessel by the introduction of foreign matter or moisture. As far as possible a positive pressure shall be maintained in the inner vessel. Guidance for oxygen cleaning can be found in EIGA Doc 33 [13]. Oxygen clean

inspection standards can be found in EN 12300 *Cryogenic vessels - Cleanliness for cryogenic service* [14].

4.10 Failure mechanisms cryogenic vessels

Failure mechanisms that potentially could affect the integrity of the pressure vessel include:

4.10.1 Corrosion

This does not occur in service due to the materials of construction and the non-reactive properties of the cryogenic fluids that they are in contact with.

4.10.2 Fatigue

These vessels are subjected to a very low number and rate of pressure cycles due to the:

- method of filling and operation; and
- design of the vessel itself is based on a simple, balloon type inner vessel with a limited number of nozzles and attachments.

4.10.3 Erosion

There is no known erosion mechanism present in this type of vessel.

In most countries, these features and the particular operating conditions have been recognised and the required periodic testing and inspection has been adjusted accordingly.

Numerous internal inspections of cryogenic vessels have been carried out by EIGA Member Companies and in all cases no defects or evidence of deterioration compared to the new conditions have been reported.

There are also few problems relating to these types of vessels in service. The inspection reports and incident reports support the view that the current design features are satisfactory.

4.11 Specific requirements

4.11.1 Oil, grease, combustible material and other foreign matter

Most oils, grease and organic materials constitute a fire or explosion hazard in oxygen enriched atmospheres and shall on no account be used on equipment which is intended for oxygen service. Only materials acceptable for oxygen service application shall be used.

Before putting equipment into service with oxygen, either for the first time or following maintenance, it is essential that all surfaces that could come into contact with an oxygen enriched environment are clean for oxygen service, which means: dry and free from any loose or virtually loose constituents, such as slag, rust, weld residues, blasting materials and entirely free from hydrocarbons or other materials incompatible with oxygen.

The maintenance and assembly of equipment for oxygen shall be carried out under clean, oil free conditions. All tools and protective clothing, such as overalls, gloves and footwear, shall be clean and free of grease and oil, where gloves are not used, clean hands are essential.

Degreasing of an installation or parts of it demands the use of a degreasing agent which satisfies a number of requirements: including compatibility with oxygen and toxicity. Guidance for oxygen cleaning can be found in EIGA Doc 33 [13]. Oxygen clean inspection standards can be found in EN 12300 *Cryogenic vessels - Cleanliness for cryogenic service* [14].

It is important that all traces of degreasing agents are removed from the system prior to commissioning with oxygen. Some agents, such as halogenated solvents, can be non-flammable in air, but can explode in oxygen enriched atmospheres or in liquid oxygen.

Good housekeeping is necessary to prevent contamination by loose debris or combustibles.

Neither nitrogen nor argon react with oil or grease, it is good practice to apply a good standard of cleanliness, although not as stringent as those required for oxygen installation.

4.11.2 Embrittlement of materials

Many materials, such as some carbon steels and plastics, are brittle at very low temperatures and the use of an appropriate material for the service conditions is essential. Protection for pipework and vessel downstream of vaporisers shall be considered if they could be subject to low temperatures, see EIGA Doc 133, *Cryogenic Vaporisation Systems – Prevention of Brittle Fracture of Equipment and Piping* [15].

4.11.3 Insulation materials

Where they can be exposed to either gaseous or liquid oxygen insulating materials shall be suitable for oxygen service, see 4.3.3 on air condensation/air liquefaction.

4.11.4 Smoking and hot work

Smoking, hot work, unless suitable precautions are taken, and open flames shall be prohibited within the minimum distance specified in Appendices A and B.

5. Layout and design features for installation

5.1 General

Static cryogenic vessels shall be installed, put into service, tested and maintained in accordance with the applicable codes.

Vessels shall be sited and operated taking into account the safety of staff and other persons, property and the environment.

The location of potentially hazardous processes in the vicinity, which could jeopardise the integrity of the storage installation shall be assessed.

5.2 Safety distances

The safety distances are evaluated based on

- nature of the hazard, for example, flammable, oxidising, asphyxiant, explosive and pressure;
- equipment design and operating conditions;
- external mitigating protection; and
- object which is to be protected, for example, people, environment and equipment.

They are considered as protection against risks involved, according to practical experience, in normal operation in cryogenic liquid storage installations. They are not intended to provide protection against catastrophic events or major releases, which should be addressed by other means to reduce the possibility and effects to an acceptable level.

The distances shown in Appendix B1 and B2 correspond to established practices and are derived from operational experience within Europe and the USA. They relate to in excess of 300 000 tank years of service.

The safety distances given are the minimum recommended safety distances measured in plan view from either the outer shell of the liquid cryogenic tank or from any point of the permanent installation where leakage during normal operation can occur, such as at filling points and pressure relief devices.

For further information on determination of safety distances, see EIGA Doc 75, *Determination of Safety Distances* [16].

5.3 Location of the vessel

Vessels should be installed in open, well ventilated areas with consideration of local circumstances, for example, urban area, trees, overhead electric cables and passing vehicles.

Vessels below ground level or in enclosed or confining areas shall have a documented risk assessment carried out and applicable mitigating measures taken.

The storage tank should be placed at the same level as the tanker parking area to enable the operator/driver to control the transfer operations.

Provisions shall be made for the drainage of surface water from the installation.

The installation should allow the inspection of the vessel(s) from all sides.

Vessels shall be installed such that adequate space is provided for maintenance and cleaning, as well as access to all equipment.

The space for maintenance and cleaning should be at least 0.6m around the installation. Vessels shall not be installed in corridors, passages or thoroughfares, public areas, stairways or near steps. Vessels shall not be installed close to these areas, if this obstructs traffic routes, escape routes or access to the vessel.

The installation shall be protected from mechanical damage, for example, by vehicle crash barrier, enclosures, safety distances.

There shall be access to the tanker transfer area to enable a controlled and safe filling operation.

5.4 Protection against electrical hazards

The location shall be chosen so that damage to the installation by electric arcing from overhead or other cables cannot occur. All parts of the installation shall be earthed and protected against lightning according to local regulations.

5.5 Installation level and slope

Where liquid cryogenic storage tanks are required to be installed at an elevated level, they shall be supported by purpose designed structures which shall withstand, or be protected, from damage by cryogenic liquid spillage. In case of a major leakage, measures shall be in place to prevent the liquid or gas from spreading into lower rooms, ducts, shafts or air intakes.

The slope of the ground shall be such as to provide surface water drainage.

For oxygen it shall also take into account the prevention of directing hazardous materials, such as oil, towards the oxygen installation.

5.6 Position of gas vents

Vents, including those of safety relief devices, shall vent to a safe location in the open, taking into account the hazards of the vented gas, so as not to impinge on personnel, occupied buildings and structural steelwork.

Oxygen vents shall be positioned so that the flow from them cannot mix with flammable gas or liquid vents.

Vents shall be designed to the prevention of accumulation of water, including that from condensation, in vent outlets.

5.7 Vapour clouds

When siting an installation, consideration shall be given to the possibility of the movement of vapour clouds, originating from spillage or venting. The development and effects of vapour clouds shall be considered, including hazards such as decreased visibility an oxygen enrichment/deficiency. Cold vapours from cryogenic gases are heavier than air and can accumulate in pits and trenches.

Gas shall be discharged to a safe location in the open taking into consideration the hazards of the vented gas. The prevailing wind direction and the topography shall be taken into account.

5.8 Liquid transfer area

The liquid transfer area should be designated a "NO PARKING" area.

The liquid transfer area shall be kept free, not obstructed and provide access to and exit from the installation for road tankers.

A road or rail tanker, when in position for filling from or discharging to the installation, shall be in the open and not be in a walled enclosure from which the escape of liquid or heavy vapour is restricted. Tankers should have easy access to and exit from the installation at all times.

The liquid transfer area should always be located adjacent to the gate of the installation enclosure where installed and orientated in such a way that it facilitates driving straight out in case of an emergency.

Transfer of liquid with the tanker standing on public property is not recommended. However, when necessary, the hazard area shall be clearly defined using suitable notices during the transfer period. Access to this area during transfer shall be strictly controlled.

The road tanker transfer area shall be made of concrete or any other suitable non porous and for oxygen non-combustible material.

5.9 Ventilation of pump enclosure

Where pumps and/or vaporising equipment are located in enclosures, these shall be ventilated. Openings used for access and/or free or forced ventilation shall lead to a place where there is free escape for cold vapour and in case of oxygen where there will be no accumulation of combustible material liable to form a hazard.

5.10 Equipment layout

All vessel connections. equipment and equipment controls shall be designed and installed so as to provide for safe access, operation and maintenance.

5.11 Isolation valves

The protection of isolation valves from external damage shall be evaluated and protection installed as required.

5.12 Secondary isolation

Consideration shall be given for the provision of a secondary means of isolation for those lines greater than 9 mm nominal bore emanating from below the normal liquid level and having only one means of