REFRIGERATED CARBON DIOXIDE STORAGE AT USERS' PREMISES

Doc 66/22

Revision of Doc 66/08

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Doc 66/22

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Prepared by WG-6 Cryogenic Vessels

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Amendments to 66/08

Section	Change
	Editorial to align with EIGA Style Manual
All	Complete re-write to align with EIGA Doc 224, *Static Vacuum Insulated Vessels Operation and Inspection* [1]

NOTE Technical changes from the previous edition are underlined

1 Introduction

This publication provides the minimum requirements and the practices for design, construction, installation, operation, and maintenance of refrigerated liquefied carbon dioxide (CO_2) storage at users' premises.

2 Scope and purpose

Refrigerated liquified carbon dioxide can be stored at users' premises in two types of vessel; vacuum insulated cryogenic vessels or pressure vessels with foam insulation and cladding. General and detailed requirements for storage of gases at users' premises, particularly vacuum insulated vessels, can be found in EIGA Doc 224, *Static Vacuum Insulated Cryogenic Vessels – Operation and Inspection* [1].[1]

This publication describes the operation and hazards specific to refrigerated liquified carbon dioxide vessels at users' premises.

This publication covers outdoor refrigerated liquified carbon dioxide vessels up to 40 bar design pressure, and a 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 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.

This publication does not address the tankers and containers used for bulk transport and delivery of liquified carbon dioxide, which are covered by the Transportable Pressure Equipment Directive (TPED) and transport of dangerous goods regulations (ADR) [2, 3].

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

This publication does not address usage equipment connected after / downstream the vessel or vaporiser system, such as 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.

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

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

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

3.1.5 Can

Indicates a possibility or ability.

3.2 Technical definitions

3.2.1 Pressure

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

4 General information

Carbon dioxide may also be called carbonic acid gas or CO_2.

A complete Safety Data Sheet is available from the gas supplier. A short summary of the properties of carbon dioxide is this section.

4.1 Physical properties

Carbon dioxide is a colourless, odourless, slightly acidic gas that is approximately 50% heavier than air. It is non-flammable and will not support combustion. Carbon dioxide can exist as a solid, liquid, gas, or supercritical fluid, depending upon conditions of temperature and pressure.

Carbon dioxide at its triple point exists simultaneously as a liquid, gas, and solid at –56.6 °C and 4.18 bar. Any change in pressure or temperature causes carbon dioxide to revert to a two-phase condition (see Figure 1 in Appendix A).

Carbon dioxide at its critical point exists simultaneously as a liquid, gas, and supercritical fluid at 31.1 °C and 72.8 bar. At pressures and temperatures greater than the critical point, carbon dioxide exists only as a supercritical fluid.

Carbon dioxide is classified as a non-toxic gas but affects breathing at concentration greater than 1%, with affects becoming more serious with increasing concentrations (see EIGA Safety Info 24, *Carbon Dioxide Physiological Hazards “Not just an asphyxiant”* and EIGA Doc 23.06, *Safety Training Leaflet – Carbon Dioxide* [4, 5]).

Liquid carbon dioxide is transported, stored and handled either at ambient temperature in cylinders or non-insulated storage vessels at pressures in the range of 45 to 65 bar or as refrigerated liquid in insulated transportable vessels and storage vessels at a temperature range of –35 °C to –15 °C and at pressures of 12 to 25 bar. The carbon dioxide, in refrigerated state is a liquid at its boiling point.

The expansion of liquid carbon dioxide to atmospheric pressure is used to produce carbon dioxide snow at a temperature of –78.5 °C. The snow is pressed into dry ice blocks or pellets. Dry ice is handled in insulated atmospheric containers.

4.2 Chemical properties

Carbon dioxide does not support combustion. When dissolved in water, carbonic acid (H_2CO_3) is formed. The pH value of carbonic acid varies from 3.7 at atmospheric pressure to 3.2 at 23.4 bar. Carbonic acid is corrosive and provides the biting taste of soda water; it reacts in alkaline solutions producing carbonates. It has very few vigorous reactions with other substances except under conditions of high temperature and pressure in the presence of reactive substances such as sodium and magnesium. For this reason, carbon dioxide should not be used as a fire extinguishing agent for reactive metals like sodium and magnesium.

4.3 Precautions

The properties of liquid carbon dioxide require that a number of specific precautions are taken.

4.3.1 Substantial release of carbon dioxide

Any substantial release of carbon dioxide is potentially hazardous especially inside a poorly ventilated building. Enclosed low-lying areas, where CO_2 gas could accumulate in high concentration, are particularly hazardous because the gas is slow to disperse unless the spaces are well ventilated.

Further information on the hazard from oxygen deficiency in EIGA Doc 44, *Hazards of Inert Gases and Oxygen Depletion* [6]. More details about physiological effects are found in EIGA Safety Info 24 [4].

Emergency procedures for a substantial release of CO_2 should be established, including an evaluation of the need of self-contained breathing apparatus and a recommendation to inform the supplier as soon as possible.

In case of a substantial release of carbon dioxide in confined areas, evacuate all personnel as soon as possible. Personnel shall not enter such areas before they are completely ventilated to a safe atmosphere.

When confined spaces are entered before they are properly ventilated, the personnel entering such areas shall use self-contained breathing apparatus, be trained in its use and follow tried and tested procedures. Confined space entry may be governed by national regulations.

WARNING Canister respirators give no protection for atmospheres containing dangerous concentrations of carbon dioxide.

Substantial releases of carbon dioxide may occur through:

- failure of pipework containing carbon dioxide;
- failure of flexible hoses through movement of the road tanker while the hoses are still connected between road tanker and storage vessel;
- release from a relief valve;
- inadvertent opening of a drain or vent valve while the system contains CO_2;
- failure of connections, for example flexible hoses, flanges etc; or
- failure of a regulating device resulting in gas release through the body vent holes.

4.3.2 Low pressure in storage vessel

When compressed gas is allowed to expand or liquid to evaporate, the temperature of the system falls. If larger quantities of carbon dioxide gas are rapidly lost from the storage vessel, either accidentally through automatic or manual relief, or through excessive withdrawal of CO_2, the temperature in the vessel could fall below the minimum permitted operating temperature.

If the temperature and respective pressure falls to the triple point (4.18 bar at –56.6 °C) solid CO_2 forms in the tank.

If the pressure is reduced to atmospheric pressure, the temperature of the dry ice will be –78.5 °C. At this temperature most carbon steels, if not thermally treated, can become brittle and fail if highly stressed.

Under normal conditions the pressure should remain above 10 bar.

Should the pressure fall below this value, the customer should stop withdrawal to avoid dry ice formation and contact the gas supplier immediately. If the pressure falls below 4.18 bar, dry ice can form in the tank. The supplier must be informed and take actions, see EIGA Doc 164, *Safe Handling of Liquid Carbon Dioxide Containers that have Lost Pressure* [7].

4.3.3 Low temperature

The snow produced from leaks of liquid carbon dioxide is extremely cold (–78.5 °C) and can cause frostbite if touched with bare hands. If carbon dioxide snow comes into contact with the eyes it can cause severe eye injury.

Touching of pipes and connections containing liquid carbon dioxide can cause frostbite. For this reason, gloves and eye protection shall be worn when handling equipment in liquid carbon dioxide service.

Where there has been a major release of gas, the atmosphere will be very cold and visibility is likely to be limited. These factors can make escape or rescue difficult.

4.3.4 Flailing hoses and tow-away incidents

If a hose connection fails during the transfer of liquid carbon dioxide, the hose may flail and endanger people and equipment in the vicinity. The use of safety slings during filling, securing each end of the hose to fixed points on the tanker and the storage tank is recommended.

A system to prevent towaway accidents should be used, see EIGA Doc 63, *Prevention of Tow-Away Incidents* [8].

4.3.5 Dry ice plugs in pipes and hoses

Dry ice plugs can form inside hoses and piping when liquid carbon dioxide pressure is decreased below its triple point pressure of 4.18 bar. The dry ice can be compacted into a plug which can trap gas. The pressure behind or within a plug may increase as the dry ice sublimes until the plug is forcibly ejected or the hose or pipe ruptures. A dry ice plug may be ejected from an open end of hose or pipe with enough force to cause serious injury to personnel, both from the impact of the dry ice plug and / or the sudden movement of the hose or pipe as the plug ejects.

Pipes and hoses shall be pressurised with gas above 5 bar before introducing liquid carbon dioxide to prevent formation of dry ice plugs.

Liquid carbon dioxide shall be purged from the hose or pipe before reducing the pressure below 5 bar. This can be done by supplying carbon dioxide vapour to one end of the hose or piping system to maintain the pressure above the triple point while removing the remaining liquid from the other end from a low point. For more information see EIGA SI 28, *Operation of Carbon Dioxide Road Tankers and Equipment while Loading and Unloading* [9].

If dry ice plugging is suspected, the supplier should be informed and take appropriate action.

4.4 Carbon dioxide equipment

4.4.1 Cryogenic vacuum insulated vessels

These vessels consist of two vessels, an outer vessel and an inner vessel (see Appendix D).

The outer vessel has a durable protective coating to guard against corrosion, the inner vessel is made of steel resisting to low temperature (see 4.5 and 4.6). In these vessels the insulation is made creating vacuum between the inner and the outer vessel and additionally filling the annular space with perlite or superinsulation (multi-layer insulation). A refrigeration unit can be fitted for specific applications. Further information on static vacuum insulated cryogenic vessels can be found in EIGA Doc 224 [1]. See Appendix D for an example vessel flow diagram.

4.4.2 Non-vacuum insulated vessels

Two further types of vessel insulation can be used, to maintain carbon dioxide's low temperature:

- A foam insulated vessel with a layer of polyurethane or polyisocyanurate foam (normally from 100 mm to 200 mm thickness) with a vapour-proof seal and a protective metal cladding, i.e. aluminium (see Appendix B); or

- A storage consisting of two vessels, an outer and inner vessel. The outer vessel has a durable protective coating to guard against corrosion. The inner tank shall be made from a steel resisting to low temperature. The inter-space is filled with perlite and with the addition of molecular sieve absorber (see Appendix C).

Non-vacuum insulated vessels are normally equipped with a suitable refrigeration unit to maintain the desired operating pressure during period of low usage or increased heat input. The refrigeration unit removes heat from the contents by condensing carbon dioxide vapour, which results in a corresponding decline in pressure. The refrigeration evaporator coil is typically installed in the vapour space of the vessel. The refrigeration unit is switched on and off automatically by means of pressure switches to keep the pressure (and temperature) of the liquid CO_2 within operating limits.

Many refrigeration units contain refrigerants that are no longer permitted by local regulation. When installing new units or performing maintenance, replacement or management of refrigerant is required.

4.4.3 Vaporisers

Carbon dioxide may be used by the customer in liquid or gaseous form. If carbon dioxide gas is required, the installation requires a vaporising system. The vaporiser should be capable of providing an adequate supply of gaseous carbon dioxide to the customer.

A separate pressure build-up vaporiser is provided to maintain the pressure in the storage vessel. Where internal electrically heated pressure build-up vaporisers are used, attention should be given to safety devices to cut off the electricity supply to the heater elements when overheated, when the upper limit of the set pressure is reached, or when the heater elements are no longer covered by liquid.

Where warm / hot water or steam is used to vaporise liquid CO_2, following devices should be installed in addition to a direct temperature reading of the gas:

- a low temperature audible alarm pre-set at an appropriate temperature setting; and

- a low-low-temperature trip which automatically closes the valve installed on the liquid CO_2 supply line to the vaporiser or at the vaporiser outlet.

Users should be aware of the dangers of partially closing any valve on a steam supply line to a vaporiser, causing the vaporiser water temperature to fall dangerously low on a water bath vaporiser.

If external electrical heated vaporisers or forced air vaporisers are used, a trip is recommended on the gas outlet or on the heating unit to safeguard the customer's installation against liquid carry over.

Further guidance on low temperature protection of vaporiser failure can be found in EIGA Doc 133, *Cryogenic Vaporisation Systems - Prevention of Brittle Fracture of Equipment and Piping* [10].

4.5 Materials

The materials of construction used for vacuum insulated cryogenic vessels are austenitic stainless steel, and other suitable steels containing nickel for the inner vessel and carbon steel for the outer jacket. Low temperature carbon steel (non-alloy, fine grained) can also be used for the inner vessels on vacuum insulated vessels designed specifically for carbon dioxide.

Modern non-vacuum insulated vessels are typically fabricated using low temperature carbon steels. Low temperature carbon steels at design operating conditions are both strong (have high tensile strength) and ductile. These materials remain strong as they become cold but become less ductile. Such a condition can exist if pressure is lost in the vessel. See EIGA Doc 164 for more information [7]. The specification of the low temperature rating of carbon steel vessels shall be considered when specifying and selection of storage vessels. Older non-vacuum insulated may be fabricated with coarse grained steels which have a warmer low temperature rating.

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

4.6 Construction

Storage vessels are designed for a CO_2 pressures ranging normally from 15 to 25 bar, corresponding to temperatures of –30 °C to –15 °C. In order to maintain pressures, the tanks are insulated and may be provided with a refrigeration system.

Vacuum insulated and non-vacuum insulated vessels operate at pressures at or above atmospheric pressure and are designed, manufactured, tested and inspected to recognised pressure vessels standards.

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

Vessel piping is generally welded or brazed where possible to minimise the potential for leaks. Connections to vacuum spaces and piping joints within vacuum spaces are always welded to maintain vacuum integrity. Manholes are not normally fitted to vacuum insulated vessels due to potential for vacuum loss. Vessels may use flanged or screwed connections on external piping to facilitate replacement of piping and components.

The maximum liquid fill level shall be specified to ensure the vessel does not become completely full of liquid and the relief valves discharge gas rather than liquid. Typically, this level is set between 90% and 95% of the volume of the vessel.

4.7 Relief valves

Storage vessels for liquid CO_2 shall be provided with suitable devices connected to the gas phase which prevent over-pressurisation above the maximum design pressure of the vessel.

Selection and sizing of relief valves should be in accordance with recognised standards. For example, the capacity of relief valves should take into consideration the maximum heat input through the insulation, the failure of the refrigeration circuit, the failure of pressure building system (electrical, steam or ambient vaporiser) and, where applicable, failure of vacuum insulation.

It is normal practice for each bulk storage vessel to be equipped with at least two suitable sized relief valves directly connected with the gas phase.

An adequately sized three-way valve selector valve is recommended to allow for periodic maintenance and valve testing without removing the vessel from service.

If a three-way valve is installed to accommodate two or more pressure relief devices operating, either simultaneously or alternatively, the size of the valve, regardless of the position of the actuating device, shall be such that the vessel is adequately protected. The three-way valve should be provided with a position indicator showing which relief devices are on-line.

Relief valves shall be installed in such a way that dirt, moisture or other foreign objects cannot accumulate on the valve seat and the relief valves are not enveloped by ice.

Bursting / rupture discs are not recommended for refrigerated liquid carbon dioxide vessels due to the risk of premature failure, tank depressurisation and formation of solid carbon dioxide.

NOTE – Burst discs may be used on small liquid carbon dioxide vessels, typically less than 500 litres, with stainless steel inner vessels.

4.8 Corrosion

On vacuum and non-vacuum insulated vessels, the wall of the inner vessel in contact with the liquid carbon dioxide is not subject to corrosion as corrosion is non-existent at such temperatures. The outside wall of the pressure vessel is protected from corrosion by the vacuum in the interspace in the case of vacuum insulation and the vapour barrier in the case of non-vacuum insulated vessels. For non-vacuum insulated vessels consideration shall be given to painting the outside wall of the pressure vessel for additional corrosion protection.

Carbon steel vessels that have been removed from service may be kept under low pressure, for example 1-2 bar, with inert gas to prevent corrosion.

4.9 Cleanliness

Cleanliness requirements for carbon dioxide are not as stringent as for oxygen, but equipment shall still be cleaned to prevent contamination of downstream equipment and applications.

Equipment that has been used in liquid carbon dioxide service should not be used in oxygen service unless thoroughly cleaned and inspected, see EIGA Doc 33, *Cleaning of Equipment for Oxygen Service* [11].

4.10 Pipework

Where liquid carbon dioxide can be trapped, for example between two valves, it can lead to excessive pressure if the temperature then rises. All piping in which liquid carbon dioxide may be trapped shall be equipped with suitable sized safety relief valves. These safety relief valves should be set to discharge within the design pressure of the part of the system they protect.

If ball valves are used, they shall be designed to ensure that no internal overpressure is developed when closed (for example provided with a pilot hole in the ball that relieves pressure upstream).

All pipework from the pressure vessels, except those for safety devices, shall have shut off valves which are located as close to the vessel as practicable.

4.11 Filling from road tankers

Road tankers are equipped with safety devices, transfer pump(s), and pipe work for transferring liquid carbon dioxide into or out of the storage tank. Connections between the CO_2 tanker and storage vessel are made with flexible hoses.

If there is a gas balance line between CO_2 tanker and CO_2 storage tank, this hose may be connected either to the gas phase of the vessel or to an overfilling tube installed inside the storage vessel which prevents overfilling of the vessel by returning liquid CO_2 to the tanker.

A trycock valve should be used, to prevent overfilling of the storage tank. The trycock valve indicates the maximum liquid level in the storage tank, when it is reached during the filling operation, the filling operation should stop (manually or automatically). The transfer pumps shall be stopped immediately if the tank pressure rises above maximum operating pressure.

For single hose filling where the maximum delivery pressure of the transfer pump can exceed the upper pressure limit of the storage vessel, protective measures shall be used to prevent overpressure. See EIGA Doc 151, *Prevention of Excessive Pressure during Filling of Cryogenic Vessels*, for more information [12].

The interior surface of the hoses shall be compatible with carbon dioxide to avoid swelling, blistering, shrinking, or other forms of deterioration. The hoses should have an effective protection to prevent accumulation of dirt or humidity (water), for example hose caps.

The flexible hoses required for the transfer are normally carried by the delivery tanker. However, if hoses have been supplied to the user and are retained on the customers premises, they should be regularly inspected and tested by a competent person according to local legislation.

Further information on delivery procedures and protection of hoses can be found in EIGA Doc 56, *Guide for the Delivery of Bulk Carbon Dioxide* [13].

The procedure for offloading shall be determined according to a risk assessment, for more information see EIGA Doc 68, *Prevention of Carbon Dioxide Backfeed Contamination* [14].

Pressurising and purging procedures shall be available in order to avoid forming dry ice plugs.

5 Layout and design feature for installation

5.1 General requirements

Vessels shall be installed, put into service, tested and maintained in accordance with the applicable codes and local legislation.

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.

EIGA Doc 224 gives further information on [1]:

- safety distances, see also EIGA Doc 75, *Determination of Safety Distances* [15];
- location of the vessel;
- protection against electrical hazards;
- installation level and slope;
- position of gas vents;
- vapour clouds;
- liquid transfer area;
- ventilation of pump enclosures;
- equipment layout;
- isolation valves;
- couplings;
- fencing;

- foundation, construction of floor and bolting down;
- modifications;
- access to installation;
- notices and instructions; and
- operating and emergency instructions.

The installation of vessels indoors is not recommended. If indoor installation is unavoidable a specific risk assessment together with the customer shall be carried out. The vessel shall be within a purpose-designed building or within an existing building provided with specific requirements described in EIGA Doc 224 [1].

5.2 Backfeed contamination

All deliveries of liquefied carbon dioxide potentially represent a risk for backfeed and contamination of the supplying tanker. The widespread use of a gas phase return connection when delivering carbon dioxide increases the probability of spreading that contamination to other customers. Requirements for filling arrangements are given in EIGA Doc 68, [11].

6 Putting into service / commissioning – Checks and testing

Prior to putting the cryogenic vessel into service inspections and in-service tests, such as pressure tests shall be performed by an authorised representative in accordance with written / established procedures.

Further information on putting into service can be found in EIGA Doc 224, including [1]:

- checking the installation;
- checking the markings;
- ready for start-up review;
- checking the equipment;
- testing the installation;
- pressure test;
- pressure relief devices;
- adjustment of controlling devices; and
- commissioning;

7 Maintenance, repair and taking out of service

Maintenance of equipment shall be carried out on a periodic basis and recorded.

Maintenance is required to ensure that equipment remains in a safe and serviceable condition and complies with the requirements mentioned in the approval documentation. The responsibility for the maintenance and repair shall be established between the contracting parties, for example, the owner, user and filler. On-site regulations and procedures shall be complied with.

Maintenance includes, but is not limited to:

- checking the condition of the vessel, piping and accessories;
- checking the operability of valves;
- minor repairs, for example changing of seals; and
- cleaning external surfaces.

Maintenance operations shall only be carried out by personnel of the vessel owner qualified for the task, using manufacturer's instructions.

More information on maintenance, repairs, management of change, work permit and taking out of service can be found in EIGA Doc 224 [1].

NOTE – Consideration shall be given to cleaning the inner surface of the pressure vessel on non-vacuum storage tanks that have been removed from service prior to reuse.

8 Daily, filling and periodic inspections

To ensure that the equipment is maintained in a safe and operable condition, it shall be inspected on a planned basis and the inspection shall be recorded.

Safety can be compromised when inspections are not performed, and this can lead to potential equipment failure and possible personal harm.

There are three categories of inspections:

- daily inspections / checks;
- inspections before, during and after filling; and
- periodic inspections.

Further information can be found in EIGA Doc 224 [1].

9 Periodic inspection

Carbon dioxide vessels shall be inspected on a periodical basis and when commissioned. Inspection shall be carried out by an authorised person.

The inspection shall follow local regulations. Inspections should include:

- external visual inspection of the vessel and equipment on damage and corrosion;
- assessment of the vacuum between the inner vessel and the outer jacket (annular space), for vacuum insulated vessels;
- assessment of the insulation for non-vacuum insulated vessels;
- where applicable, internal inspection of the inner vessel of non-vacuum insulated vessels equipped with a manway;
- visual inspection and functional test or replacement of the safety relief valves;
- leak test under operating conditions; and
- assessment of any changes of the operational conditions of the installation and its direct surroundings.

The inspection intervals shall be determined either by local regulations or by an authorised person taking into account, the operating conditions and the recommendations of the vessel manufacturer.

All inspections shall be recorded.

Further information on inspection requirements and recommended frequencies can be found in EIGA Doc 224 [1]. Recommended relief valve inspection frequencies from EIGA Doc 224 for liquid carbon dioxide vessels can be modified based on risk assessment [1].

10 Training of personnel

All personnel directly involved in the commissioning, operation, inspection and maintenance of liquid carbon dioxide storage systems shall be aware of the hazards associated with carbon dioxide and trained to carry out their functions. It is also the responsibility of the user to ensure that this training and awareness is ongoing and current.

Training and information shall be carried out under a formalised system. A training record shall be maintained which details the training and information personnel has received and what additional training is required.

The gas supplier can assist in providing operating manuals and training of staff involved in the operation of the equipment.

The training programme shall include, but not necessarily be limited to, the following subjects:

- normal operating procedures / safe operating limits;
- information on cryogenic equipment and accessories;
- product and hazard identification;
- physical and chemical properties of carbon dioxide and its effect on the human body;
- site safety regulations;
- emergency procedures;
- use of protective clothing / apparatus including self-contained breathing apparatus where appropriate;
- first aid treatment for cryogenic burns; and
- fire-fighting equipment.

In addition, personnel shall receive specific training in the activities for which they are employed.

The training programme shall be repeated, and refresher courses organised on a periodic basis.

11 References

Unless otherwise specified, the latest edition shall apply.

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

[2] Directive 2010/35/EU *on transportable pressure equipment*, www.europa.eu.

[3] *European Agreement concerning the International Carriage of Dangerous Goods by Road* (ADR), www.unece.org.

[4] EIGA Safety Info 24, *Carbon Dioxide Physiological Hazards "Not just an asphyxiant"*, www.eiga.eu.

[5] EIGA Doc 23.06, *Safety Training Leaflet – Carbon Dioxide*, www.eiga.eu.

[6] EIGA Doc 44, *Hazards of Inert Gases and Oxygen Depletion*, www.eiga.eu.

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

[8] EIGA Doc 63, *Prevention of Tow-Away Incidents*, www.eiga.eu.

[9] EIGA SI 28, *Operation of Carbon Dioxide Road Tankers and Equipment while Loading and Unloading*, www.eiga.eu.

[10] EIGA Doc 133, *Cryogenic Vaporisation Systems - Prevention of Brittle Fracture of Equipment and Piping*, www.eiga.eu.

[11] EIGA Doc 33, *Cleaning of Equipment for Oxygen Service*, www.eiga.eu.

[12] EIGA Doc 151, *Prevention of Excessive Pressure during Filling of Cryogenic Vessels*, www.eiga.eu.

[13] EIGA Doc 56, *Guide for the Delivery of Bulk Carbon Dioxide*, www.eiga.eu.

[14] EIGA Doc 68, *Prevention of Carbon Dioxide Backfeed Contamination*, www.eiga.eu.

[15] EIGA Doc 75, *Determination of Safety Distances*, www.eiga.eu.

Appendix A: P-T Diagram of carbon dioxide

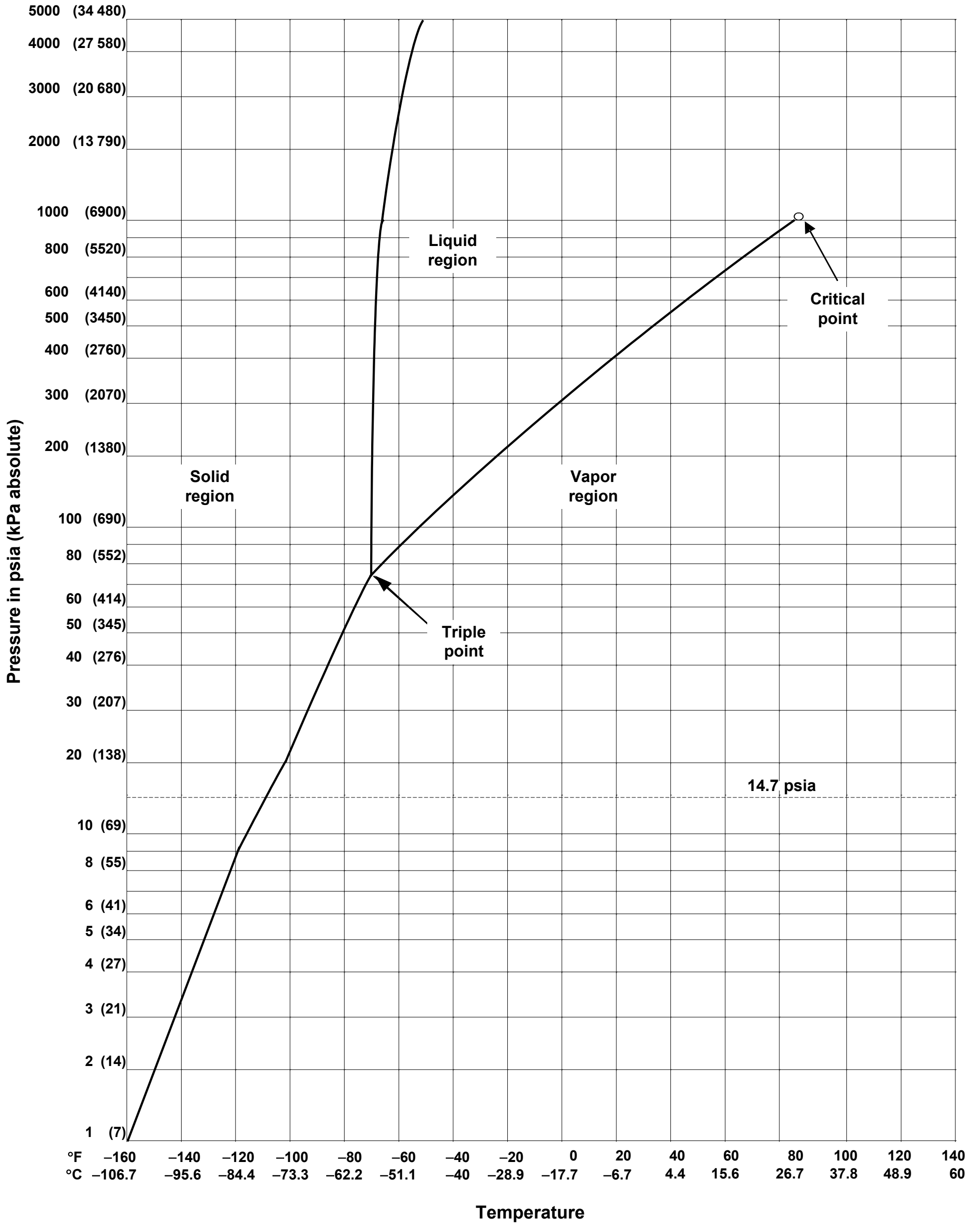

Figure 1 – P-T Diagram of carbon dioxide

Appendix B: Example of a non-vacuum insulated storage tank

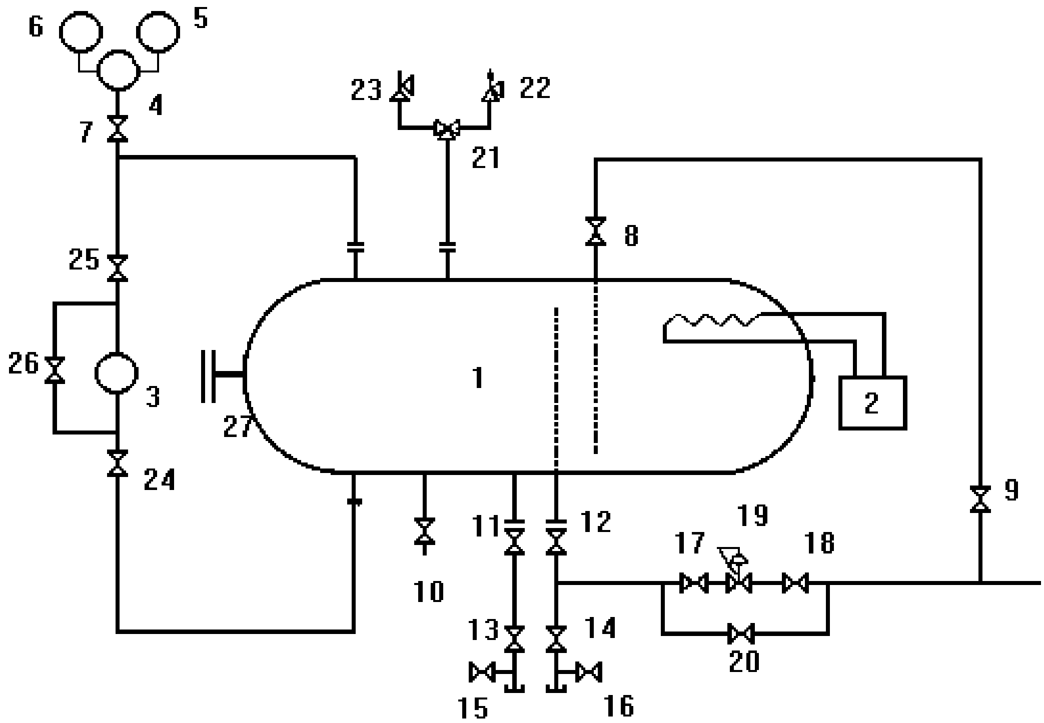

Figure 2 – Example of a non-vacuum insulated storage tank

1. **Pressure vessel**
2. **Refrigeration unit**
3. **Level indicator**
4. **Pressure gauge**
5. **Low pressure switch**
6. **High pressure switch**
7. **Isolation valve**
8. **Isolation valve**
9. **Isolation valve**
10. **Isolation valve**
11. **Isolation valve**
12. **Isolation valve**
13. **Liquid filling valve (fill)**
14. **Gas return valve (return)**
15. **Liquid vent valve**
16. **Gas vent valve**
17. **Isolation valve**
18. **Isolation valve**
19. **Pressure regulator**
20. **By-pass valve**
21. **Change-over valve**
22. **Pressure relief valve**
23. **Pressure relief valve**
24. **Isolation valve**
25. **Isolation valve**
26. **Equilibrium valve**
27. **Inspection manway**

Appendix C: Example of a non-vacuum perlite insulated storage tank

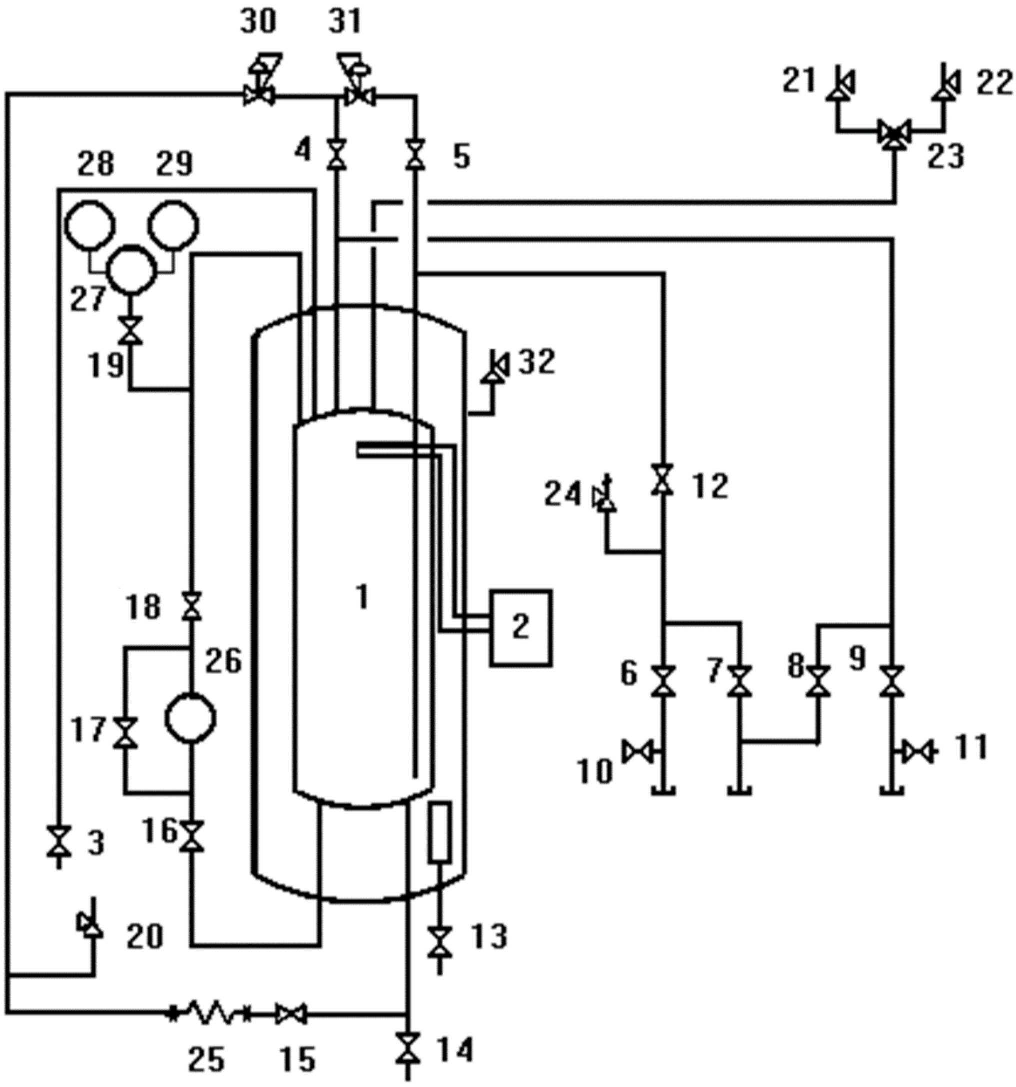

Figure 3 – Example of a non-vacuum perlite insulated storage tank

1. **Pressure vessel**
2. **Refrigeration unit**
3. **Full trycock valve**
4. **Isolation valve**
5. **Isolation valve**
6. **Liquid filling valve (fill)**
7. **Isolation valve**
8. **Isolation valve**
9. **Shut-off valve (return)**
10. **Liquid vent valve**
11. **Gas vent valve**
12. **Shut-off valve**
13. **Annular space valve**
14. **Isolation valve**
15. **Isolation valve**
16. **Isolation valve**
17. **Isolation valve**
18. **Isolation valve**
19. **Isolation -valve**
20. **Thermal relief valve**
21. **Pressure relief valve**
22. **Pressure relief valve**
23. **Change-over valve**
24. **Thermal relief valve**
25. **Pressure building unit**
26. **Level indicator**
27. **Pressure gauge**
28. **High pressure switch**
29. **Low pressure switch**
30. **Pressure regulator**
31. **Pressure regulator**
32. **Annular space relief**

Appendix D: Example of a vacuum insulated storage tank

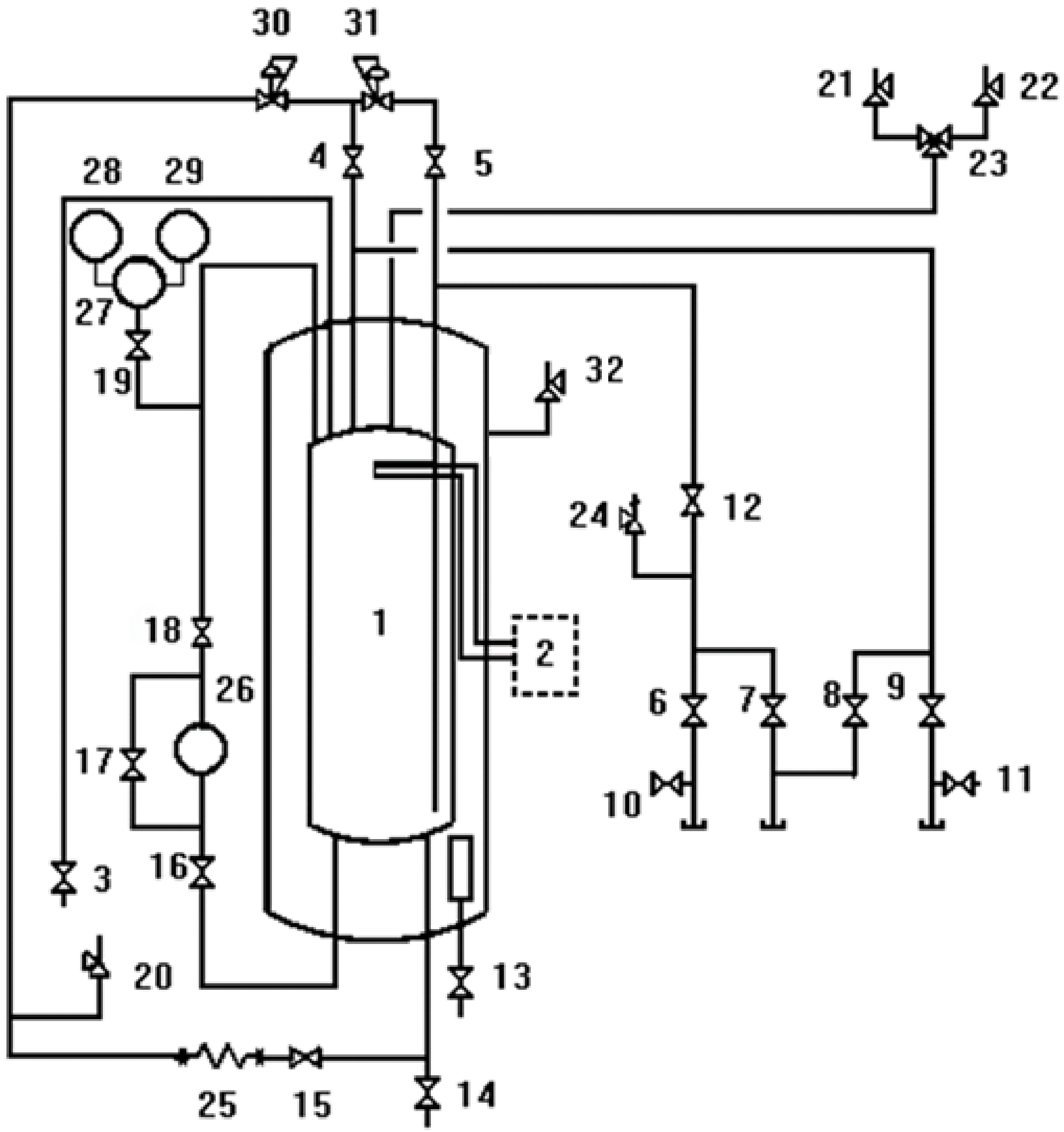

Figure 4 – Example of a vacuum insulated storage tank

1. **Pressure vessel**
2. **Refrigeration unit (optional)**
3. **Full trycock valve**
4. **Isolation valve**
5. **Isolation valve**
6. **Liquid filling valve**
7. **Isolation valve**
8. **Isolation valve**
9. **Gas return valve**
10. **Liquid vent valve**
11. **Gas vent valve**
12. **Isolation valve**
13. **Annular space valve**
14. **Isolation valve**
15. **Isolation valve**
16. **Isolation valve**
17. **Isolation valve**
18. **Isolation valve**
19. **Isolation valve**
20. **Thermal relief valve**
21. **Pressure relief valve**
22. **Pressure relief valve**
23. **Change-over valve**
24. **Thermal relief valve**
25. **Pressure building unit**
26. **Level indicator**
27. **Pressure gauge**
28. **High pressure switch**
29. **Low pressure switch**
30. **Pressure regulator**
31. **Pressure regulator**
32. **Annular space relief**